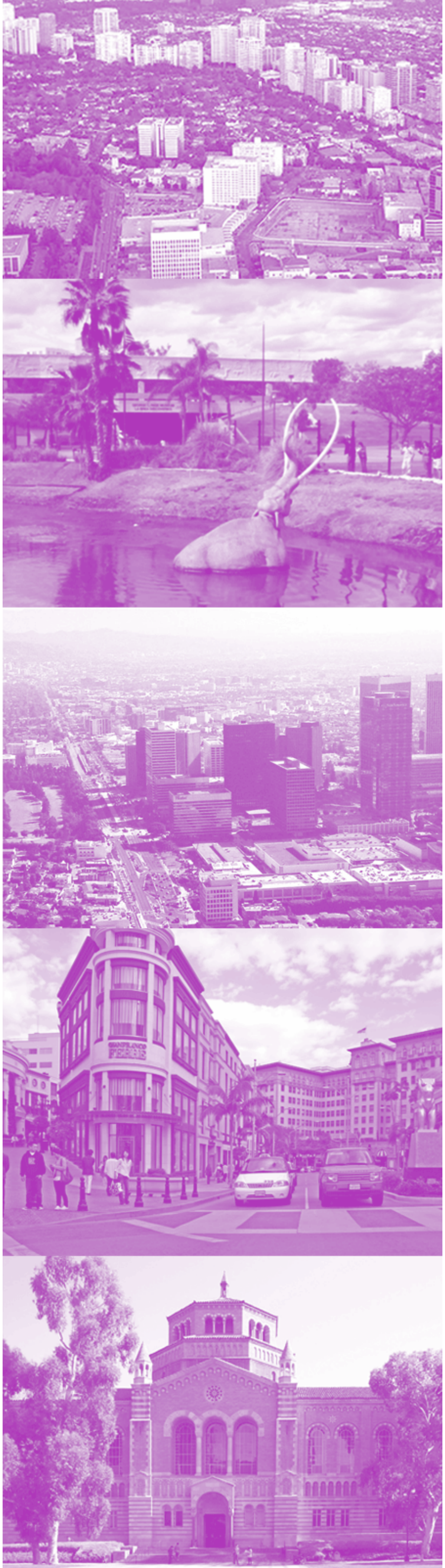


WESTSIDE SUBWAY EXTENSION

Project No. PS-4350-2000

Preliminary Geotechnical and Environmental Report
(Volume 1)

Prepared for:

Metro

Prepared by:

PARSONS BRINCKERHOFF

777 South Figueroa Street
Suite 1100
Los Angeles, California 90017

Review Copy		
	Date	Initials
Originator	8/9/11	MBH/PM
Checker	11/28/11	RR/AE
Back checker	12/2/11	MBH/PM
Verified by	12/7/11	GA

December 7, 2011

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

VOLUME 1

List of Plates

List of Tables

List of Figures

VOLUME 2

Appendix A (Geotechnical Investigation)

Appendix B (Subsurface Gas Investigation)

EXECUTIVE SUMMARY

This report presents the results of professional geotechnical and environmental services for the Preliminary Engineering (PE) phase of the proposed Westside Subway Extension (WSE) project (the Project). The Project is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital via Century City. In the Century City area, two alternative alignments are considered: one with a station along Santa Monica Boulevard, and one with a station along Constellation Boulevard. The 9-mile subway will consist of heavy rail transit operated in an 18 foot-10 inch diameter twin-tunnel configuration with seven new passenger stations and about forty-nine cross passages along the alignment, serving the cities of Los Angeles and Beverly Hills. The tunnel invert varies from 40 to 160 feet below the ground surface.

AMEC as a primary geotechnical consultant to the Parsons Brinckerhoff Team (PB Team) has prepared this report. AMEC's predecessor company MACTEC previously performed geotechnical and environmental services associated with the Alternatives Analysis (AA) phase for the project. MACTEC also performed geotechnical and subsurface gas investigations in 2009 and 2010, in support of preparation of the Draft Environmental Impact Statement (EIS)/Environmental Impact Report (EIR) and to assist the Advanced Conceptual Engineering (ACE) phase.

The investigations for the PE phase were performed to prepare a Geotechnical Data Report (GDR) in general accordance with the GDR outline discussed in Section 5.6.2.3 of the Metro Rail Design Criteria dated January 19, 2010. The scope of work for PE phase was performed under Metro assigned Task Nos. 6.01, 6.2.3, and 6.2.4.

This PE phase geotechnical and environment report consists of three volumes.

- Volume 1 is divided into several sections; Sections 1 and 2 provide background information about the project. Sections 3 and 4 discuss details of the field investigation and laboratory testing, respectively. Sections 5 and 6 present the project geology and engineering properties of the materials, respectively, encountered along the alignment. Section 7 summarizes the findings of the fault investigation, which is provided in more detail in a separate report. Sections 8 through 10 summarize the subsurface gas investigation, environmental site assessment, and oil well survey, respectively. Section 11 presents geotechnical input for tunnel design, Section 12 presents the results of the ground motion study and Section 13 provides the geotechnical recommendations for stations.
- Volume 2 is divided into Appendices A through E and provides the results of field explorations
- Volume 3 is divided into Appendices F through I and provides the results of laboratory testing

In summary, subsurface conditions starting from ground surface consist of localized fill of limited thickness, Younger and Older Alluvium, Lakewood Formation, San Pedro Formation, and Fernando Formation. Groundwater was encountered at depths as shallow as 10 feet below the ground surface along the alignment. Current fault investigation studies identified two active fault zones in the Century City area: the northeast-southwest trending Santa Monica fault zone and the northwest-southeast trending West Beverly Hills Lineament. Both the northern (Santa Monica Boulevard) and southern (Constellation Boulevard) tunnel alternatives and the Santa Monica (west) station option cross the two active faults. No evidence of active faults was found on the Constellation Boulevard station site. High concentrations of methane, hydrogen sulfide and gas pressures and extensive tar-impacted soils were observed in portions of the mid-Wilshire part of the alignment.

Based on the results of the investigations, the following critical issues were considered significant for the feasibility of the Project and are addressed in this report:

- Impact of fault zones on tunneling and station design
- Risks from gassy ground, oil wells and tar impacted soils
- Risks from soil and groundwater contamination
- Noise and vibrations resulting from tunnel construction and subway operation
- Geologic and seismic hazards
- Geotechnical characterization of soils and construction feasibility
- Excavation and foundation Support

Impact of fault zones on tunneling and station design

The tunnel alignment will traverse two known faults in the Century City area: the Santa Monica fault zone and the West Beverly Hills Lineament (which is the inferred northern extension of the active Newport-Inglewood fault zone). Santa Monica Boulevard effectively lies within the Santa Monica fault zone from west of Century Park West to east of Avenue of the Stars. To the east side of Century City, the West Beverly Hills Lineament (WBHL) terminates at the active Santa Monica fault. The Santa Monica Boulevard (east) station option would straddle the WBHL and is therefore not a viable option for station location. No evidence of active faulting was found on the Century City Constellation Boulevard Station site and is therefore considered as a viable option for a station location.

The Century City fault investigation was prepared under a separate cover (Metro, 2011) and is currently under review by the Metro Board of Directors. Further studies will be conducted by others in the future to estimate the amount of fault displacement and earthquake magnitude expected on the Santa Monica and WHBL Fault Zone and to address the impact of fault rupture and ground deformation on tunnel design.

Risks from gassy ground, oil wells and tar-impacted soils

It is known that a majority of the tunnel alignment passes through areas that have been designated as a “Methane Zone” by the Los Angeles Department of Building and Safety (LADBS). A portion of the alignment between La Brea Avenue and San Vicente Boulevard is located within the former Salt Lake Oil Fields and is designated as a “High Potential Risk Zone” for methane by LADBS. Within this stretch, approximately 1.1 mile between Cochran Avenue and La Jolla Avenue is located within the “Tarpit Area” and displayed higher levels of gas pressure, methane, and hydrogen sulfide in monitoring wells. Maximum recorded gas pressures in probes/wells reached 844 and 730 inches of water in 2009 and 2011, respectively. Maximum recorded methane levels reached nearly 100% in 2009 and 2011. Maximum recorded hydrogen sulfide levels were about 1,000 parts per million (ppm) in 2009 and 6,500 ppm in 2011. Elsewhere within this stretch, monitoring wells displayed gas pressure of less than or equal to 0.7 inches of water, concentrations of methane less than or equal to 2.3%, and concentrations of hydrogen sulfide less than or equal to 1 ppm.

At the Century City Constellation station located near the former Beverly Hills Oil Field, sample points in installed wells/probes measured gas pressure of less than or equal to 0.3 inches of water, recorded methane less than or equal to 24.3%, and indicated hydrogen sulfide less than or equal to 0.02 ppm. BAT sampling tests performed at Beverly Hills High School indicated negligible quantities of methane.

At and in the vicinity of the Westwood/VA Hospital station located within the former west Los Angeles Oil Field, methane concentration was less than 0.1%; hydrogen sulfide levels were about 1 ppm or less and the gas pressure was nearly zero, suggesting no subsurface gas hazards at this location.

Associated with the prior oil fields as discussed above are several abandoned oil wells along the current tunnel corridor. The potential presence of existing or abandoned oil wells along the tunnel alignment required that oil well surveys be performed, particularly at the following locations, where wells were indicated on California Department of Conservation Division of Oil, Gas and Geothermal Resources (DOGGR) maps:

- Northwest quadrant of Fairfax Avenue and Wilshire Boulevard (Johnnie's Coffee Shop)
- In Century City at 1950 Century Park East (Meridian's Bodies in Motion property)
- In Century City at the northeast quadrant of Constellation Boulevard and Avenue of the Stars, and adjacent parking lot; and
- At Beverly Hills High School (football field, lacrosse field, and tennis courts)

Based on geophysical scanning surveys performed by GeoVision, no definitive indications of abandoned oil wells could be located in the study areas. It is noted that the DOGGR records with respect to well locations could be inaccurate up to 100 feet from the mapped location. At the mapped location of the "Wolfskill" 23 oil well, the parking structure at 1950 Century Park East is currently located, and surface geophysics was not successful at providing data beneath that building's slab and foundations due to interference from the steel and concrete. An anomaly was identified in the lacrosse field at Beverly Hills High School that is possibly associated with the "Wolfskill" 23 oil well. Therefore, to further study the anomalies and possibly locate the abandoned oil wells in this area, horizontal directional drilling (HDD) with geophysical sensors will be conducted at the tunnel level in the Advanced Preliminary Engineering phase to assess the presence of oil well casings at or adjacent to the alignment.

Tunnel and station excavation between Cochran Avenue and La Jolla Avenue will encounter tar-impacted soils from depths of about 10 to 60 feet below existing grade. The tar content in these soils varies from 5 to 30% by weight, with an average value of 15%. The tar-impacted soils will present certain challenges during construction and also the disposal of these soils will have to be carefully planned, as discussed in this report.

Contaminated Soil and Groundwater

Based on the environmental site assessment study, suspect constituents of concern were detected in soil and/or groundwater samples in 21 of the 31 environmental borings. The constituents identified were related to releases of fuel compounds and/or chlorinated solvents or naturally occurring petroleum compounds. These contaminated soils and groundwater are expected at five of the station locations.

Considering the relatively lengthy history of retail/commercial (and some light industrial) development along a majority of the Project alignment, combined with the findings of this investigation, it is apparent that impacted soils and groundwater will be encountered along certain portions of the alignment during tunneling and station excavation activities. A soil and groundwater management plan is recommended to address these issues. Excavated soils and groundwater from dewatering wells and sump pumps will have to be handled in accordance with applicable environmental regulations prior to disposal.

Noise and Vibrations

Noise and vibration testing was performed to assist in predicting the levels of ground-borne vibration and noise that would be generated by the proposed subway. The tests were performed at 12 locations along the tunnel alignment and at Beverly Hills High School. Based on the results, it is predicted that ground-borne vibration from the trains would be no greater than 64 decibels and the predicted noise level would be no greater than 33 decibels, which are lower than Federal Transit Administration (FTA) thresholds for vibration and noise levels (Metro, 2011).

Geologic and Seismic Hazards

Southern California is a seismically active region, well known for its active faults and historic seismicity. As discussed previously, a portion of the tunnel and station locations cross two active fault zones in Century City and the impact of fault rupture and ground deformation on the design will be evaluated in the next phase. Another hazard from earthquakes is the effect of ground shaking which can be mitigated if structures are designed and constructed in conformance with applicable building codes and engineering practices. Using the United Stated Geologic Survey (USGS) Hazard Deaggregation models, peak ground accelerations (PGAs) for stations and for tunnels were estimated for operating design earthquake (ODE) and maximum design earthquake (MDE) levels and the results are presented in the report.

During seismic shaking, buried box-type structures and tunnel experience racking deformation or ovaling due to seismic waves travelling perpendicular to the longitudinal axis and associated ground deformation. Site-specific analyses were performed to estimate free-field shear displacement for ODE and MDE levels and the results are presented in this report.

According to the California Geologic Survey Liquefaction Hazard maps (CDMG, 1998 and 1990) for Hollywood and Beverly Hills Quadrangles, the Wilshire/La Cienega, Westwood/UCLA and Westwood/VA Hospital Stations are within liquefaction hazard zones. Site-specific liquefaction evaluation performed during this phase indicates no potential for liquefaction below the station foundations during a ODE seismic event. However, there is potential for liquefaction within the upper deposits at the Wilshire/La Cienega and Westwood/UCLA Stations. Liquefaction-induced earth pressures on station walls will need to be considered in the design, if the soils are not remediated in-place. For areas with liquefiable upper soils, ancillary structures can be supported on conventional spread footings within remediated soils or on deep foundations, such as piles.

Geotechnical characterization of Soils and Construction Feasibility

Tunnel and station excavations will encounter several geologic units. The geologic units from oldest to youngest are the Pliocene-age sedimentary strata of the Fernando Formation, Pleistocene San Pedro and Lakewood Formations, Pleistocene (Older) Alluvium, and Holocene (Younger) Alluvium and artificial fill. About 75% of the tunnel excavation is expected to be within discrete geologic units (about 2.8 miles in Older Alluvium, about 3.5 miles in San Pedro Formation and about 0.6 miles in siltstone bedrock of the Fernando Formation). The remaining 25% of the tunnel excavation is expected to be in mixed-face conditions (about 1.3 miles in San Pedro/Fernando Formations, about 0.6 miles in Lakewood/San Pedro Formation, and 0.2 miles in Older Alluvium/Lakewood Formation).

Cobbles and boulders were not observed in the borings. Based on the geologic understanding of the formations and their depositional characteristics, occasional cobbles or boulders may be encountered within excavations. If encountered in station excavations, these materials are not expected to pose problems for excavating using conventional earth-moving equipment. However, considerations should be given to potentially encountering cobbles and boulders when selecting the type of tunnel boring machine.

Siltstone bedrock of the Fernando Formation is not expected within excavations at any of the stations, except during shoring installation. Occasional concretionary materials in siltstone bedrock should be expected within the planned shoring depth. Tunnel excavation using either a slurry-shield tunnel boring machine (SS TBM) or earth pressure balance machine (EPB TBM) as currently planned should be feasible.

Along much of the alignment, the tunnel and stations will be excavated below groundwater encountered at depths of 10 to 70 feet below ground surface; accordingly, a dewatering system consisting of deep wells and/or gravel-filled trenches and sumps will required. In addition, since the majority of the tunnel is within a LABDS designated “methane zone,” an impermeable membrane will need to be provided to prevent gas and/or water intrusion into the system.

The presence of existing tie-back anchors from former basement construction will likely protrude into the tunnel and station excavations. Major utility lines crossing the station footprint will need to be re-routed or protected in-place.

Excavation and Foundation Support

Considering that most of the stations are below existing streets and adjacent to existing buildings, station excavation will have to be shored. Shoring could range from conventional soldier piles with lagging, secant piles, to slurry wall construction. Due to space restrictions, conventional tieback shoring, commonly used for building excavations will not be feasible. Therefore, shoring will be internally braced.

Portions of the excavated sandy soils, free of tar, organics and high sulfates may be reused as backfill material over the station roof and for minor retaining wall backfills, if not contaminated. However, the onsite clayey soils will be difficult to compact and might not be suitable as backfill material.

Foundation soils at planned station depths are expected to be sufficiently firm to allow support of station structures on spread footings or a mat or quasi mat-type foundation system. To achieve firm foundation support for ancillary structures in the vicinity of the Wilshire/La Cienega and Westwood/UCLA Stations, some in-stu ground improvement prior to the construction of station structures may be necessary where there is a potential for liquefaction beneath those structures.

Advanced Preliminary Engineering (APE) Studies

The recommendations presented in this report are based on data collected in prior investigations, ACE and PE phases and the interpretation of subsurface conditions encountered in these investigations. Additional studies in the APE phase will be required for the following:

- Fault studies for WBHL along Pico boulevard (south of Beverly Hills High School) in Century City
- Fault rupture/displacement analysis for Santa Monica Fault Zone and WBHL
- Deepening of geotechnical explorations to obtain deeper subsurface data for tunnel and station design
- Dewatering evaluations at Wilshire/La Cienega Station and others (if necessary)

1.0 INTRODUCTION

This report presents the results of geotechnical and environmental services for the Preliminary Engineering (PE) phase of the proposed Westside Subway Extension. The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. In the Century City area, two alternative alignments are considered; one with a station along Santa Monica Boulevard, and one with a station along Constellation Boulevard. The subway will consist of heavy rail transit operated in a twin tunnel configuration with seven new passenger stations along the alignment, serving the cities of Los Angeles and Beverly Hills.

AMEC is the primary geotechnical consultant to the Parsons Brinckerhoff Team (PB Team). AMEC's services in support of the PE phase of the project consisted of:

- Geotechnical Investigation, including:
  - Geotechnical Explorations
  - Geotechnical Laboratory Testing
  - Geotechnical Analyses
- Noise and Vibration Program
- Fault Hazard Investigation for Santa Monica fault zone and West Beverly Hills Lineament
- Hydrogeologic Studies
- Geologic/Seismic Hazards Evaluation
- Subsurface Gas Investigation
- Phase II Environmental Investigation
- Oil Well Surveys, and
- Existing Foundations Research

AMEC's predecessor company MACTEC previously performed geotechnical and environmental services associated with the Alternatives Analysis (AA) phase for the project. The previous geotechnical consultation for the AA phase consisted of a review of prior geotechnical investigations and geologic data along the proposed alignments being considered, and a discussion of the results from that review.

Subsequent to the AA phase, MACTEC performed geotechnical and subsurface gas investigations for the project in 2009, in support of preparation of a Draft Environmental Impact Statement (EIS)/Environmental Impact Report (EIR) and to assist in the Advanced Conceptual Engineering (ACE) phase. The results of those investigations were submitted in a report dated November 15, 2010.

The current studies were performed to provide more comprehensive data, especially in previously unexplored sections of the current tunnel alignment. Considering the FHWA/USACE guidelines for geotechnical investigations for tunnels, new geotechnical explorations were added in the PE phase; the most notable exception is for the Century City alignment alternatives, where a few of the planned borings have been deferred. Information from AMEC's current and prior explorations was used to develop the geologic profiles, soil/bedrock engineering properties, and recommendations presented in this report.

1.1 Scope of Work

A detailed description of AMEC's scope of work is provided in the following sections.

1.1.1 Geotechnical Investigation

To supplement our previous geotechnical investigations along the route of the Westside Subway Extension, AMEC's scope included performing subsurface explorations and laboratory testing, engineering analysis of the data, and providing reports with the results. This scope of work was developed with the intention of providing data for the design of the tunnel and stations, for either a design-build or design-bid-build project delivery system.

AMEC developed a draft scope of work proposal on July 7, 2010. Following a meeting with the Tunnel Advisory Panel (TAP), AMEC was requested to revise the scope of work based on FHWA/USACE guidelines for geotechnical investigations for tunnels. The basis of the draft scope of work was developed on the assumption that borings (proposed and prior) would be spaced on the order of 500 feet on centers along the tunnel alignment and 300 feet on centers at each station. The revised scope was submitted on August 13, 2010 (Revision 1) for review by the Metro and TAP. Based on a meeting between AMEC, Parsons Brinckerhoff, Metro and TAP on August 19, 2010, the scope for geotechnical and environmental investigation for the PE phase was amended to include:

- A more extensive exploration program involving more closely spaced explorations to characterize potential mixed-face geotechnical conditions for the tunnel alignment that runs along Wilshire Boulevard between Western Avenue and approximately San Vicente Boulevard;
- An increased number of CPTs and sonic core borings along the alignment in order to provide a continuous stratigraphy of the subsurface conditions; and
- In the portion of the alignment between La Brea Avenue and San Vicente Boulevard where there is a higher likelihood of methane and hydrogen sulfide, and within the limits of Beverly Hills High School, CPTs equipped with the BAT® system in order to obtain samples of groundwater and/or gases and maintained at the in-situ pressure.

The borings were planned to extend at least one tunnel diameter (20 feet) below the tunnel invert and to depths of about 40 feet below the station bottom. However, part-way through the field exploration program, the planned tunnel profile was deepened in some areas east of Hancock Park, in Beverly Hills and in the Comstock Hills area of Los Angeles. When the field schedule allowed, some of the borings were drilled about 20 to 40 feet deeper than originally proposed to obtain subsurface data of the deeper soils. However, several of the borings, particularly in Beverly Hills and the Comstock Hills area of Los Angeles will have to be re-drilled to greater depths in Advanced Preliminary Engineering (APE) phase, if the final tunnel profile remains at the currently planned depths.

Field exploration for the geotechnical work within the PE phase consisted of subsurface drilling and sampling, Standard Penetration Testing (SPT), in-situ pressuremeter testing, in-situ dilatometer testing, groundwater monitoring well installation, CPTs and Photo Ionization Detector (PID) monitoring for Volatile Organic Compounds (VOCs).

Plate 1 shows the project alignment and locations of proposed geotechnical explorations. The field explorations for the current PE phase consisted of:

- 80 rotary-wash borings
- 17 sonic core borings
- 27 CPTs
- 6 BAT® groundwater sampling locations
- Pressuremeter tests in 24 borings
- 3 dilatometer tests

At five locations in the Hancock Park area, within a zone of tar-impacted soils, rotary-wash borings were replaced with sonic core borings to obtain more samples of tar-impacted soil (since the sonic core borings produce larger diameter samples than rotary-wash borings).

Geotechnical laboratory testing was performed on representative samples obtained in the borings in general accordance with the scheme and methodology that were approved by the TAP.

An evaluation of the data was performed to determine relevant engineering properties of principal geologic units and to provide preliminary recommendations for the tunnel design, station design, excavation support, groundwater control, and waterproofing/gas barrier.

1.1.2 Noise and Vibration Monitoring Program

Noise and vibration monitoring testing was performed by ATS Consulting as part of AMEC's overall geotechnical and environmental scope. The testing was performed in 12 borings using the vibration source of the drill rig (generated by the "hammer" used to drive the sampler during the process to obtain geotechnical samples). To accomplish the testing, a sensor was attached to the lowest portion of the drill rod to measure the vibration produced during driving of samples. Sensors were also placed at the ground surface at various distances from the drill rig. In addition, some sensors were placed in or on adjacent buildings. In this manner, the noise and vibration produced by the hammer at depth were measured at the ground surface and in/on buildings. The testing was performed as drilling progressed at three different depths: near the crown, center and invert of the tunnel. The data was usd to understand the attenuation of vibration and noise through the site-specific soil conditions, in order to be able to provide estimates of noise and vibration that would arise from the passage of a train at depth. The locations for noise and vibration testing were chosen by ATS Consulting to correspond to some of the noise and vibration points of interest that were developed as part of the previous phase of work by the PB team.

As part of the work, ATS Consulting also requested that some downhole seismic velocity data be obtained in the vicinity of the noise and vibration tests.

1.1.3 Fault Hazard Investigation for Santa Monica Fault and West Beverly Hills Lineament

The fault hazard investigation included fault studies in Century City to investigate the Santa Monica fault zone and the West Beverly Hills Lineament. The results of the comprehensive fault hazard investigation are summarized in this report, but a detailed discussion of the fault hazard investigation is presented in a separate report: Century City Fault Investigation Report (Metro, 2011).

1.1.4 Hydrogeologic Studies for Stations and Tunnel

For this phase of work, AMEC proposed three pumping tests be performed at or near three stations with potentially different hydrogeologic environments. The purpose of these pumping tests is to obtain hydrogeologic data that can be predicatively used in planning for dewatering during construction, groundwater inflow along tunnel reaches, and other hydrogeologic data requirements.

The following are the general locations and status of the three pumping tests:

- Westwood/UCLA station;
- Wilshire/La Cienega Station (well installation complete, pump test to be provided as part of APE phase); and
- a third location to be determined to estimate the water inflow rates expected during planned dewatering for station construction, currently considered to be possibly performed at the Wilshire/La Brea station.

At each of the first two above-mentioned pumping test locations, a pumping well was installed and one or more observation wells were installed nearby. Depending on the local stratigraphy, the pumping and observation wells are screened across various vertical intervals in order to characterize different hydrogeologic units. Pump test results were evaluated to estimate the ground inflows expected into the station excavation.

1.1.5 Geologic/Seismic Hazards Evaluation

The scope of work for the geologic/seismic hazards evaluation consisted of the following:

- Review pertinent geological and geohazard reports
- Discuss geological hazard that are applicable to the alignment
- Develop data tables for historic seismicity
- Perform ground motion studies using one-dimensional (1-D) evaluation of seismic wave propogation, for computation of free-field racking displacements at station locations
- Prepare exhibits that show the regional seismic and geologic hazards as it applies to the proposed alignment

The fault rupture hazard evaluation in Century City is treated as a separate major scope item discussed in Section 3.3.

1.1.6 Subsurface Gas Investigation

The subsurface gas investigation was performed to supplement the data obtained during ACE phase regarding concentrations of gases in soil and bedrock formations and dissolved gases in groundwater; the investigation was performed along the portion of the alignment located between Wilshire/La Brea and Wilshire/San Vicente, and in the vicinity of the Century City Constellation Station and the Westwood VA Hospital Station.

Gas monitoring wells M-1 through M-25 that were previously installed by AMEC and prior wells GW-1 through W-GW-3 and P-36 through P-47, which were previously sampled semiannually by TRC and installed by others were re-sampled and gas level readings were recorded at the commencement of PE phase exploration.

In addition, 19 multi-stage gas probes/standpipes ("wells") were installed along the proposed alignment in the PE phase. Field measurements were performed, as well as laboratory testing of gas samples collected in the field. There were several instances of sampling after installation of the wells. The field and laboratory gas data was evaluated to study the hazards from gases in different tunel reaches.

1.1.7 Phase II Environmental Investigation

The Phase II environmental investigation was performed as a site assessment study, to evaluate man-made contaminants in soil and/or groundwater along the proposed tunnel alignment and at stations. The scope of work included performing environmental explorations to obtain data on potential contaminated soil and/or groundwater along the alignment. These services consisted of the following:

- Exploration (direct push or boring) locations near areas of potential environmental concern
- Obtaining permits from appropriate agency
- Soil cuttings were drummed and disposed following environmental testing
- Environmental laboratory testing of Chemicals of Concern (COC)
- Reporting of results

The Environmental Site Assessment scope of investigation included advancing a total of 31 explorations along the proposed alignment. The exploration locations were selected based on the findings of previous preliminary environmental site assessment reports from the ACE phase that identified the suspect sources of environmental concern with the highest likelihood to impact the alignment. Each exploration location was initially marked as close as possible to the suspect source of concern (e.g., existing dry cleaner or former gasoline station facility) while staying within the public street area under which the proposed tunnel alignment is being considered. In several cases, the exploration locations had to be moved further away from the suspect source due to the presence of underground utilities and/or traffic control issues. Samples were collected at various depths, and laboratory testing for chemicals of concern were performed within the planned tunnel depth along tunnel portions of the alignment and for portions of the alignment where cut-and-cover techniques will be used for construction (such as stations or cross-overs).

The field and laboratory data was evaluated to identify the potential contaminated soil and groundwater to be expected during tunnel and station excavation.

1.1.8 Oil Well Surveys

Oil well surveys were performed for existing or abandoned oil wells along the tunnel alignment at the following locations: (a) at the northwest quadrant of the intersection of Fairfax Avenue and Wilshire Boulevard, (b) in Century City at 1950 Century Park East, (c) in Century City at the vacant lot and adjacent parking lot at the northeast corner of the intersection of Constellation Boulevard and Avenue of the Stars, and (d) at the Beverly Hills High School campus. The oil well surveys were performed using geophysical techniques from the ground surface, and were focused on areas where prior oil wells had been mapped by California Department of Conservation Division of Oil, Gas and Geothermal Resources (DOGGR).

1.1.9 Existing Foundation Data Record Search

This work involved research of foundation, basement wall, and tie-back data for buildings adjacent to the alignment, using records kept by AMEC as part of its archives for projects where an AMEC predecessor firm had served as the geotechnical engineer of record. These records were provided to the PB team and were provided in separate transmittals.

1.2 Report Structure

This report has been prepared in three volumes:

- Volume 1 (this volume) – the main text of the exploration program and findings
  - Field Exploration Program Summary
  - Laboratory Testing Program Summary
  - Project Geology (including Geologic/Seismic Hazards Evaluation)
  - Engineering Properties of Principal Geologic Units
  - Summary of Findings of Fault Studies
  - Findings of Subsurface Gas Studies
  - Findings of Hydrogeologic Studies
  - Findings of Oil Well Surveys
- Volume 2, Field Explorations – results of the subsurface explorations and field studies
  - Boring Logs and CPT Plots from ACE and PE Phases
  - Groundwater Monitoring Well Diagrams from ACE and PE Phases
  - Sonic Core Photographic Logs from PE Phase
  - Noise and Vibration Test Data
  - Oil Well Survey Results

- Volume 3, Laboratory Test Results – results of the laboratory testing on samples collected during the explorations from the ACE and PE Phases

1.3 Limitations and Basis for Recommendations

The professional services have been performed using the degree of care and skill ordinarily exercised, under similar circumstances, by reputable geotechnical consultants practicing in this or similar localities. No other warranty, expressed or implied, is made as to the professional advice included in this report. This report has been prepared for Metro, and their design consultants to be used solely for the evaluation of the proposed Westside Subway Extension. The report has not been prepared for use by other parties, and may not contain sufficient information for purpose of other parties or other uses.

In developing the interpretations and recommendations presented in this report, AMEC (PB team member) relied partly on subsurface information obtained by its predecessor company MACTEC in the AA and ACE phase studies and its other predecessor companies, LeRoy Crandall and Associates and Law/Crandall, and from information obtained by other firms. Subsurface conditions are, by their nature, uncertain and may vary from those encountered at the locations where visual inspections, borings, surveys, or other explorations were made.

THIS PAGE INTENTIONALLY LEFT BLANK

2.0 PROJECT DESCRIPTION

2.1 General

The proposed alignment for the PE phase of work extends from the intersection of Wilshire Boulevard and Western Avenue to the West Los Angeles VA Hospital through Century City. In the Century City area, two alternative alignments are being considered: one with a station along Santa Monica Boulevard, and one with a station along Constellation Boulevard, as shown on Figure 2-1.

The proposed subway alignment is about 9 miles long. The depth to tunnel invert varies along the alignment from 40 to 160 feet below ground surface. The currently proposed tunnel configuration is referred to as the twin-bore tunnel option and consists of dual tunnels of the same size at the same depth, separated horizontally from each other. Seven stations are planned along the tunnel. The locations of the stations are listed below.

1. Wilshire/La Brea Station
2. Wilshire/Fairfax Station
3. Wilshire/La Cienega Station
4. Wilshire/Rodeo Station
5. Century City Station Options
    a. Century City Constellation Station or
    b. Century City Santa Monica Station
6. Westwood/UCLA Station
7. Westwood/VA Hospital Station

The tunnel is expected to have an interior diameter of 18 feet 10 inches. For the purpose of this study, tunnel bore diameter was considered to be about 21 feet.

Tunnels will be constructed in a side-by-side configuration. Tunnel cross passages are typically spaced at about 800 feet. The cross passages allow passengers and emergency response personnel to move from one tunnel to the other in the event of an emergency on a train. Excavations of cross passages are typically performed using smaller equipment or are manually excavated.

It is currently being considered to construct the tunnels using either a slurry-shield tunnel boring machine (SS TBM) or earth pressure balance machine (EPB TBM). Cut-and-cover construction methods are expected to be employed for all stations and double cross-over structures. The cut-and-cover construction technique is similar to a basement excavation, starting at the ground surface, with construction of shoring along the sides of the streets, then placement of a temporary roadway bridge structure (decking) above the excavation during construction to permit the flow of traffic.

The tunnel alignment, locations of stations and cross passages are shown on Figure 2-1, Tunnel Alignment.

2.2 Stations/Crossovers

The stations and double crossovers, all of which will require cut and cover construction currently planned and shown on PE drawings are listed below (from east to west). It is noted that locations and plan dimensions of the stations may be adjusted in subsequent phases.

Wilshire/La Brea Station (including No. 10 Double Crossover)

The Wilshire/La Brea station is about 1,000 feet long and extends about 75 to 80 feet below Wilshire Boulevard, from about South Orange Drive on the east to South Detroit Avenue on the west.

Wilshire/Fairfax Station

The Wilshire/Fairfax station is about 850 feet long and extends about 60 to 70 feet below Wilshire Boulevard, from about 100 feet west of South Ogden Drive to about 300 feet west of South Fairfax Avenue.

Wilshire/La Cienega Station (including No. 10 Double Crossover)

The Wilshire/La Cienega station is about 1,000 feet long and extends about 65 to 70 feet below Wilshire Boulevard, from South Tower Drive on the east to South La Cienega Boulevard on the west.

Wilshire/Rodeo Station (including No. 10 Double Crossover)

The Wilshire/Rodeo station is about 1,050 feet long and extends about 65 to 80 feet below Wilshire Boulevard, from South Canon Drive on the east to South El Camino Drive on the west.

Century City Santa Monica Station Option (including No. 10 Double Crossover)

Two options were considered for the location of the Century City Santa Monica station: at approximately Avenue of the Stars, and east of Century Park East. Based on the results of the evaluation of the Santa Monica fault zone, the station option east of Century Park East is being carried forward in this evaluation. The Century City Station option at Santa Monica Boulevard (at the eastern station location) is about 1,350 long and extends about 70 feet to 85 feet below Santa Monica Boulevard, from east of South Moreno Drive past Century Park East on the west.

Century City Constellation Station Option (including No. 10 Double Crossover)

The Century City Station option at Constellation Boulevard is about 1,000 long and extends about 80 feet to 95 feet below Constellation Boulevard, from Century Park East on the east, past Avenue of the Stars on the west.

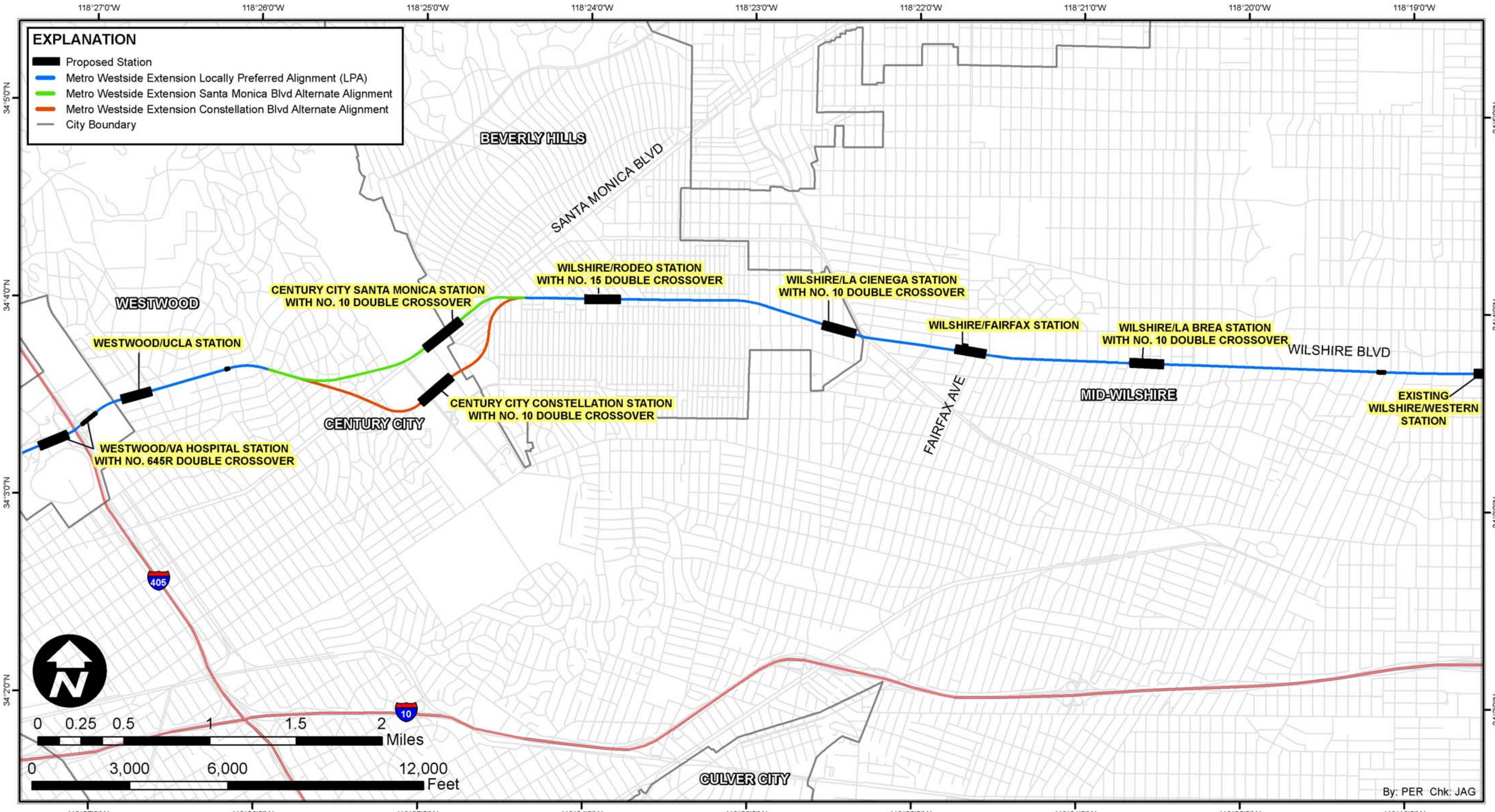
Westwood/UCLA Station (including No. 10 Double Crossover)

The Westwood/UCLA station is about 900 feet long and extends about 70 to 75 feet below Wilshire Boulevard, from Westwood Boulevard on the east to about 150 feet east of Veteran Avenue.

GSA Crossover

The GSA crossover is about 550 feet long and extends about 70 feet below ground surface just south of Wilshire Boulevard. The crossover structure extends east of Sepulveda Boulevard to GSA property.

Figure 2-1: Tunnel Alignment



THIS PAGE INTENTIONALLY LEFT BLANK

Westwood/VA Hospital Station (including No. 645R Double Crossover)

The Westwood/VA Hospital station is about 960 feet long and extends about 65 to 80 feet below ground surface. The majority of the station will be constructed in the north portion of the VA hospital surface parking lot, immediately south of Wilshire Boulevard. The station extends from about 50 feet east of the existing southbound (I-405) San Diego Freeway Wilshire Boulevard on-ramp to about 100 feet west of Bonsalle Avenue. Since this station is the western terminus of the subway, a tail track about 600 feet to west of the station and a vent shaft about 75 feet deep will be constructed at the west end.

2.3 Cross Passages

Cross passages spaced at about 800 feet are planned along the tunnel alignment. Since the cross passages are constructed at the level of the tunnel, the depth of the tunnel governs the depth of the cross passages. The locations and depths of the cross passages are shown on Plates 1-01 through 1-21.

THIS PAGE INTENTIONALLY LEFT BLANK

3.0 FIELD EXPLORATIONS

3.1 General

The planning and execution of field explorations consisted of several steps that had to be performed in sequence almost on a daily basis, to ensure that approvals from necessary government agencies were received on-time to plan the field schedule, notify the public of road closures several days prior to field work, and to ensure field work was done safely and to meet Metro's schedule. A work plan was prepared by AMEC (at that time as MACTEC) and submitted to Parsons Brinckerhoff for review, including exhibits that showed proposed explorations (similar to that attached as Plate 1). The field explorations were performed in general accordance with the approved work plan, with minor amendments, as suggested or approved by Parsons Brinckerhoff. Some of the key elements of the field program and planning are described below.

3.1.1 Health and Safety Plan

Before the field exploration program was performed, a site-specific health and safety plan (HASP) was prepared to identify potential health and job safety issues and to outline the safe procedures to be followed by the field personnel. The HASP was made available to AMEC's subcontractors for review and to be briefed about the safety hazards and safe practices for hazards expected in the field. In addition, AMEC's subcontractors were briefed about the daily field activities by their respective AMEC field team leader prior to the start of the day's work.

3.1.2 Permits

Permits were obtained from different agencies, as listed below, depending on location of the field work, type of field activities and the hours of field operations:

- City of Los Angeles – Department of Transportation (LADOT), Bureau of Engineering (BOE)and Bureau of Street Services (BSS)
- City of Beverly Hills – Department of Public Works
- County of Los Angeles – Department of Health Services
- Regional Water Quality Control Board
- Los Angeles Police Department (for night work)

The following section provides a brief description of the permitting process followed for the project.

After researching existing utilities from plans obtained electronically from Beverly Hills or Los Angeles, the locations of the explorations were selected to avoid conflicts with existing utilities and were marked in the field. Accordingly, traffic control plans (TCPs) showing planned traffic lane closures in order to accommodate the exploration activities were submitted to the Los Angeles Department of Transportation (LADOT) or the City of Beverly Hills for review and approval. In addition, utility maps prepared for each exploration along with the TCPs were submitted to the City of Los Angeles Bureau of Engineering (BOE) for an E-Permit or to the City of Beverly Hills. After receiving approval from the agency and paying necessary fees, a permit (designated an E-permit in the City of Los Angeles) was obtained. If field work required no-parking signs for lanes with paid parking, LA DOT or the City of Beverly Hills was contacted for posting of these signs during field work hours.

In the City of Los Angeles, the E-permit covers a single lane closure, but if two or more lanes required closure, an application was submitted to the Bureau of Street Services (BSS) for multiple lane closures. The approved TCPs and LA DOT sign control numbers were submitted to BSS for further review and approval. After receiving approval from BSS, a necessary fee was paid online to obtain the street use permit. For most explorations, a two-lane closure was sufficient to perform drilling.

Finally, prior to the field work in the City of Los Angeles, a Los Angeles City inspector was notified of impending work on a weekly basis. In addition, in the City of Los Angeles, the Police and Fire Departments were notified of street access restrictions that were expected to be caused by drilling activities. For night work in the City of Los Angeles, an approval from the Police Commission was obtained prior to field work.

3.1.3 Mark Borings and Underground Service Alert (Dig Alert)

Before starting the exploration program, a field reconnaissance was conducted to observe site conditions and to mark locations of planned explorations. Electronic versions of utility maps were used in planning exploration locations.

In addition, considering that most of the explorations were within Wilshire Boulevard, and based on our prior drilling experience during the ACE phase, a relatively large potential exploration area was marked out on the streets. As required by the State of California, Underground Service Alert (USA) was notified of locations of planned explorations at least 48 hours prior to drilling activities. During this timeframe, based on the USA notification, the utility stakeholders marked out their utilities in the field and provided notification regarding potential utility conflicts affecting exploration locations. The majority of the explorations have been performed within about 50 feet of the planned exploration locations. However, few of the explorations had to be moved to a greater distance from the originally planned locations to avoid conflict with utilities.

3.1.4 Utility Clearance

USA services are only helpful in identifying potential conflicts with certain utilities in the public right-of-way. For example, non-pressurized sanitary sewers are often not marked by the City of Los Angeles. To further identify potential utilities below exploration locations and to further reduce the risk of damaging utilities, a private utility locator (GeoVision) was subcontracted to locate potential conflicts of underground utilities with exploration locations using geophysical equipment. As a supplemental precaution, explorations were typically performed at least 2 to 3 feet away from the utilities identified with this geophysical method. Finally, the upper 5 to 10 feet of the explorations were excavated using hand and/or vacuum auger equipment. Excavation using hand and/or vacuum auger equipment continued until any natural soils were encountered.

3.1.5 Traffic Control Measures

Traffic control measures were implemented by A Cone Zone, Inc. of Corona, California (under subcontract to AMEC), when closing traffic or parking lanes during field work. Based on the exploration location and site conditions and governing city requirements, site-specific traffic control plans (TCPs) were prepared by A Cone Zone, Inc. and submitted to the specified agency for approval of traffic control measures. The approved traffic control plans provided procedures for closing lanes and directing street traffic in the field activity area.

3.1.6 Public Notification of Field Work

As requested by Metro, public notifications were prepared detailing field activities, such as the field work area, duration of field activities, types of equipment and traffic lane closures. The notifications were distributed to stakeholders through specified Metro personnel on a weekly basis, prior to the field work.

3.2 Geotechnical Explorations

3.2.1 Prior Explorations - Advanced Conceptual Engineering (ACE) Phase

As part of the ACE phase, a total of 39 geotechnical borings and 25 soil gas borings were drilled for the previously studied tunnel and station alternatives. The information from the ACE phase pertinent to the currently studied alignment is included in this report; some of the previously studied alignments have been eliminated and are no longer part of the current alignment. Subsurface information from 18 of the prior borings is pertinent to the currently proposed alignment and is included in the report. Plate 1 shows the locations of these 18 prior borings.

The borings for the ACE phase were drilled by using the rotary-wash drilling technique by C&L Drilling under the supervision of MACTEC personnel. The soil/gas borings were drilled using hollow stem drilling equipment by Cascade Drilling.

The rotary wash borings were converted to groundwater monitoring wells at 12 locations. The borings were drilled to depths ranging from 80 to 101 feet below ground surface at the locations shown in Table 3-1. However, only five of the 12 groundwater monitoring wells installed during the ACE phase are applicable to the current alignment. Plate 1 shows the locations of these five monitoring well locations. These monitoring wells are active and still in use; ground water levels were recorded in these wells during the PE phase.

The information from the 18 borings and five monitoring wells was used along with explorations performed during the PE phase in developing the geologic cross-sections along the tunnel alignment and in evaluating the material properties.

3.2.1.1 Sampling in Prior Rotary-Wash Borings (ACE Phase)

Bulk samples and relatively undisturbed Crandall ring samples of soil materials were collected at selected depth intervals during ACE phase drilling activities. The Crandall sampler is similar to a Modified California sampler, but has less sample disturbance because of the larger diameter of the Crandall sampler. The Crandall sample barrel contains six one-inch thick brass rings. A three-dimensional schematic of the Crandall sampler is shown on Figure A-7 included in Volume 2.

In addition to obtaining undisturbed samples, standard penetration tests (SPT) were performed in the borings. The number of blows required to drive the Crandall and SPT sampler 12 inches, the hammer weight and hammer drop are indicated on the boring logs.

Table 3-1: Summary of Prior Geotechnical Borings (ACE Phase)

Boring No.	Boring Depth (ft)	Street Location	Station
G-1	81	Wilshire Blvd/South Irving Blvd	
G-2	101	Wilshire Blvd /South Windsor Blvd	
G-3	101	Wilshire Blvd /South La Brea Avenue	Wilshire/La Brea
G-4*	95	Wilshire Blvd /South Cloverdale Avenue	Wilshire/La Brea
G-5	101	Wilshire Blvd /South Orange Avenue	Wilshire/Fairfax
G-6*	80½	Wilshire Blvd /South Fairfax Avenue	Wilshire/Fairfax
G-7	101	Wilshire Blvd /South Fairfax Avenue	Wilshire/Fairfax
G-7A* #	180	Wilshire Blvd /South Fairfax Avenue	Wilshire/Fairfax
G-8	81½	Wilshire Blvd /South Stanley Drive	
G-9	90	Wilshire Blvd /South Carson Road	
G-10	81	Wilshire Blvd /South La Peer Drive	
G-11*	91½	Wilshire Blvd /South Canon Drive	Wilshire/Rodeo
G-12	80	Wilshire Blvd /South Beverly Drive	Wilshire/Rodeo
G-13	101	Santa Monica/Avenue of the Stars	
G-14*	85½	Santa Monica/Avenue of the Stars	
G-16alt	86	Santa Monica/Benicia Avenue	
G-20*	100	Lindbrrok Drive/Gayley Avenue	
G-23	101½	Wilshire Blvd /Veteran Avenue	
G-24	81½	Wilshire Blvd /I-405	Westwood/VA Hospital

*monitoring wells installed in borehole
Boring G-7A was performed prior to PE phase for the evaluation of a possible deeper tunnel option

Selected bulk and ring samples were submitted to the laboratory for testing to evaluate engineering properties. Logs of subsurface conditions encountered in the borings were prepared in the field by AMEC field personnel. Details regarding the field exploration program and final boring logs prepared based on the field logs presented in Appendix A of Volume 2, Field Explorations and laboratory tests presented in Appendix F of Volume 3, Laboratory Tests.

3.2.1.2 Prior Groundwater Monitoring Wells (ACE Phase)

The locations of the five monitoring wells applicable for the current alignment are shown on Plates 1-01 through 1-21, Plan and Profile. Nested well pairs, consisting of two wells in a single boring were installed at these five locations.

The purpose of the ACE phase groundwater monitoring program was to permit measurement of groundwater depths for an extended period of time for use in hydrogeologic analysis. The purpose of installing nested well pairs was to monitor water levels and water pressures in shallow and deep groundwater-bearing alluvial deposits (i.e., perched water zones or variable pressure zones at depth).

The groundwater monitoring wells were installed in accordance with requirements set forth in California Well Standards Bulletin 74-90. Well installation and construction details for monitoring wells installed in ACE phase are included in Appendix A of Volume 2.

The monitoring well installation procedure is presented below:

- The boring was drilled to its target depth; subsequently, the drilling mud was thinned by re-circulating clean water through the boring, using caution to prevent the borehole from caving.
- 1-inch diameter, Schedule-40 PVC casing and well screens were lowered into the borings. The monitoring well screens have 0.0020-inch slot widths and are five feet in length. The total length of the wells varied from 20 to 85 feet.
- Monterey #3 sand filter pack sand was then placed in the annular space to a depth from approximately two feet above to two feet below the well screen.
- Bentonite pellets were hydrated in place above the sand filter pack until the depth of installation for the upper well screen and casing. The placement of the sand filter pack and bentonite pellets placement was same for the upper well placement.
- Traffic-rated flush mounted well-head boxes were installed above the PVC well casing riser and cap. The boxes were set approximately ½ to 1 inch above grade and set in concrete to prevent surface water accumulation.

Groundwater readings were collected in the monitoring wells in 2009, as well as in 2011 during the PE phase. The groundwater level measurements recorded in these wells are presented in Table 3-2.

3.2.2 Current Explorations - Preliminary Engineering (PE) Phase

Field explorations for the current PE phase consisted of:

- 80 rotary-wash borings
- 17 sonic core borings
- 27 cone penetration tests
- 6 BAT® groundwater sampling locations
- 58 pressuremeter tests in 24 borings
- 3 dilatometer tests
- 12 noise/vibration tests

Plate 1 shows the locations of the PE phase soil explorations.

The following sections provide a more detailed description of the type of explorations performed for this phase. Since several drilling contractors with different types of drill rigs were used; the subcontractor names and drill rigs used are identified in the following sections and also indicated on the boring logs.

The information from these explorations was used along with explorations performed during the ACE phase to develop geologic cross-sections along the proposed tunnel alignment and to characterize engineering properties of the geologic materials.

Table 3-2: Groundwater Monitoring Well Data (ACE Phase)

Boring Number	Boring Depth (ft)	Date Boring Drilled	Number of Monitoring Wells Installed	Date Monitoring Well Installed	Screen Interval(s) (ft below ground surface)	Depth to Groundwater (ft below ground surface)	Date of Groundwater Measurement	Station Name
G-4	95	7/16/09 to 7/20/09	2	7/20/09	25-30 and 55-60	28	7/20/09	Wilshire/La Brea
						13.5 (shallower screen), 15.5 (deeper screen)	5/26/11	
G-6	81½	8/17/09 to 8/18/09	2	8/18/09	12.5-17.5 and 40.5-45.5	Not Measured	Not applicable	Wilshire/Fairfax
						12.6 (shallower screen), dry (deeper screen)	5/26/11	
G-7A	180	8/16/2010 - 8/17/2010	3	8/17/2010	87	73.5	9/20/2010	
					117	77.3		
					150	68.7		
G-11	91½	6/15/09	2	6/15/09	27.5-32.5 and 55-60	32.1 (shallower screen) 57 (deeper screen)	8/21/09	Wilshire/Beverly
						dry (shallower screen), 53.5 (deeper screen)	5/26/11	
G-14	85½	7/14/09 to 7/15/09	2	7/15/09	15-20 and 44-49	20 (shallower screen) 26.6 (deeper screen)	8/21/09	Santa Monica/Avenue of the Stars
						Dry (shallower screen) 44.5 (deeper screen)	5/26/11	
G-20	100	8/21/09 to 8/24/09	2	8/24/09	30-35 and 80-88	Not Measured	Not applicable	North of Wilshire/Midvale
						Dry (shallower screen) 26.8 (deeper screen)	5/26/11	

3.2.2.1 Rotary-Wash Borings

A total of 80 geotechnical borings were performed for the current tunnel and station alternatives planned as part of the PE phase. All of the geotechnical borings were drilled using 4-7/8-inch-diameter rotary wash-type drilling equipment with drilling mud to prevent caving. The mud was removed following completion of the drilling in the borings to permit measurements of the groundwater level. The soils encountered were logged by field personnel and undisturbed and bulk samples were obtained and transported to the laboratory for visual inspection and testing.

The subcontractors used for drilling (and the drilling rigs used) for the PE phase borings are listed below:

(1) C&L Drilling (Mayhew 1000)

(2) Fugro Consultants, Inc. (CME 75)

(3) Tri County Drilling, Inc. (CME 75)

C&L Drilling (C&L) performed the majority of the rotary-wash borings; Fugro and Tri County were used during later stages of the field work to meet the project schedule set by Metro for field exploration. The types of drilling rigs used by different subcontractors and the hammer weights and drop used to drive the Crandall and SPT samplers are noted on the respective logs. C&L used a 300 to 380 pound hammer with 18-inch drop for driving the Crandall sampler, while Tri County and Fugro used 140-pound automatic hammer and 30-inch drop to drive the Crandall sampler. For SPT sampler, all drillers used 140-pound automatic hammer and 30-inch drop as required by ASTM D 1586. The hammer energy ratios (ER) of C&L, Fugro and Tri County SPT hammers were 0.6, 0.86, and 0.81, respectively.

The borings were drilled to depths ranging from 85 to 151.5 feet below ground surface at the locations shown on Plates 1-01 through 1-21. To differentiate from the ACE phase borings, the PE phase borings are represented using a three-digit designation (G-101 through G-207). The ACE phase borings were represented as G-1 through G-20.

Groundwater monitoring wells were installed upon completion of drilling at nine borehole locations. The borings in which groundwater monitoring wells were installed are represented on the figures as (MW).

The logs of rotary-wash borings drilled for the PE phase are presented in Appendix A of Volume 2. The well construction diagrams are also presented in the same appendix. The locations of the borings and type of field testing performed in these boreholes are presented in Table 3-3.

3.2.2.2 Sampling in Rotary-Wash Borings

In the geotechnical borings, undisturbed samples were obtained using the Crandall sampler at 3 to 5-foot intervals. The Crandall sampler is similar to the modified California sampler, but has less sample disturbance due to the larger diameter of the Crandall sampler. The Crandall sampler has an inside diameter of 2.625 inches and an outside diameter of 2.75 inches. The Crandall sample barrel contains six one-inch thick brass rings. A three-dimensional schematic of the Crandall sampler is shown on Figure A-7 included in Volume 2.

Table 3-3: Summary of Geotechnical Rotary-Wash and Sonic Borings (PE Phase)

Boring No.	Boring Depth (ft)	Location	Station	Comments
G-101	85	Wilshire Bl & Manhattan Pl		
G-102	86	Wilshire Bl & S. Saint Andrews Pl		P
G-103	86.5	Wilshire Bl & Van Ness Ave		
G-104	101.5	Wilshire Bl & Lorraine Bl		MW, P
G-105	111.5	Wilshire Bl & Plymouth Bl		
G-106	90	Wilshire Bl & Freemont Pl		NV
G-107	101	Wilshire Bl & Freemont Pl W		
G-108	121	Wilshire Bl & Mullen Ave		
G-109	141	Wilshire Bl & Hudson Ave		MW, P
G-110	131	Wilshire Bl & Tremaine Ave		P
G-111	106	Wilshire Bl & Highland Ave		
G-112	121	Wilshire Bl & Sycamore Ave	Wilshire/ La Brea	P
G-113	106	Wilshire Bl & Mansfield Ave		
G-114	120	Wilshire & Sycamore Ave		
G-116	106.5	Wilshire Bl & Cochran Ave		
G-118	105.5	Wilshire Bl & Masselin Ave		
G-119	106	Wilshire Bl & Court Yard Place		
G-121	111	Wilshire Bl & Spaulding Ave		P
G-123	110	Wilshire Bl & Orange Grove Ave	Wilshire/ Fairfax	P
G-124	106	Wilshire Bl, west of Fairfax Ave		NV
G-125	120	Wilshire Bl & La Jolla Ave		
G-126	111.5	Wilshire Bl, east of San Vicente Bl		
G-127	112	Wilshire Bl & San Vicente Bl		
G-128	111	Wilshire Bl & San Vicente Bl	Wilshire/ La Cienega	P
G-129	120	Wilshire Bl & Gale Dr		
G-130B	121	Wilshire Bl, west of Gale Dr		
G-131	121.5	Wilshire Bl & La Cienega Bl		P
G-132	111.5	Wilshire Bl & Ledoux Rd	Wilshire/ La Cienega	
G-133	111	Wilshire Bl & Carson Rd		
G-134	111.5	Wilshire Bl & Willman Dr		NV
G-135	120	Wilshire Bl & Amaz Dr		
G-136	121	Wilshire Bl & Robertson Pl		
G-137	120	Wilshire Bl & Clark Dr		
G-138	116	Wilshire Bl, east of S. Swall Dr		
G-139	111.5	Wilshire Bl & Altmont Dr		MW
G-140	105	Wilshire Bl & Wetherly Dr		
G-141	106.5	Wilshire Bl & Oakhurst Dr		

Table 3-3: Summary of Geotechnical Rotary-Wash and Sonic Borings (PE Phase) (continued)

Boring No.	Boring Depth (ft)	Location	Station	Comments
G-142	96	Wilshire Bl & Maple Dr		
G-143	91.5	Wilshire Bl & Crescent Dr	Wilshire/ Rodeo	
G-144	121.5	Wilshire Bl & Reeves Dr		P
G-145	121	Wilshire Bl & El Camino Dr		NV
G-146	105	Wilshire Bl & Rodeo Dr		
G-147	121.5	Wilshire Bl & Peck Dr		
G-148	141.5	Wilshire Bl & Roxbury Dr		
G-149	111.5	Wilshire Bl & Linden Dr		
G-150	111	Wilshire Bl & Spaulding Dr		P
G-152	111	Santa Monica Bl, east of Charleville Bl		NV
G-154	86.5	Santa Monica Bl & Moreno Dr	Century City Santa Monica	
G-156	121	Santa Monica Bl, 100 feet west of Century Park East		MW
G-159	121.5	Santa Monica Bl, and Ensley Drive		
G-161	121.5	Lasky Dr, south of Charleville Bl		
G-162	121	Lasky Dr, north of Young Dr		P
G-164	150.5	Moreno Dr & Young Dr		NV
G-165	150.5	Beverly Hill H.S.		MW, NV
G-166A/B	151	Beverly Hill H.S.		MW, P, NV
G-168	112	Constellation Bl, west of Century Park East	Century City Constellation	
G-169	121	Constellation Bl & Avenue of the Stars		P
G-171	120.5	Century Park West, south of Missouri Ave		
G-173	116.5	Fox Hills Dr & Missouri Ave		P, NV
G-174A	121	Santa Monica Bl & Comstock Ave		MW
G-175	151.5	Kinnard Ave & Pandora Ave		
G-176	131	Warner Ave , north of Thayer Ave		P, NV
G-177	141	Rochester Ave, south of Thayer Ave		
G-178	110	Wilshire Bl & Manning Ave		NV
G-179	121.5	Wilshire Bl, east of Selby Ave		MW, P
G-180	126.5	Wilshire Bl & Selby Ave		
G-181	131	Wilshire Bl & Malcolm Ave		
G-186	121	Wilshire Bl, east of Veteran Ave	Westwood/ UCLA	MW, P
G-187	131.5	Wilshire Bl, west of Malcolm Ave		P
G-188	101	Wilshire Bl, east of Westwood Bl		
G-189	121	Wilshire Bl, east of Midvale Ave		
G-190	121	Wilshire Bl & Midvale Ave	Westwood/ UCLA	
G-191	121	Wilshire Bl, west of Midvale Ave		P
G-199	121.5	Wilshire Bl & on-ramp to Northbound San Diego Fwy		P
G-200Alt	116	Warnall Ave, east of Comstock Ave		
G-203	121.5	Wilshire Bl, east of Bonsalle Ave	Westwood/ VA Hospital	NV, MW

Table 3-3: Summary of Geotechnical Rotary-Wash and Sonic Borings (PE Phase) (continued)

Boring No.	Boring Depth (ft)	Location	Station	Comments
G-204	121.5	Wilshire Bl, 30 feet west of Bonsalle Ave	Westwood/ VA Hospital	P
G-205	121.5	Wilshire Bl, 110 feet west of Bonsalle Ave		P
G-206	121	Wilshire Bl & Windsor Bl		
G-207	101	Wilshire Bl & Norton Ave		P
S-101	92	Wilshire Bl, west of Saint Andrews Pl		
S-102	90	Wilshire Bl & Loraine Bl		
S-103A	127	Wilshire Bl, east of Tremaine Ave		
S-104	116.2	Wilshire Bl, south of Cloverdale Ave		
S-105	102	Wilshire Bl, east of S. Curson		
S-106	122	Wilshire Bl & Fairfax Ave	Wilshire/ Fairfax	MW
S-107	122	Hamilton Dr, south of Wilshire Bl	Wilshire/ La Cienega	
S-108	107	Wilshire Bl, east of La Peer Dr		
S-109	122	Wilshire Bl & El Camino Dr	Wilshire/ Rodeo	
S-110	122	Santa Monica Bl, east of Century Park West		
S-111	150	S. Marino Dr & Young Dr		
S-113	122	Fairburn Ave & Wellworth Ave		
S-114	120	Wilshire Bl, east of Veteran Ave	Westwood/ UCLA	
S-115	122	Vie Hospital Parking lot	Westwood/ VA Hospital	
S-116	107	Wilshire Bl & S. Stanley Ave		
S-117	102	Wilshire Bl, east of S. Ogden Dr		
S-118	102	Wilshire Bl, east of S. Richlee Dr		

P – Pressuremeter Test; MW – Monitoring Well; NV – Noise/Vibration Test
Boring Nos. with designation “G” and “S” indicate Rotary-wash and Sonic borings, respectively

In addition to obtaining undisturbed samples, standard penetration tests (SPTs) were performed in the borings. The number of blows required to drive the Crandall and SPT sampler 12 inches, the hammer weight, and the hammer drop are indicated on the boring logs.

After each Crandall sample was retrieved from the borehole and brought to the ground surface, a photo ionization detector (PID) or a four-gas meter was used to measure the concentrations of volatile organic compounds (VOCs) in the headspace of the samples. The OVA readings are indicated on the boring logs.

Selected Crandall and SPT samples were submitted to the laboratory for testing to evaluate relevant engineering properties.

3.2.2.3 Testing in Rotary-Wash Borings

In-situ pressuremeter testing was performed in 24 of the rotary-wash borings. To accommodate the borehole diameter requirements for the pressuremeter probe, a smaller auger (about 2-7/8 inch diameter) was used to drill a 5-foot run within the testing interval. After testing, a typical 4-7/8 diameter auger was used to ream out the smaller hole to continue sampling below this depth. The smaller diameter holes for pressuremeter testing were drilled near the top, center and invert of the tunnel.

Noise/vibration testing was performed in 12 of the rotary-wash borings by ATS Consulting, Inc. The borehole noise/vibration tests were performed by generating vibration at the bottom of the hole using the 140-pound hammer that was supplied by the drilling rigs. The load cell was lowered to the test depth and then ground surface vibration at several horizontal distances from the boring was recorded. Since the size of the load cell was less than about 4 inches, unlike pressuremeter testing, special drilling diameters were not required for noise/vibration testing. Noise/vibration tests were performed at desired depths as the drilling progressed using a 4-7/8 inch diameter auger.

The borings in which noise/vibration and pressuremeter testing were performed are represented on Plates 1-01 through 1-21, as (NV) and (P), respectively. A list of borings in which pressuremeter testing was performed is presented below. Details of the pressuremeter testing and noise/vibration testing are presented below.

3.2.2.4 Pressuremeter Testing

Pressuremeter tests were performed to determine the elastic modulus (E_m) and at-rest lateral earth pressure coefficient (K_o) of the soil and bedrock expected along the tunnel and at the stations locations.

Pressuremeter testing was performed in 24 of the rotary-wash borings for the PE phase. The pressuremeter tests were performed in accordance with ASTM D 4719-07 using the TEXAM model and an N-size probe that has a diameter of 70 millimeters and is 46 centimeters long.

To conduct a pressuremeter test, the probe was lowered to the test zone, which typically was a 5-foot run drilled using a 2-7/8 inch diameter tricone auger bit. The rate of penetration of the auger and the drilling mud was controlled such that a clean borehole was achieved and that the borehole diameter met ASTM requirements. The probe was lowered to the test depth, as soon as the drilling of the pressuremeter test hole was completed. A longer delay between drilling and testing could potentially allow sufficient time for caving of borehole, particularly in fine-grained granular soils below groundwater.

A strain controlled test was conducted by applying equal increments of volume (typically 40 cubic centimeters) and taking pressure readings at about 15 second intervals. The test was terminated after the soil reached its plastic zone. In several of the pressuremeter tests, a unload re-load cycle was also performed within the pseudo-elastic zone to evaluate the rebound modulus of the soil and bedrock.

Pressuremeter tests were performed at depths roughly corresponding to the top, center and invert of the tunnel. At station locations, pressuremeter tests were performed at shallower depths of roughly 20, 40 and 60 feet below ground surface. However, test depths were adjusted in the field, depending on how the drilling program progressed and soil types encountered at these depths. Tests were not performed, if gravelly soils were encountered, since the borehole diameter would be enlarged and would likely not meet the ASTM requirements for borehole size and would also pose a greater risk of damage to the probe in these soils.

An average total unit of 120 and 125 pounds per cubic foot (pcf) for soil and bedrock formation, respectively, were used in estimating the Elastic Modulus (E_m) and horizontal stress coefficient (aka at-rest earth pressure) (K_o). The results of pressuremeter tests performed during PE phase are presented in Table 3-4 and also shown on Plates 3-1 and 3-2. Limited pressuremeter tests were performed in the ACE phase, however, due to the change in the tunnel alignment and station locations, none of the prior test results are applicable for the current alignment and are therefore not included in this report.

Table 3-4: Pressuremeter Test Results (PE Phase)

Boring No.	Test Depth (ft.)	ASTM Soil Classification	Geologic Formation	At-Rest Lateral Earth Pressure Coefficient, K_o	Menard Modulus, E_m (ksf)
G-102	37	Sandy Lean Clay (CL)	San Pedro (Qsp)	0.58	403
G-102	48	Clayey Sand (SC)	San Pedro (Qsp)	0.85	634
G-104	30	Silty Sand (SM)	Lakewood (Qlw)	0.76	259
G-104	60	Sandy Lean Clay (CL)	San Pedro (Qsp)	0.57	576
G-104	70	Silty Sand (SM)	San Pedro (Qsp)	0.90	1,584
G-104	79	Silty Sand (SM)	San Pedro (Qsp)	0.90	1,008
G-109	93	Siltstone	Fernando (Tf)	0.57	1,109
G-109	113	Siltstone	Fernando (Tf)	0.57	1,109
G-109	118	Siltstone	Fernando (Tf)	0.57	1,109
G-110	63	Poorly Graded Sand with Silt (SP-SM)	San Pedro (Qsp)	0.62	619
G-110	73	Siltstone	Fernando (Tf)	0.54	907
G-110	83	Siltstone	Fernando (Tf)	0.56	720
G-112	18	Silty Sand (SM)	Lakewood (Qlw)	1.01	245
G-112	48	Fat Clay (CH)	San Pedro (Qsp)	0.83	792
G-112	68	Poorly Graded Sand with Silt (SP-SM)	San Pedro (Qsp)	0.59	792
G-121	42	Poorly Graded Sand with Silt (SP-SM)	San Pedro (Qsp)	0.59	230
G-123	23	Silty Sand (SM)/Silt (ML)	Older Alluvium (Qalo)	1.12	302
G-123	38	Silty Sand (SM)	San Pedro (Qsp)	0.72	835
G-128	18	Fat Clay (CH)	Older Alluvium (Qalo)	0.8	130
G-128	38	Fat Clay (CH)/Clayey Sand with Gravel (SC)	San Pedro (Qsp)	0.58	288
G-128	63	Sandy Lean Clay (CL)	San Pedro (Qsp)	0.70	893
G-131	33	Lean Clay (CL)	San Pedro (Qsp)	0.62	216
G-131	43	Sandy Silt (ML)	San Pedro (Qsp)	0.79	259
G-144	23	Fat Clay (CH)	Older Alluvium (Qalo)	0.68	403

Boring No.	Test Depth (ft.)	ASTM Soil Classification	Geologic Formation	At-Rest Lateral Earth Pressure Coefficient, K_o	Menard Modulus, E_m (ksf)
G-144	53	Lean Clay with Sand (CL)	Older Alluvium (Qalo)	0.45	360

Table 3-4: Pressuremeter Test Results (PE Phase) (continued)

Boring No.	Test Depth (ft.)	ASTM Soil Classification	Geologic Formation	At-Rest Lateral Earth Pressure Coefficient, K_o	Menard Modulus, E_m (ksf)
G-144	63	Lean Clay with Sand (CL)	Older Alluvium (Qalo)	0.57	806
G-150	54	Lean Clay with Sand (CL)	Older Alluvium (Qalo)	0.51	288
G-150	64	Clayey Sand (SC)	Older Alluvium (Qalo)	0.72	1,080
G-150	85	Fat Clay (CH)	Older Alluvium (Qalo)	0.36	576
G-162	74.5	Clayey Sand with Gravel (SC)	Older Alluvium (Qalo)	0.55	720
G-162	84.5	Lean Clay with Sand (CL)	Older Alluvium (Qalo)	0.56	1,469
G-166	72	Elastic Silt (MH)	Lakewood (Qlw)	0.54	893
G-169	50	Poorly Graded Sand with Silt (SP-SM)	Lakewood (Qlw)	0.98	1,469
G-173	75	Silty Sand (SM)	Lakewood (Qlw)	0.64	1,541
G-173	90	Poorly Graded Sand with Silt (SP-SM)	San Pedro (Qsp)	0.80	1,210
G-176	87.5	Silty Sand (SM)/ Clayey Silt (ML)	Older Alluvium (Qalo)	0.71	1,152
G-176	100	Sandy Lean Clay (CL)/Silt (ML)	Older Alluvium (Qalo)	0.65	1,253
G-176	110	Clayey Sand (SC)	Older Alluvium (Qalo)	0.58	1,872
G-179	74.5	Sandy Lean Clay (CL)	Older Alluvium (Qalo)	0.50	1,469
G-179	90	Silty Sandy (SM)	Older Alluvium (Qalo)	0.61	2,232
G-179	104	Clayey Sand (SC)	Older Alluvium (Qalo)	0.52	1,310
G-186	58	Silty Sand with Gravel (SM)	Older Alluvium (Qalo)	0.78	619
G-186	37	Silty Sand (SM)	Older Alluvium (Qalo)	0.62	130
G-187	83	Lean Clay with Sand (CL)	Lakewood (Qlw)	0.46	778
G-187	93	Silty Sand (SM)	Lakewood (Qlw)	0.38	950
G-187	108	Sandy Lean Clay (CL)	Lakewood (Qlw)	0.50	1,325
G-191	60	Clayey Sand (SC)	Older Alluvium (Qalo)	0.59	749
G-191	30	Silty Clayey Sand with Gravel (SC-SM)	Younger Alluvium (Qal)	0.80	389
G-191	42	Silty Sand (SM)	Younger Alluvium (Qal)	0.70	677
G-199	45	Silty Clayey Sand with Gravel (SC-SM)	Older Alluvium (Qalo)	0.53	245
G-199	55	Silty Clayey Sand with Gravel (SC-SM)	Older Alluvium (Qalo)	0.55	562
G-199	70	Sandy Lean Clay (CL)	Older Alluvium (Qalo)	0.58	1,267
G-204	23	Sandy Silt with Gravel (ML)/Silty Sand (SM)	Older Alluvium (Qalo)	1.04	331

G-204	43	Sandy Lean Clay (CL)/Silty Sand (SM)	Older Alluvium (Qalo)	0.54	389
G-205	23	Sandy Lean Clay (CL)	Older Alluvium (Qalo)	0.89	1,210
G-205	43	Silty Sand (SM)	Older Alluvium (Qalo)	0.70	274
G-205	67	Silt with Gravel (ML)	Older Alluvium (Qalo)	0.50	432
G-207	42	Silty Sand (SM)	San Pedro (Qsp)	1.02	576

Based on the pressuremeter results, the median, standard deviation, and minimum and maximum values of K_o estimated in different geologic formations are listed below.

Geologic Formation	Test Depth (feet)	Data Points	Median (Ko)	Standard Deviation	Minimum (K_o)	Maximum (K_o)
Younger Alluvium (Qal)	30-42	2	0.75	0.07	0.7	0.8
Older Alluvium (Qalo)	18-110	27	0.58	0.17	0.36	1.12
Lakewood (Qlw)	18-108	8	0.59	0.24	0.38	1.01
San Pedro (Qsp)	33-90	16	0.71	0.14	0.57	1.02
Fernando (Tf)	73-118	5	0.57	0.01	0.54	0.57

The computed range (minimum, maximum), median and standard deviation of estimated static elastic modulus (referred to as Menard Modulus) for different formations is also presented below.

Geologic Formation	Test Depth (feet)	Data Points	Median (Em)	Standard Deviation	Minimum (E_m)	Maximum (E_m)
Younger Alluvium (Qal)	30-42	2	533	204	389	677
Older Alluvium (Qalo)	18-110	27	619	560	130	2,232
Lakewood (Qlw)	18-108	8	922	502	245	1,541
San Pedro (Qsp)	33-90	16	626	379	216	1,584
Fernando (Tf)	73-118	5	1,109	175	720	1,109

E_m- Menard Modulus (in ksf)

3.2.2.5 Noise/Vibration Testing

Noise/vibration testing was performed in 12 of the rotary-wash borings by ATS Consulting, Inc. The vibration propagation tests were performed to assist in predicting the levels of groundborne vibration and noise level that would be generated by the proposed Subway.

Borehole vibration tests were performed to determine directly the vibration propagation characteristics for subsurface vibration sources at a given site. The test method consists of generating ground vibration at the bottom of the hole using the drill rig penetration drop hammer. The impulsive forces transmitted into the soil at the bottom of the borehole were measured using a special load cell and the resulting surface acceleration measured on the ground at varying distances (25, 37, 50, 75, 100, and 150 feet) from the hole.

The 12 sites listed in Table 3-5 were selected for the vibration survey based on two criteria. The first consideration was to select test sites based on their proximity to previously identified vibration-sensitive sites. The second was to select locations that would provide reasonably uniform sampling along the proposed subway alignment. Three of the sites selected for this study (G-164, G-165, and G-166) were located at or near Beverly Hills High School, which had been identified as a site of particular concern.

Table 3-5: Noise/Vibration Test Locations and Test Depths

Borehole	Location / Cross Street	Test Date(s)	Test Depths (feet)
G-106	Wilshire / Arden	24-Mar-2011	50, 60, 70
G-124	Wilshire / Fairfax	17-Mar-2011	40, 55, 60
G-134	Wilshire / Hamel	30-Mar-2011	50,60, 70
G-145	Wilshire / El Camino	14 - 15 Mar 2011	50, 60, 70
G-152	Santa Monica / Wilshire	31 Jan - 1 Feb 2011	55, 65, 75
G-164	Moreno / Young	26 - 27 Jan 2011	45, 55, 65
G-165	Beverly Hills HS (classrooms)	5-Mar-2011	55, 65, 75
G-166	Beverly Hills HS (Lacrosse field)	19-Mar-2011	55, 65, 75
G-173	Missouri / Fox Hills	21 - 22 Feb 2011	60, 70, 80
G-176	Warner / Thayer	27-Dec-2010	80, 90, 97
G-178	Wilshire / Manning	17-Jan-2011	65, 75, 85
G-203	VA Hospital	3-May-2011	55, 65, 75

The borings in which noise/vibration testing was performed are represented on Plates 1 and 1-1 though 1-21, as (NV). Details of the noise/vibration testing and test results are presented in Appendix A of Volume 2.

Based on the results, it is predicted that ground-borne vibration from the trains would be no greater than 64 decibels and the predicted noise level would be no greater than 33 decibels, which are lower than Federal Transit Administration (FTA) thresholds for vibration and noise levels (Metro, 2011).

3.2.3 Sonic Core Borings

A total of 17 sonic core borings were performed for the PE phase. The sonic core borings were performed using sonic coring drilling equipment by Boart Longyear. Sonic drilling employs the use of high-frequency, resonant energy to advance a core barrel or casing into subsurface formations. The sonic drilling method advances a casing as the borehole is drilled to prevent caving of the borehole. A 4-inch diameter core barrel was used to retrieve samples. The drilling was performed in 5-foot runs and the samples were collected in bags or 4-inch diameter acrylic tubes. Samples within a depth range from 10 feet above the tunnel to 20 feet below the tunnel invert were collected in acrylic tubes; the samples outside of this zone were collected in bags. The soils encountered were logged by AMEC field personnel and the samples were transported to the AMEC laboratory for visual inspection, further logging of soil stratigraphy and for laboratory testing.

The sonic borings were drilled to depths ranging from 90 to 150 feet below ground surface at locations shown on Plates 1-01 though 1-21. The sonic core borings are designated as S-101 through S-118 on these plates.

A groundwater monitoring well was installed upon completion of drilling at one sonic core location (S-106). The groundwater well consisted of dual 2-inch diameter PVC pipes screened at two different depths to measure piezometric pressures and to collect water samples in two different groundwater bearing zones. The primary objective of the monitoring wells was to permit measurement of groundwater levels for an extended period of time and to obtain groundwater samples for water quality testing and for measuring concentrations of gases collected in the headspace of the wells.

The logs of sonic core borings drilled for the PE phase are presented in Appendix A of Volume 2.

During the visual inspection of bag and tube samples in the laboratory, AMEC personnel also took photographs of the samples and documented them. The photographs of the sonic core borings are also presented in Appendix A of Volume 2.

3.2.4 Cone Penetration Testing

A total of 27 Cone Penetration Tests (CPTs) were performed for the PE phase of the project. The CPTs were performed using a 30-ton truck-mounted CPT rig and a 15 cm^2 piezocone (CPTu) with enhanced capability of measuring pore water pressures and seismic velocities. The subcontractors used for performing the CPTs for the PE phase were:

(1) Kehoe Testing and Engineering, Inc (Kehoe);

(2) Gregg Drilling and Testing, Inc (Gregg); and

(3) Fugro Consultants (Fugro).

The CPTs were advanced to depths of about 54 to 120 feet below ground surface at the locations shown on Plates 1-01 though 1-21. The CPTs are designated as C-101 through C-128 on these plates.

The CPTs were terminated upon reaching the planned exploration depth or upon reaching refusal from hard subsurface conditions. Pore pressure dissipation tests were performed at depths below the expected groundwater level to evaluate the static piezometric pressure and to estimate the groundwater level in selected CPTs. Due to time restrictions, pore pressure dissipation tests could not be performed at all CPT locations.

Downhole seismic velocity measurements were collected in several of the CPTs at 5-foot intervals. The results of the CPTs and seismic velocity data are presented in Appendix A of Volume 2.

3.2.5 Dilatometer Testing

Three Dilatometer tests (DMTs) were performed for the PE phase. The dilatometer testing was performed by Fugro using a 30-ton truck-mounted CPT rig. After three initial DMTs, it was decided to not perform additional DMTs due to hard driving conditions which caused refusal of the test probe above the tunnel zone. In addition, considering the DMT is not known to provide reasonable data in stiff fine-grained and dense granular soils, the use of DMT was discontinued after the initial three tests. Therefore, the results of the DMTs are not included in this report.

3.2.6 BAT® Groundwater/Gas Sampling in CPTs

A total of six BAT® groundwater sampling CPTs were performed as part of the PE phase. The BAT® CPTs were advanced to depths ranging from 58 to 85 feet below ground surface at the locations shown on Plates 1-01 though 1-21. Four of the BAT® CPTs were performed between Wilshire/La Brea and Wilshire/La Cienega stations to obtain gas and water samples within the tar-impacted soils and gassy ground conditions. The remaining two BAT® CPTs were performed at Beverly Hills High School. The BAT® CPTs performed between La Brea Avenue and La Jolla Avenue are designated as CB-101 through CB-104 and those at Beverly Hills High School are represented as C-117B, C-119B and C-120B on these plates.

The subcontractors used for performing BAT CPTs were:

(1) Gregg Drilling and Testing, Inc (at Beverly Hills High School) and

(2) Fugro Consultants (from Wilshire/La Brea to Wilshire/La Cienega)

The BAT® groundwater monitoring system (BAT-GMS) sampling is performed first by advancing the CPT to the desired sampling depth and then lowering the BAT® sampler down the CPT drill rods using an extension cable onto the BAT® filter tip. Then, by gravity, the double-ended needle penetrates both the septum in the filter tip and the septum of the sample tube to collect both water and gas samples. The action of both the groundwater pressure and the suction in the sample tube draws groundwater and/or soil gas into the sample tube. Upon lifting the BAT® sampler, the flexible septa in both the filter tip and the sample tube automatically reseal. The liquid and/or gas sample is thereby kept hermetically sealed from the point of sampling to the laboratory. In each sampling run, water and/or gas samples can be collected in up to three 35 milliliter glass tubes.

The collected water samples were stored in an ice chest and transported to environmental labs for analytical testing. Analytical testing of gas tubes (no water/liquid) was performed by Air Technology, Inc. to determine concentrations of Ethane, Methane and Butane in soil gas. Analytical testing of water samples was performed by Orange Coast Analytical to determine concentrations of dissolved volatile organic compounds (VOCs), hydrogen sulfide (H_2S) and fixed gases in groundwater. The results of the analytical testing are presented in Appendix F of Volume 2.

The sampling procedures and the analytical test tesults of the BAT® CPTs performed between Wilshire/La Brea to Wilshire/La Jolla and those at Beverly Hills High School are discussed below.

3.2.6.1 Wilshire/La Brea to Wilshire/La Jolla - BAT® CPTs

Between Wilshire/La Brea and Wilshire/La Jolla, BAT® sampling was performed at four locations, identified as CB-101 through CB-104 on Plates 1-1 though 1-21.

CB-101 (Wilshire Boulevard /South Detroit Street)

BAT sampling in CPT CB-101 was successful in obtaining water sample at a depth of about 57 feet below ground surface. Dissolved gases in water samples were analyzed by Orange Coast Analytical Laboratory and the results are presented in Appendix A of Volume 2.

CB-102, CB-103, CB-104 (Wilshire Boulevard, between S. Ridgeley Dr and S. Fairfax Ave)

BAT sampling in these CPTs was not successful due to the presence of tar-impacted soils. Tar in the water-bearing stratum apparently smeared the porous filter membrane of the CPT and impeded the flow of water into the BAT sampler. A groundwater sample was not recovered after a wait time greater than 75 minutes.

3.2.6.2 Beverly Hills High School - BAT® CPTs

BAT® CPT sampling was planned at three locations, identified as C-117B, C-119B and C-120B. BAT sampling was attempted at location C-119B. Due to stiff or dense soils, CPT C-120B reached refusal at a depth of about 17 feet below ground surface. Since this depth was above the groundwater level observed at the site, BAT® sampling was not attempted at this location. Due to work time restrictions at the school, BAT® sampling at CPT C-117B was also not attempted.

At C-119B, BAT® sampling was attempted at depths of about 30, 40, 55, 75 feet below ground surface. A 5-foot-thick sand zone was encountered at a depth of about 30 feet; however, water was not recovered in the sampling tubes, even after about 45 minutes had lapsed. Similarly, water samples were not obtained after a 45-minute waiting period at depths of about 40 and 55 feet because of the presence of fine-grained soils. Accordingly, the sampling wait time was increased to 90 minutes at a depth of about 75 feet; however, water samples were still not recovered. In order to characterize the gas concentrations, gas samples from BAT® tubes were tested, which were collected at depths of 30, 55 and 75 feet. Tests indicated non-detect values of methane, ethane, and propane at all three depths and 0.012 percent of methane at a depth of 75 feet below ground surface (bgs).

3.2.7 Groundwater Monitoring Wells

The purpose of the groundwater monitoring program was to measure the depth to groundwater for an extended period of time for use in future hydrogeologic analysis. The purpose of installing nested well pairs was to monitor partially or fully hydraulically isolated groundwater bearing intervals within the alluvial deposits (i.e., perched water zones or variable pressure zones at depth). In addition, some of the monitoring wells were also "developed" to permit collection of groundwater samples for water quality testing and to measure concentrations of gases collected in the headspace of the wells.

The groundwater monitoring wells were installed in accordance with requirements set forth in California Well Standards Bulletin 74-90. The monitoring wells for the current exploration were installed using the following procedure:

- The boring was drilled to its target depth; subsequently, the drilling mud was thinned to a level considered feasible by re-circulating clean water through the boring, while using caution to prevent the borehole from caving.
- 1- and/or 2-inch diameter, Schedule-40 PVC pipes with a screened (slotted) depth interval were lowered into the borings. The monitoring well details are provided in Appendix A of Volume 2.
- Monterey #3 sand filter pack sand was then placed in the annular space between the PVC pipe and the soil to a depth range from approximately two feet above the top of the screened depth interval to two feet below the bottom of the screened interval.

- Bentonite pellets were placed in the annular space, from the top of the sand filter pack up to the depth of installation for the upper well screen and casing. The bentonite pellets were hydrated in place. The placement of the sand filter pack and bentonite pellet placement was similar for the upper well placement.
- Traffic-rated flush-mounted well-head boxes were installed above the PVC well casing riser and cap. The boxes were set approximately ½ to 1 inch above grade and set in concrete to prevent surface water accumulation.

The monitoring wells were "developed" at three locations (G-165, G-166, S-114) to permit collection of groundwater samples for water quality testing and to measure concentrations of gases collected in the headspace of the wells. Monitoring wells installed in Borings S-114 is designated as P-103, a pump well used for pumping testing at Westwood/UCLA Station.

Well installation and construction details for monitoring wells installed in the PE phase are included in Appendix A of Volume 2.

3.2.7.1 Groundwater Monitoring

All of the current and prior ACE phase monitoring wells had groundwater depth readings collected from April through June 2011. The water level readings collected in the monitoring wells installed during the ACE phase were presented earlier in Table 3-2. The water level readings taken in the monitoring wells installed in PE phase are presented in Table 3-6. Additional discussions pertaining to groundwater data in subsurface gas monitoring wells installed as a part of subsurface gas investigation are presented in Section 3.4.4.1.

Table 3-6: Monitoring Well Data in Geotechnical Borings (PE Phase)

Boring/Well No.	Station Name	Location	Date of Groundwater Measurement	Depth of Water (feet) (s)-shallow well, (d)-deep well**
G-104		Wilshire, west of Crenshaw	7/29/2011	33.3 (s)
				34.5 (d)
G-109		Wilshire, west of Hudson Av	7/29/2011	28.5 (s)
				40.9 (d)
G-139		Wilshire, west of Altmont Dr	7/29/2011	36.3 (s)
				42.2 (d)
G-156		S. Monica Bl, Century City	6/10/2011	27.02 (s)
				45.38 (d)
G-165		Beverly Hills High School	4/22/2011	26.0 (s)
				64.5 (d)
G-166		Beverly Hills High School	4/22/2011	43.0 (s)
				64.5 (d)
G-174A		Santa Monica Bl, west of Fox Hills Dr	3/29/2011	0 (s)
				0 (d)
G-179		Wilshire/Manning	1/20/2011	33.7 (s)
				N/A* (d)

G-186	Westwood/UCLA	Westwood/UCLA	5/28/2011	Dry (s)
				47.91 (d)
G-203	Westwood/VA Hospital	Veterans Administration Hospital	6/10/2011	Dry (s)
				71 (d)
S-106		Wilshire, west of Fairfax Av	6/10/2011	17.48 (s)
				47.72 (d)

*N/A – no reading. **see monitoring well diagrams in Appendix F for shallow and deep well screen depths

3.3 Fault Investigation

AMEC performed fault studies in Century City to evaluate the location of active faults in the vicinity of the Century City Station options. The tunnel alignment alternatives in the Century City/west Beverly Hills area will cross two mapped fault zones – the Santa Monica fault zone and the West Beverly Hills Lineament. The east-west trending Santa Monica fault zone is known to be active with zones of ground surface rupture in the past approximately 11,000 years (Holocene). However, until this study was undertaken the location of the active strand(s) of the Santa Monica Fault zone in the Century City/West Beverly Hills area had not been specifically evaluated through subsurface geologic investigations.

The north-south trending West Beverly Hills Lineament, a linear topographic feature to the east of Century City was suspected to be a fault, and appears to be a northern extension of the Newport Inglewood Fault. Until this study was undertaken, no subsurface investigation had been conducted to evaluate its precise location or existence as an active fault.

The fault study consisted of 56 core boreholes and 192 Cone Penetrometer Test (CPT) soundings along 7 transects, and 5 seismic reflection profiles along the same 7 transects in the Century City area.

A separate report provides a detailed description of the findings and backup data such as the boring logs, CPT and geophysical data (Metro, 2011).

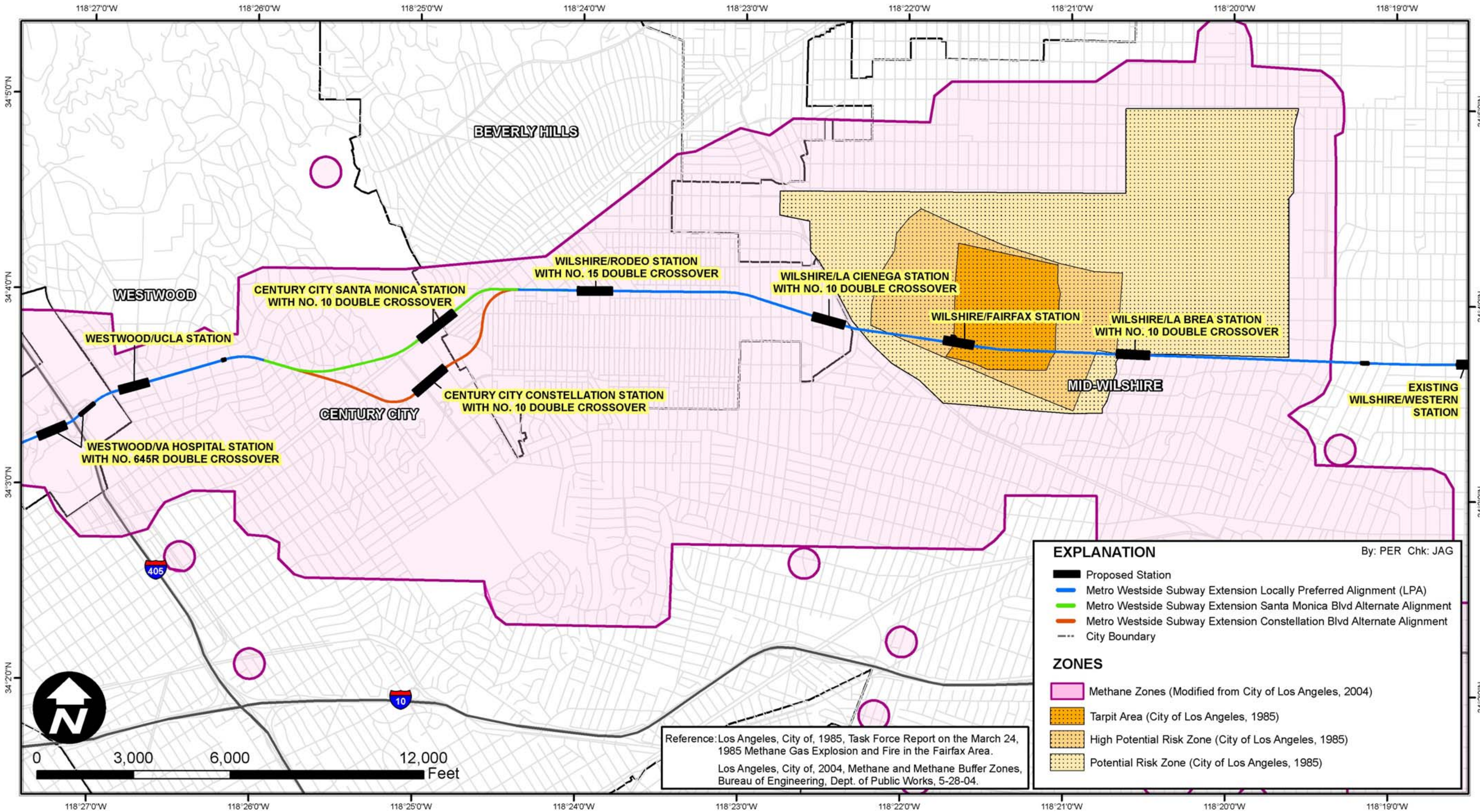
A brief discussion of the major findings from the fault studies is presented in Section 7.

3.4 Subsurface Gas Investigation

3.4.1 General

The proposed alignment of the Westside Subway Extension passes through or near active and abandoned oil fields in the West Los Angeles, Beverly Hills and Westwood areas. The proposed alignment extends through portions of the South Salt Lake, Beverly Hills, and west Los Angeles Oil Fields, as mapped by the California Department of Conservation, Division of Oil, Gas and Geothermal Resources (DOGGR). The rock and soils overlying these oil fields are known to commonly contain methane and/or hydrogen sulfide gases, either derived directly from leakage from the oil reservoirs below or from bacterial breakdown of shallow oil-bearing sediments, including oil sands, tar sands, and fine-grained oil source rocks. The tunnel alignment passes through areas that have been designated as "Methane Zones" by the Los Angeles Department of Building & Safety (see Figure 3-1). About 3,500 feet of the tunnel alignment west of the existing Wilshire/Western station is outside the "Methane Zone".

Figure 3-1: Methane Hazard Zones



THIS PAGE INTNETIONALLY LEFT BLANK

A significant amount of subsurface data has been compiled for the proposed alignment over the last three decades. This data indicates the subway will extend predominately through deposits associated with the Lakewood, San Pedro and Fernando Formations. High levels of methane gas and hydrogen sulfide gas are present locally within these formations along the alignment. In addition, portions of the proposed alignment extend below the existing groundwater into formations with high levels of gas concentrations. Therefore, potential off-gassing of methane and hydrogen sulfide from groundwater will need to be considered in conjunction with the construction and operation of the subway system. The tunneling operations are expected to be classified as "Gassy Operations", as defined by the Occupational Safety & Health Administration (OSHA).

Methane and hydrogen sulfide are expected to be the primary gases of concern that will be encountered in the subsurface on the project. The general characteristics of both of these gases are summarized below.

Methane:

Methane gas is combustible with a Lower Explosive Level (LEL) of 53,000 parts per million (5.3% by volume) in the presence of oxygen at atmospheric levels. Methane is not toxic, although it can be an asphyxiant at high concentrations to the extent it displaces oxygen. There are no published Permissible Exposure Limits (PELs) for methane. Methane is approximately 40% lighter than air with a density of approximately 0.7 grams per liter at atmospheric pressure. Methane is moderately soluble in water. Approximately 33 cubic centimeters of methane can be dissolved in a liter of water at atmospheric pressure. The maximum allowable methane level in the subway excavations for design purposes is expected to be 10% LEL, or approximately 5,000 parts per million (0.5%).

Hydrogen Sulfide:

Hydrogen sulfide is a flammable, toxic gas with a characteristic odor of rotten eggs. Its LEL is approximately 40,000 parts per million (4% by volume), with an OSHA PEL of 20 parts per million and a National Institute for Occupational Safety and Health Recommended Exposure Limit (NIOSH REL) of 10 parts per million. For most people, hydrogen sulfide has an odor threshold of approximately 0.3 parts per million, and has an odor described as objectionable at concentrations above approximately 1 parts per million. Hydrogen sulfide is approximately 15% heavier than air with a density of 1.4 grams per liter at atmospheric pressure. Hydrogen sulfide is highly soluble in water. Approximately 2,800 cubic centimeters of hydrogen sulfide can be dissolved in a liter of water at atmospheric pressure. The off-gassing of hydrogen sulfide from a liter of water that is saturated with the gas can produce a 1 part per million concentration within a 2,800 cubic meter air space.

Off-gassing of hydrogen sulfide from nuisance water and/or groundwater extracted in conjunction with dewatering operations represents a potentially significant source of the gas. Sufficient quantities of hydrogen sulfide may be present along sections of the alignment such that treatment of the effluent ventilation air may be necessary in order to control odors that would otherwise be objectionable to the community. Hydrogen sulfide is typically oxidized rapidly in the subsurface (or if dissolved in water) when exposed to even low levels of oxygen. This can make accurate measurement of subsurface hydrogen sulfide levels difficult when exposed to air and false negative readings may result. The oxidation of hydrogen sulfide in-situ also represents a means by which gas concentrations can be mitigated in advance of construction.

3.4.2 Advanced Conceptual Engineering (ACE) Phase

3.4.2.1 Summary of Explorations

In ACE phase, 25 gas monitoring wells were installed. Boring logs and well completion diagrams for the wells are included in Volume 2. These wells are intended to remain in place for the long-term, so that repeated measurements may be made over time. These soil gas monitoring wells were initially sampled on August 18 and 19, 2009 and the data gathered is presented in Table 3-7. The wells were re-sampled again in May 2011 durign the PE phase and the data is presented in Table 3-8.

3.4.2.2 Summary of Prior Gas Monitoring Results (ACE Phase)

In general, only the approximately 1.1 mile long portion of Wilshire Boulevard between Cochran Avenue and La Jolla Avenue displayed significant levels of gas pressure, methane, and hydrogen sulfide. Elsewhere, no sample point displayed greater than 0.5 inches of water gas pressure, contained greater than 1.25% methane (25% of the lower explosive limit), or indicated greater than 1 part per million of hydrogen sulfide (see Table 3-7). This portion of Wilshire Boulevard also is characterized by having extensive tar sands, with tar seeps common in many areas.

East of this highly gassy area, gas levels diminish gradually to non-detectable east of Hudson Avenue. To the west, gas levels are very low west of San Vicente Boulevard. Gas levels are also very low to non-detectable in the explorations in Century City.

More data was gathered during the PE phase, as discussed below and the findings from all the gas well monitoring data are presented in the following sections.

3.4.3 Preliminary Engineering (PE) Phase

At the request of Parsons Brinckerhoff, AMEC re-sampled gas monitoring wells M-1 through M-25 that were previously installed by MACTEC and the pre-existing wells GW-1 through W-GW-3 and 36 through 47 which were previously sampled semiannually by TRC and installed by others. The gas level readings for these wells were recorded in May, 2011 during the PE phase. The results of these activities are presented in Table 3-8.

3.4.3.1 Gas Monitoring Wells (PE Phase)

As a part of PE phase, sampling and testing activities were performed to better characterize the environmental conditions along the Mid Wilshire, Century City and Westwood sections of the alignment. This information was useful to characterize the concentrations of methane and hydrogen sulfide in the subsurface, in both gaseous and dissolved phases (i.e., dissolved in groundwater). It is expected that this data will be used in conjunction with the design of ventilation and dewatering systems for the project.

Table 3-7: 2009/2010 Field and Lab Gas Monitoring Data in Prior (ACE Phase) Gas Monitoring Wells[1]

Well No.	Location	Sample Probe Depth (ft)	Depth to Water (ft)[1]	Probe Pressure (inches of H_2O)[2]	Field Methane (CH_4) (%)[3]	Lab Methane (CH_4) (%)[3]	Field Hydrogen Sulfide (H_2S) (ppm)[4]	Notes
M-1	Wilshire & S Arden Boulevards	15		0.0	ND	ND	ND	Above water
M-1		25		0.0	ND	-	ND	In water
M-1		65		0.0	ND	-	ND	In water
M-1		100	33.15	0.0	ND	-	ND	In water
M-2	Wilshire Boulevard & S Hudson Avenue	15		0.0	ND	0.0015	ND	Above water
M-2		25		0.0	ND	ND	ND	Above water
M-2		65		0.2	V	-	V	In water
M-2		90	43.85	0.0	ND	-	ND	In water
M-3	Wilshire Boulevard & S Citrus Avenue	15		0.0	0.4	0.3500	ND	Above water
M-3		25		0.0	0.2	-	ND	In water
M-3		65		0.0	0.1	-	ND	In water
M-3		90	18.99	0.0	0.1	-	ND	In water
M-4	Wilshire Boulevard & S La Brea Avenue	15		0.0	0.6	0.5700	ND	Above water
M-4		25		0.0	0.4	-	ND	In water
M-4		65		0.0	0.5	-	ND	In water
M-4		100	17.77	0.0	0.4	-	ND	In water
M-5	Wilshire Boulevard & S Cloverdale Boulevard	15		0.0	0.7	-	W	In water
M-5		25		0.0	0.1	-	ND	In water
M-5		65		0.0	0.4	-	ND	In water
M-5		90	18.28	0.0	0.3	-	ND	In water
M-6	Wilshire Boulevard & S Burnside Avenue	15		0.0/0.0[2]	ND/1.2[2]	1.9	0.410	Above water
M-6		25		0.0/0.0[2]	4.8/0.3[2]	-	ND	In water
M-6		65		2.3/0.1[2]	2.5/0.4[2]	-	ND	In water
M-6		80 (probe)		1.4/0.1[2]	1.3/0.4[2]	-	ND	
M-6		80 (1" PVC pipe)	Not Measured	-/1.4[2]	-/14.1[2]		>50	Depth to tar not measured. Headspace in 1" well at 80' was >50 ppm H_2S*
M-7	Wilshire Boulevard & S Curson Avenue	15		0/1.0/152[3]	ND	-	ND	In water (perched). Gas is bubbling up around well casing.
M-7		25		>5/1.0/291[3]	H	60	30/1.5	Above water
M-7		65	Flowing	W/W/844[3]	W	-	W	In water
M-7		90	Flowing	W/W/38[3]	W	-	W	In water

Table 3-7: 2009/2010 Field and Lab Gas Monitoring Data in Prior (ACE Phase) Gas Monitoring Wells1 (continued)

Well No.	Location	Sample Probe Depth (ft)	Depth to Water (ft)1	Probe Pressure (inches of H2O)2	Field Methane (CH4) (%)3	Lab Methane (CH4) (%)3	Field Hydrogen Sulfide (H2S) (ppm)4	Notes
G-7A	Wilshire Boulevard & Fairfax Avenue	87		-	-	ND	ND	
G-7A		117		-	-	0.694	ND	
G-7A		150		-	-	0.857	ND	
M-8	Wilshire Boulevard west of S Stanley Avenue	15		2.6/3.9[2]	84.5	-	W	In water
M-8		25		>5/32[2]	84.3	-	W	In water
M-8		65		4.0/0.0[2]	W	-	W	In water
M-8		95	Surface	1.4/0.0[2]	W	-	W	Gas bubbling from water in well
M-9	Wilshire Boulevard & S Spaulding Avenue	15		0.0	0.6	-	W	In water
M-9		25		0.2	5.5	-	ND	In water
M-9		65		0.0	5.7	-	ND	In water
M-9		95	17.60	0.0	9.1	-	ND	In water
M-10	Wilshire Boulevard & S Orange Grove Avenue	15		0.4	82.6	75	0.170	Above water
M-10		30		0.0	W	-	W	In water
M-10		65		0.0	37.9	-	ND	In water
M-10		100	Tar @ 30'	W	W	-	W	In water
M-11	Wilshire Boulevard & S Fairfax Avenue	15		2.2	H	86	ND	Above water
M-11		35		0.0	90.4		ND	Above water
M-11		62.5	Tar @ 63'	0.3	39.1	37	0.350	
M-11		95	Tar @ 65'	0.8	H	58	0.920	
M-12	Wilshire Boulevard between S Fairfax Avenue and S Crescent Heights Boulevard	15		0.0/0.0[2]	2.7	-	0.110	Above water
M-12		35		0.0/0.0[2]	1.6	-	ND	Above water
M-12		65		>5/>5[2]	20.6	-	ND	Above water
M-12		100	71.00	1/>5[2]	48.2	-	ND	Water on tar in well at 71'
M-13	Wilshire Boulevard & S Crescent Heights Boulevard	55	Dry	-/16[2]	H	-/100	>50/>50, 1,000*	No water at bottom of well at 60'

[1] Refer to explanation at the end of table

Table 3-7: 2009/2010 Field and Lab Gas Monitoring Data in Prior (ACE Phase) Gas Monitoring Wells1 (continued)

Well No.	Location	Sample Probe Depth (ft)	Depth to Water (ft)1	Probe Pressure (inches of H2O)2	Field Methane (CH4) (%)3	Lab Methane (CH4) (%)3	Field Hydrogen Sulfide (H2S) (ppm)4	Notes
M-14	Wilshire Boulevard & S La Jolla Avenue	15		0.0	ND	0.0280	ND	Above water
M-14		30		0.0	0.7	0.7100	ND	Above water
M-14		65		0.0	3.2	-	ND	In water
M-14		100	59.03	0.0	4.3	-	ND	In water
M-15	Wilshire Boulevard between San Vicente Boulevard & S La Jolla Avenue	15		0.0	ND	ND	ND	Above water
M-15		30		0.0	ND	0.0015	ND	Above water
M-15		65		0.0	ND	-	ND	In water
M-15		100	55.42	0.0	ND	-	W	In water
M-16	Wilshire Boulevard & San Vicente Boulevard	15		0.0	ND	0.0022	ND	Above water
M-16		25		0.0	ND	0.0027	ND	Above water
M-16		65		0.0	0.6	-	ND	In water
M-16		100	41.45	0.0	0.6	-	ND	In water
M-17	Wilshire Boulevard & S Stanley Drive	15		0.0	ND	0.041	ND	Above water
M-17		25		0.0	ND	-	ND	In water
M-17		65		0.2	ND	-	ND	In water
M-17		90	26.72	0.2	ND	-	ND	In water
M-18	N Santa Monica Boulevard & Century Park East	15		0.0	ND	ND	ND	Above water
M-18		25		0.0	ND	ND	ND	Above water
M-18		65		0.0	ND	-	ND	In water
M-18		100	56.58	0.0	ND	-	ND	In water
M-19	Avenue of the Stars & Constellation Avenue	15		0.0	ND	-	ND	Above water
M-19		40		0.0	ND	0.0310	ND	Above water
M-19		70	Dry	0.0	0.7	0.2900	ND	No water at bottom of well at 70'
M-20	Santa Monica Blvd & N Ogden Drive	15		0.0	ND	ND	ND	Above water

[1] Refer to explanation at the end of table

Table 3-7: 2009/2010 Field and Lab Gas Monitoring Data in Prior (ACE Phase) Gas Monitoring Wells1 (continued)

Well No.	Location	Sample Probe Depth (ft)	Depth to Water (ft)1	Probe Pressure (inches of H2O)2	Field Methane (CH4) (%)3	Lab Methane (CH4) (%)3	Field Hydrogen Sulfide (H2S) (ppm)4	Notes
M-20		25		0.0	ND	ND	ND	Above water
M-20		65	64.81	0.0	ND	ND	0.220	Above water (possibly perched)
M-20		90	86.98	0.0	ND	ND	0.240	Above water
M-21	Santa Monica Blvd & N W Knoll Drive	15		0.0	ND	ND	ND	Above water
M-21		25		0.0	ND	ND	ND	Above water
M-21		65		0.1	ND	-	ND	In water
M-21		90	33.93	0.1	ND	-	ND	In water
M-22	N San Vicente Boulevard & Melrose Avenue	15		0.0	ND	0.0040	ND	Above water
M-22		25		0.5	ND	-	ND	In water
M-22		65		W	W	-	W	In water
M-22		90	Flowing	W	W	-	W	In water
M-23	San Vicente Boulevard & Gracie Allen Drive	15		0.0	ND	ND	ND	Above water
M-23		25		W	W	-	W	In water
M-23		65	Flowing	W	W	-	W	In water
M-23		90	Flowing	W	W	-	W	In water
M-24	La Cienega Boulevard & W 3rd Street	15		0.0	ND	0.0053	ND	Above water
M-24		25		0.0	ND	-	ND	In water
M-24		65		0.0	ND	-	ND	In water
M-24		90	11.90	0.0	ND	-	ND	In water
M-25	N San Vicente Boulevard & W 5th Street	15		0.0	ND	0.0012	ND	Above water
M-25		25		0.0	ND	-	ND	In water
M-25		57.5	23.82	0.0	ND	-	0.120	In water
M-25		95	22.98	0.0	ND	-	0.130	In water

Explanation:
"V" indicates no reading due to pulling a vacuum in the tubing headspace (sample interval below water)
"W" indicates no reading due to water in the tubing (shallow or flowing groundwater)
"H" indicates no reading due to methane content too high for field meter
H_2O – Water pressure in probe; CH_4 – Methane; H_2S – Hydrogen Sulfide; ppm – parts per million
*The maximum limit of the gauge is 50 ppm
[1]Depth to water measured in 1" or 2" PVC pipe screened at indicated depth. "Flowing" indicates water flowing under artesian conditions from tubing or PVC pipe.
[2] "xx/yy" indicates two readings taken—first on 8/18/09 to 8/20/09, second on 11/4/09
[3] "xx/yy/zzz" indicates three readings taken—first on 8/18/09 to 8/20/09, second on 11/4/09, and third on 1/15/10

Note: Monitoring wells M-12 and G-7A were abandoned October 15, 2011 due to tar leaking to the ground surface.

Table 3-8: Current (2011) Field Gas Monitoring Data in Prior (ACE Phase and TRC) Gas Monitoring Wells and Vapor Probes

Well No.	Diameter (inches)	Location	Probe Tube Color	Sample Probe Depth (feet)	Depth to Water (feet)[1]	Date	Time	Probe Pressure (inches of H_2O)[2]	Field CH_4 (%)[3]	Field H_2S (ppm)[4]	Notes
M-1	0.25	Wilshire & South Arden Blvds	G	15		5/14/2011	932	0.0	0.0	0.0	
M-1	0.25		R	25		5/14/2011	930	0.0	0.0	0.0	
M-1	0.25		B	65		5/14/2011	937	0.2	0.0	0.0	
M-1	0.25		Y	100		5/14/2011	935	0.0	1.2	0.0	
M-1	1		W	100	31.02	5/14/2011					
M-2	0.25	Wilshire Blvd & South Hudson Ave	G	15		5/14/2011	1008	0.0	0.0	0.0	
M-2	0.25		R	25		5/14/2011	1007	0.0	0.0	0.0	
M-2	0.25		B	65		5/14/2011	1010	2.1	0.0	0.0	
M-2	0.25		Y	90		5/14/2011	1009	2.3	0.0	0.0	
M-2	1		W	90	41.83	5/14/2011	1009				
M-3	0.25	Wilshire Blvd & South Citrus Ave	G	15		5/14/2011	1032	0.0	0.0	0.0	
M-3	0.25		R	25		5/14/2011	1030	0.0	0.0	0.0	
M-3	0.25		B	65		5/14/2011	1034	0.0	0.0	0.0	
M-3	0.25		Y	90		5/14/2011	1033	0.0	0.0	0.0	
M-3	1		W	90	16.28	5/14/2011					
M-4	0.25	Wilshire Blvd & South La Brea Ave	G	15		5/14/2011	1114	0.3	0.0	0.0	
M-4	0.25		R	25		5/14/2011	1112	0.5	0.0	0.0	
M-4	0.25		B	65		5/14/2011	1117	0.7	0.0	0.0	
M-4	0.25		Y	100		5/14/2011	1115	0.5	0.0	0.0	
M-4	1		W	100	15.30	5/14/2011					
M-5	0.25	Wilshire Blvd & South Cloverdale Blvd	G	15		5/13/2011	1154	0.0	0.0	0.0	
M-5	0.25		R	25		5/13/2011	1151	0.0	0.0	0.0	
M-5	0.25		B	65		5/13/2011	1158	0.5	0.0	0.0	
M-5	0.25		Y	90		5/13/2011	1155	0.2	0.0	0.0	
M-5	1		W	90	15.91	5/13/2011					
M-6	0.25	Wilshire Blvd & South Burnside Ave	G	15		5/17/2011	1230	0.0	0.0	0.005	
M-6	0.25		R	25		5/17/2011	1232	0.0	0.0	0.000	
M-6	0.25		B	65		5/17/2011	1236	0.0	0.0	0.005	
M-6	0.25		Y	80		5/17/2011	1234	0.0	0.0	0.008	
M-6	1		W	80	Tar at 0.1 feet	5/17/2011					
M-7	0.25	Wilshire Blvd & South Curson Ave	G	15	No Reading due to gases in casing.	5/17/2011 / 12/3/2011	1300 / 805	> 30 / 168	46 / 75	75.0 / 37.0	5/17/2011: Lab sample M7-15 H = Too high for field instrument
M-7	0.25		R	25		5/17/2011	1310	0.0	0.6	0.140	Constant gases bubbling up from well box, escaping from
M-7	0.25		B	65		5/17/2011	1320	0.0	Water	Water	well casing cap
M-7	0.25		Y	90		5/17/2011	1330	0.0	0.9	0.010	
M-7	1		W	90		5/17/2011					

Metro

Table 3-8: Current (2011) Field Gas Monitoring Data in Prior (ACE Phase and TRC) Gas Monitoring Wells and Vapor Probes (continued)

Well No.	Diameter (inches)	Location	Probe Tube Color	Sample Probe Depth (feet)	Depth to Water (feet)1	Date	Time	Probe Pressure (inches of H2O)2	Field CH4 (%)3	Field H2S (ppm)4	Notes
M-8	0.25	Wilshire Blvd west of South Stanley Ave	G	15		5/16/2011	1120	0.42	Water	Water	
M-8	0.25		R	25		5/16/2011	1120	0.0	Water	Water	Some gases bubbling from well box
M-8	0.25		B	65		5/16/2011	1121	0.0	Water	Water	Well box needs replacement
M-8	0.25		Y	95		5/16/2011	1121	0.0	Water	Water	
M-8	1		W	95	0.97	5/16/2011					
M-9	0.25	Wilshire Blvd & South Spaulding Ave	G	15		5/16/2011	1415	0.0	3.2 then water in tube	0.106	
M-9	0.25		R	25		5/16/2011	1410	0.0	7.8	0.100	
M-9	0.25		B	65		5/16/2011	1420	0.0	1.3	0.004	Water in tube
M-9	0.25		Y	95		5/16/2011	1417	0.0	water	0.004	
M-9	1		W	94	15.42	5/16/2011					
M-10	0.25	Wilshire Blvd & South Orange Grove Ave	G	15		5/17/2011	1450	0.0	5.5	0.003	
M-10	0.25		R	30	During previous reading (2004) tar at 30 feet	5/17/2011	1445	0.0	0.0	0.005	
M-10	0.25		B	65		5/17/2011	1500	0.0	0.0	0.000	
M-10	0.25		Y	100		5/17/2011	1455	0.0	15.5	0.004	
M-10	2		W	100		5/17/2011					
M-11	0.25	Wilshire Blvd & South Fairfax Ave	R	15		5/18/2011 / 11/29/2011 / 11/30/2011	1056	0.0/1.0/0.0	36.7/2.9/1.1	0.220/0.0/0.0	Lab sample M11-yellow 2 – 2-inch wells & 2 probes red & yellow
M-11	0.25		Y	35		5/18/2011 / 11/29/2011 / 11/30/2011	1520	0.0/3.0/5.0	0.0/79.7/78.5	0.006/0.0/0.0	
M-11	2		SP	65		5/18/2011 / 11/29/2011 / 11/30/2011	1058	2.7/0.0/0.0	76.1/58.6/51.9	0.230/0.0/0.0	
M-11	2		DP	95	Tar at 68 feet	5/18/2011 / 11/29/2011 / 11/30/2011	1525	2.2/10.0/0.4	49.0/67.4/73.3	ND/0.0/0.0	H = Too high for field instrument
M-12	0.25	Wilshire Blvd between South Fairfax Ave and South Crescent Heights Blvd	G	15		5/18/2011	1005	0.0	0.0	water	
M-12	0.25		R	35		5/18/2011	1000	0.0	water	water	
M-12	0.25		B	65		5/18/2011	1010	0.2	0.0	water	
M-12	0.25		Y	100		5/18/2011	1007	water	water	water	
M-12	2		W	100		5/18/2011					
M-13	2	Wilshire Blvd & South Crescent Heights Blvd	W	55	Dry	5/18/2011 / 11/29/2011 / 11/30/2011	1155	20.0/14.0/18.0	63.0/90.3/90.4	3,600/6,500/5,500	
M-14	0.25	Wilshire Blvd & South La Jolla Ave	G	15		5/18/2011	1247	0.0	0.0	0.006	
M-14	0.25		R	25		5/18/2011	1245	0.0	0.0	0.110	
M-14	0.25		B	65		5/18/2011	1251	0.0	0.0	0.000	
M-14	0.25		Y	95		5/18/2011	1250	0.0	0.0	0.000	
M-14	1		W	95	58.04	5/18/2011					
M-15-alt	0.25	Wilshire Blvd between San Vicente Blvd & South La Jolla Ave	G	15		5/18/2011	1308	0.0	0.0	0.000	
M-15-alt	0.25		R	25		5/18/2011	1307	0.0	0.0	0.000	
M-15-alt	0.25		B	65		5/18/2011	1312	0.0	0.0	0.000	

Table 3-8: Current (2011) Field Gas Monitoring Data in Prior (ACE Phase and TRC) Gas Monitoring Wells and Vapor Probes (continued)

Well No.	Diameter (inches)	Location	Probe Tube Color	Sample Probe Depth (feet)	Depth to Water (feet)1	Date	Time	Probe Pressure (inches of H2O)2	Field CH4 (%)3	Field H2S (ppm)4	Notes
M-15-alt	0.25		Y	100		5/18/2011	1310	0.0	0.0	0.000	
M-15-alt	2		W	100	54.28	5/18/2011					
M-16	0.25	Wilshire Blvd & San Vicente Blvd	G	15		5/20/2011	1000	0.0	0.6	0.000	
M-16	0.25		R	25		5/20/2011	1005	0.0	0.0	0.003	Lab Sample M16-25
M-16	0.25		B	65		5/20/2011	1010	0.0	0.0	0.004	
M-16	0.25		Y	100		5/20/2011	1007	0.0	0.9	0.003	
M-16	2		W	100	39.60	5/20/2011					
M-17	0.25	Wilshire Blvd & South Stanley Dr	G	15		5/18/2011	1340	0.0	5.8	0.000	
M-17	0.25		R	25		5/18/2011	1338	0.0	0.0	0.000	
M-17	0.25		B	65		5/18/2011	1342	0.0	0.0	0.000	
M-17	0.25		Y	90		5/18/2011	1339	1.6	0.0	0.000	
M-17	1		W	90	24.20	5/18/2011					
M-18	0.25	N Santa Monica Blvd & Century Park East	G	15		5/20/2011	1130	0.0	0.0	0.000	
M-18	0.25		R	25		5/20/2011	1132	0.0	0.0	0.000	
M-18	0.25		B	65		5/20/2011	1134	0.0	0.0	0.001	
M-18	0.25		Y	100		5/20/2011	1136	0.0	0.0	0.000	
M-18	1		W	100	54.20	5/20/2011					
M-19	0.25	Avenue of the Stars & Constellation Ave	R	15		5/20/2011	1210	0.0	0.0	0.000	
M-19	0.25		B	40		5/20/2011	1212	0.0	0.0	0.017	
M-19	0.25		Y	70		5/20/2011	1214	0.0	0.0	0.000	
M-19	1		W	70	Dry	5/20/2011					
M-20	0.25	Santa Monica Blvd & North Ogden Dr	G	15		5/23/2011	1310	0.0	0.0	0.003	
M-20	0.25		R	25		5/23/2011	1312	0.0	0.0	0.000	
M-20	0.25		B	65	Dry	5/23/2011	1314	0.0	0.0	0.002	
M-20	0.25		Y	90		5/23/2011	1316	0.0	0.0	0.007	
M-20	1		W	90	89.64	5/23/2011					
M-21	0.25	Santa Monica Blvd & North West Knoll Dr	G	15		5/16/2010	1131	0.0	0.0	0.000	
M-21	0.25		R	25		5/16/2010	1130	0.0	0.0	0.000	
M-21	0.25		B	65		5/16/2010	1132	0.0	0.0	0.004	
M-21	0.25		Y	90		5/16/2010	1133	0.0	0.0	0.006	
M-21	1		W	90	31.40	5/16/2010					
M-22	0.25	San Vicente Blvd & Melrose Ave	G	15							
M-22	0.25		R	25							
M-22	0.25		B	65							
M-22	0.25		Y	90							
M-22	1		W	90							
M-23	0.25	San Vicente Blvd & Gracie Allen Dr	G	15		5/16/2011	1030	0.0	Water	Water	
M-23	0.25		R	25		5/16/2011	1030	0.0	Water	Water	Artesian conditions
M-23	0.25		B	65		5/16/2011	1031	0.0	Water	Water	

Table 3-8: Current (2011) Field Gas Monitoring Data in Prior (ACE Phase and TRC) Gas Monitoring Wells and Vapor Probes (continued)

Well No.	Diameter (inches)	Location	Probe Tube Color	Sample Probe Depth (feet)	Depth to Water (feet)1	Date	Time	Probe Pressure (inches of H2O)2	Field CH4 (%)3	Field H2S (ppm)4	Notes
M-23	0.25		Y	90		5/16/2011	1031	4.2	Water	Water	
M-23	1		W	90	Flowing	5/16/2011					
M-24	0.25	La Cienega Blvd & West 3rd St	G	15				0.0	0.0	0.001	
M-24	0.25		R	25				0.0	0.0	0.003	Not Sampled
M-24	0.25		B	65				0.0	0.0	0.004	
M-24	0.25		Y	90				0.0	0.0	0.002	
M-24	1		W	90	13.68						
GW-1	2	S. Ridgely Dr N. of Wilshire	W	1 of 3	3.50	5/20/2011	1005	0.0	H	0.001	H = Too high for field instrument Lab sample GW-1 (1 of 3)
GW-1	2		W	2 of 3	Tar	5/20/2011	1010	0.0	0.2	0.080	Sampled with quick connect, could not open valve on cap
GW-1	2		W	3 of 3	5.15	5/20/2011	1015	0.0	3.4	0.000	removed cap and put on quick connect
W-GW-1	2	Wilshire between Las Palmas & Highland	W	29.4	Dry	5/20/2011	830	0.0	0.0	0.002	
W-GW-1	2		W	41	25.52	5/20/2011	835	0.0	0.0	0.001	
W-GW-1	2		W	63.5	20.72	5/20/2011	840	0.0	0.0	0.002	
W-GW-2	2	Wilshire & Rossmore	W	25	21.66	5/19/2011	1420	-	0.0	0.001	Sampled from well casing, valve on cap stuck
W-GW-2	2		W	40	21.75	5/19/2011	1422	-	0.0	0.000	
W-GW-2	2		W	69	33.88	5/19/2011	1424	0.0	0.0	0.000	
W-GW-3	2	Wilshire between Las Palmas & Highland	W	29.9	23.73	5/19/2011	1340	0.0	0.0	0.000	
W-GW-3	2		W	50.2	28.10	5/19/2011	1342	0.0	0.0	0.000	
W-GW-3	2		W	73.9	33.14	5/19/2011	1344	0.0	0.0	0.000	
P-36	1	Wilshire & Windsor	W	14.9'	Dry	5/19/2011	1315	0.0	0.0	0.004	
	1		W	51.1'	22.71	5/19/2011	1317	0.0	0.0	0.004	
P-38	1	Wilshire & Muirfield	W	14.5'	Dry	5/19/2011	1257	0.0	0.0	0.000	
	1		W	52.7'	24.20	5/19/2011	1255	0.0	0.0	0.000	
P-39	1	Wilshire west of Rimpau	W	18.4'	Dry	5/19/2011	1227	0.0	0.0	0.002	
	1		W	54.4'	37.45	5/19/2011	1220	1.5	0.0	0.000	
P-40	1	Wilshire & Las Palmas	W	25.7'	-	5/19/2011	1150	0.0	0.0	0.000	Cannot take water reading
	1		W	50.2'	-	5/19/2011	1152	0.4	0.0	0.000	
P-41	1	Wilshire & Highland	W	28.0'	-	5/19/2011	1130	0.0	0.0	0.000	Cannot take water reading
	1		W	54.4'	-	5/19/2011	1132	0.0	0.0	0.002	
P-44	1	Wilshire & Burnside	W	10.3'	Dry	5/20/2011	905	0.0	0.0	0.000	
	1		W	38.2'	11.46	5/20/2011	907	0.0	0.0	0.004	
P-45	1	Wilshire & Hauser Blvd	W	tar	-	5/19/2011	930	0.0	10.7	0.004	North side of box
	1		W	tar	-	5/19/2011	932	0.0	0.0	0.002	South side of box

Table 3-8: Current (2011) Field Gas Monitoring Data in Prior (ACE Phase and TRC) Gas Monitoring Wells and Vapor Probes (continued)

Well No.	Diameter (inches)	Location	Probe Tube Color	Sample Probe Depth (feet)	Depth to Water (feet)1	Date	Time	Probe Pressure (inches of H2O)2	Field CH4 (%)3	Field H2S (ppm)4	Notes
P-47	1	Wilshire & Spaulding	W	-		5/19/2011					Cannot locate, may be covered by soil or shrubs
	1		W	-		5/19/2011					

Explanation:
GW-1 through W-GW-3 and 36 through 47 were previously sampled semiannually by TRC and installed by others.
M-1 through M-25 were installed by MACTEC in 2009.
P-36 through P-47 were installed by MACTEC's predecessor company in 1992
Probe Tube Color: G – green; R – red; B – blue; Y – yellow; W – white PVC pipe
"ppm" stands for parts per million
"V" indicates no reading due to pulling a vacuum in the tubing headspace (sample interval below water)
"W" indicates no reading due to water in the tubing (shallow or flowing groundwater)
"H" indicates no reading due to methane content too high for field meter
[1]Depth to water measured in 1" or 2" PVC pipe screened at indicated depth. "Flowing" indicates water flowing under artesian conditions from tubing or PVC pipe.
[2]Readings >0.5 inch of water in bold
[3]Readings >1.25% (25% LEL) in bold
[4]Readings >5ppm in bold

THIS PAGE INTENTIONALLY LEFT BLANK

The PE phase activities involved the installation of 19 multi-stage nested PVC standpipes with vapor probes along the proposed alignment. The general locations of these installations are shown on Plates 1-22 through 1-28, and are designated as M-101 through M-124. Originally 24 multi-stage wells were planned however those in Century City were postponed (M-117, M-118, M-121, and M-122) until it became clearer which alignment (of the two considered) would be chosen. Two of the wells (M-120 and M-121) will be installed in the next phase. M-123 was cancelled since M-122 was placed further west and can therefore provide gas data representative of the area near the intersection of Sepulveda Boulevard and Wilshire Boulevard (where No. 15 Double Crossover is planned).

The well locations were chosen in consultation with Metro and Parsons Brinckerhoff, and were typically located in areas where additional information on methane and hydrogen sulfide gases was needed based upon results of the M-series wells installed in the ACE phase and based on prior data. Fifteen wells were installed between La Brea Avenue and La Jolla Avenue along Wilshire Boulevard (an area of known high concentrations of methane and pockets of hydrogen sulfide). One nested well (M-116) was installed near San Vicente Boulevard, on Wilshire Boulevard, just east of Beverly Hills. One well was installed in Century City (M-119) and another (M-124) near the VA Hospital/San Diego Freeway area to evaluate the gas concentrations due to historical oil field activity in this area (i.e., former west Los Angeles Oil Field).

The monitoring well installations typically consisted of two nested soil gas probes and two PVC standpipes within a single boring. The soil gas probes were installed at shallower depths above the apparent groundwater level that was encountered at the time of drilling. The PVC standpipes were typically screened at, and below, the proposed depth of the tunnel. This configuration provided a means of measuring soil gas concentrations and pressures within the vadose zone along with the concentrations of gases dissolved in the ground water at the depths of the proposed tunnel alignment. The standpipe installations allowed relatively large quantities of ground water to be purged prior to sample collection, as well as the collection of large volume samples for analysis. Both of these capabilities were considered important with respect to the accurate measurement of dissolved hydrogen sulfide levels. The gas sampling probes consisted of 1/4-inch diameter polyethylene tubing with a 6-inch long stainless steel screen attached at the bottom. The standpipes typically consisted of 2-inch diameter PVC casing with 5 to 10 foot long screened sections. A traffic-rated well box was set in concrete at the surface to house and protect the installations. The sampling and testing protocol adapted for this phase of investigation is outlined in Section 3.4.3.2.

The gas monitoring wells were installed by AMEC's subcontractors Jet Drilling, Inc., Martini Drilling Inc., and Gregg Drilling and Testing, Inc. The drillers provided services under direct supervision of a licensed geologist. In most cases a dual casing nested well was installed in an 11.25-inch outside diameter (OD) hole with 5- to 10-foot long screens. A few of the wells were single 2-inch diameter PVC casings in a 7.25-inch diameter hole (with 10- to 20-foot long screened intervals in a 2-inch diameter PVC casing). The specific well configuration (i.e. number of gas probes, depth of gas probes, number of standpipes, and depth of screen intervals) was determined by the geologist based upon the conditions that were logged at the time of installation. Samples of soil were retained during drilling at 5-foot intervals using a Standard Penetration Test barrel to provide lithologic information. The stratagraphic log and installation schematic for each monitoring well is included in Appendix B of Volume 2 An effort was made to place the standpipe screens primarily within any saturated zones that were present at the proposed tunnel and station bottom depths. The screen intervals were adjusted at some locations to avoid oil or tar-bearing sands.

The standpipes were immediately sealed (capped) following their installation and subsequently developed using nitrogen air lift methods in order to minimize the introduction of oxygen to the subsurface. The introduction of nitrogen into the casing prevented any additional atmospheric oxygen from entering the standpipe during the development process. The standpipes were purged in this manner until the effluent water was relatively clear and without significant levels of suspended solids or sediment.

3.4.3.2 Sampling Procedures

The M-10 series and M-100 series installations were monitored in May through July of 2011 between the hours of 9:00 a.m. and 3:30 p.m. (as required by the City). Three of the installations in the area where the highest hydrogen sulfide levels were measured were monitored again in November of 2011. The following three types of sampling or monitoring were performed:

1. Gas concentrations were measured in the standpipes and gas probes using hand-held detectors. The gas pressure in the probe or standpipe was also measured along with the barometric pressure.
2. Confirmatory gas samples were collected for analysis at a State-certified laboratory;
3. The groundwater levels in the standpipes were measured.
4. Groundwater samples were collected for analysis of dissolved gases, hydrocarbons, metals, and other substances.
5. Large volume groundwater samples were collected for extraction and analysis of the dissolved gases.

These sampling procedures and the associated field results are discussed in the subsequent sections of this report. The laboratory test results are discussed in Section 4.3.Soil Gas Monitoring

The concentrations of methane, hydrogen sulfide, oxygen, and carbon dioxide in each standpipe and gas probe were measured and recorded during the monitoring events using hand-held infrared gas analyzers (Table 3-8). The gas probe pressures and the barometric pressure were recorded during each monitoring event. The gas pressure within the standpipe of gas probe was initially measured using a Magnehelic guage with a resolution of approximately 0.05 inches of water. This measurement was typically made through a quick-connect fitting that was fixed to the standpipe or gas probe to prevent the loss of gas, and the potential associated dissipation of pressure, from the installation. A multi-gas infrared analyzer was then connected to the installation through the quick-connect fitting. The gas analyzer contained an integral pump that typically extracted gas from the installation at the rate of approximately 500 c.c. per minute during sampling. The methane, hydrogen sulfide, oxygen, and carbon dioxide levels were typically monitored continuously while a minimum of one liter of gas was purged from the installation. Significant variations in the indicated gas concentrations generally did not occur during the measurement process. In each case, the highest indicated gas concentration was recorded. In some cases the gas probes could not be sampled due to the accumulation of tar or perched groundwater at the tip depth. The results of these sampling activities are summarized in Table 3-8.

At selected locations, gas samples were collected into tedlar bags for analysis at a state-certified laboratory. The results of the laboratory testing are presented in Section 4.3.

Following the pressure and gas concentration measurements, the caps were removed from the standpipes and the groundwater level was measured using a conductivity-based water level indicator. For some of the standpipes that were installed in the vicinity of the La Brea Tar Pits, oil or tar accumulation prevented the groundwater levels from being recorded. The water level monitoring results are summarized in Table 3-9.

3.4.3.3 Sampling of Groundwater for Analysis of Dissolved Gases

After the standpipes were developed and purged, groundwater samples were collected at in-situ pressures in two 18-inch long by 2-inch diameter PVC tube canisters for fixed lab analysis of dissolved hydrogen sulfide, methane, and other gases (CO_2, ethane, etc.). In some cases groundwater samples were collected for analyses of volatile organic compounds, metals, and other substances as per the request of Parsons Brinckerhoff/Metro. A dedicated pneumatic pump was installed in each standpipe to facilitate the collection of the groundwater samples for dissolved gas analysis. The pumps were driven with compressed nitrogen to prevent the introduction of air (oxygen) into the standpipes. The nitrogen feed and groundwater effluent lines for the in-casing pumps extended to gas-tight fittings at the standpipe cap such that the installations could be purged, and groundwater samples could be collected, without removing the caps. The groundwater samples were collected into sealed, clear, sch. 40 PVC sampling containers that were 18-inches long by 2-inches in diameter. A gas-tight quick-connect fitting on one end of the container was connected to the pump discharge line at the well cap. Another gas-tight quick-connect fitting on the other end of the container was connected to an adjustable back-pressure valve. Prior to sampling, the valve was adjusted to maintain a back-pressure equivalent to the hydrostatic pressure at the bottom of the standpipe. Several volumes of groundwater were then purged through the container using the nitrogen driven pneumatic pump. After a minimum of three casing volumes was pumped through the sampling container, the quick-connect fittings were detached and the container was transported to a State-certified laboratory under chain-of-custody protocol. The results of the laboratory testing are discussed in Section 4.3.

3.4.3.4 Disolved Gas Extraction

Relatively large volume groundwater samples were collected from the standpipes into 5 to 10 liter Tedlar bags. The bags were evacuated and sealed prior to sample collection. The groundwater was purged from the standpipes using the same dedicated nitrogen-driven pneumatic pumps described above. The groundwater was maintained at, or above its in-situ hydrostatic pressure until it entered the Tedlar bag. Once filled, the sealed bag was transported to a fixed laboratory and placed in a vacuum chamber. The pressure in the chamber was reduced to less than 1% of atmospheric pressure and the dissolved gases in the sample were allowed to evolve over a period of several hours. At that point, atmospheric pressure was restored and the volume of accumulated gas was measured. The evolved gas was then extracted from the Tedlar bag using a large volume syringe and injected into a train of infrared gas analyzers to quantify methane, hydrogen sulfide, oxygen, and carbon dioxide. The results of this testing are summarized in Table 3-10.

Table 3-9: 2011 Field and Lab Measurements of Methane, Hydrogen Sulfide, Oxygen and Carbon dioxide Concentrations in Air Monitoring of Nested Probes and Wells (PE Phase)

Location		Monitoring Date	Standpipe or Gas Probe Depth (feet)	Depth to Water (feet)	Gas Concentration						Standpipe or Gas Probe Pressure (inches H_2O)	Barometric Pressure (inches Hg)
					CH_4 (%)		CO_2 (%)	O_2 (%)	H_2S (ppm)			
					Field	Lab	Field	Field	Field	Lab		
M-6		5/13/2011	NA	NA	NA	ND	NA	NA	NA	ND	NA	NA
M - 101	Gas Probe	7/19/2011	15	NA	0.2	NA	0.0	12.1	0.0	NA	0.0	29.4
		7/19/2011	30	NA	0.0	NA	0.0	20.5	0.0	NA	0.0	29.4
	Standpipe	7/19/2011	45-50	15.1	0.1	NA	0.1	20.6	0.0	NA	0.0	15.1
		7/19/2011	60-80	15.9	0.1	NA	0.0	21.7	0.0	NA	0.0	15.9
M - 102	Gas Probe	5/10/2011	15	NA	0.5	NA	0.0	19.2	0.0	NA	0.0	29.8
		5/12/2011		NA	0.1	NA	0.0	22.7	0.0	NA	0.05	29.8
		5/10/2011	25	NA	0.2	NA	0.0	20.5	0.0	NA	0.0	29.7
		5/12/2011		NA	0.0	NA	0.0	22.8	0.0	NA	0.5	29.8
	Standpipe	5/10/2011	35-40	12.3	1.4	NA	0.1	20.3	0.0	NA	0.0	29.7
		5/10/2011	47-52	12.7	3.2	NA	0.3	19.4	0.0	NA	0.0	29.7
		5/12/2011		NA	0.1	NA	0.0	22.5	0.0	NA	0.0	29.8
M - 103	Gas Probe	5/10/2011	15	NA	48.1	NA	13	4.4	0.0	NA	0.0	29.8
		5/12/2011		NA	11.7	NA	7.3	14.6	0.0	NA	0.1	29.9
		5/10/2011	30	Flooded								
		5/12/2011		Flooded								
	Standpipe	5/10/2011	35-45	12.3	40.3	NA	15.6	6.2	0.0	NA	0.0	29.8
		5/10/2011	55-60	Tar @ 7.8 feet	22.4	NA	6.8	15.5	0.0	NA	0.0	29.8

Table 3-9: 2011 Field and Lab Measurements of Methane, Hydrogen Sulfide, Oxygen and Carbon dioxide Concentrations in Air Monitoring of Nested Probes and Wells (PE Phase) (continued)

Location		Monitoring Date	Standpipe or Gas Probe Depth (feet)	Depth to Water (feet)	Gas Concentration						Standpipe or Gas Probe Pressure (inches H_2O)	Barometric Pressure (inches Hg)
					CH_4 (%)		CO_2 (%)	O_2 (%)	H_2S (ppm)			
					Field	Lab	Field	Field	Field	Lab		
M - 104	Gas Probe	5/10/2011	10	NA	51.1	36	25.7	1.4	0.0	NA	0.0	29.8
		5/12/2011		NA	59.1	45	29.4	0.3	0.0	ND	0.0	29.8
		5/10/2011	20	NA	23.2	NA	10.7	6.8	0.0	NA	0.25	29.8
		5/12/2011		NA	25.4	NA	16.1	5.0	0.0	NA	0.0	29.9
	Standpipe	5/10/2011	35-40	Dry	Gas Tight Cap Not Yet Installed							
		5/12/2011		Dry	64.1	NA	29.5	1.4	0.0	NA	0.0	29.9
		5/10/2011	55-65	Tar @ 29 feet	63.9	NA	21.8	1.4	0.0	NA	0.0	29.8
		5/12/2011			71.8	59	21.1	1.4	36	47	0.0	29.9
M - 105	Gas Probe	5/10/2011	6	NA	3	0.22	1.9	6.5	0.0	NA	0.0	29.8
		5/12/2011		NA	23.5	29	1.5	0.4	0.0	0.65	0.0	29.8
		5/10/2011	15	NA	1.1	NA	0.1	18.4	0.0	NA	0.0	29.8
		5/12/2011		NA	7.6	NA	1.6	17	0.0	NA	0.0	29.8
	Standpipe	5/10/2011	40-45	Gas Tight Cap Not Yet Installed								
		5/12/2011		Tar @ 26 feet	30.3	NA	10.4	14.2	0.0	NA	0.0	29.8
		5/10/2011	65-70	11.3	54.4	NA	32.2	2.3	0.0	NA	0.25	29.7
M - 106	Gas Probe	5/25/2011	10	Flooded								
		5/25/2011	20	NA	79.1	43	20.9	0.0	66	290	194	29.9
	Standpipe	5/25/2011	25-30	29.8	78	NA	22	0.0	179	NA	193	29.9
		5/25/2011	60-70	16.5	76.4	NA	23.6	0.0	134	NA	30	29.9
M - 107	Gas Probe	5/24/2011	15	NA	77.7	43	21.2	1.1	0.0	ND	2.5	29.9
		5/24/2011	30	Flooded								
	Standpipe	5/24/2011	78-83	69.0	78.7	NA	20.6	0.7	0.0	NA	0.0	29.9
		5/24/2011	90-100	58.5	38.2	NA	14.3	4.1	3	NA	17.1	29.9

Table 3-9: 2011 Field and Lab Measurements of Methane, Hydrogen Sulfide, Oxygen and Carbon dioxide Concentrations in Air Monitoring of Nested Probes and Wells (PE Phase) (continued)

Location		Monitoring Date	Standpipe or Gas Probe Depth (feet)	Depth to Water (feet)	Gas Concentration CH_4 (%) Field	CH_4 (%) Lab	CO_2 (%) Field	O_2 (%) Field	H_2S (ppm) Field	H_2S (ppm) Lab	Standpipe or Gas Probe Pressure (inches H_2O)	Barometric Pressure (inches Hg)
M - 108	Gas Probe	7/11/2011	10	NA	86.8	NA	13.0	0.2	0.0	NA	4.0	29.7
		7/11/2011	18	Flooded								
		7/12/2011	10	NA	73.1	90	26.9	0.0	79.0	38	4.0	29.7
		7/12/2011	18	NA	86.8	NA	13.0	0.2	10.0	NA	60.0	29.7
	Standpipe	7/13/2011	40-50	5' to Tar	75.1	NA	24.3	0.6	56.0	NA	1.8	29.7
		7/11/2011	65-70	Standpipe cap partially submerged in tar								
M - 109	Gas Probe	5/25/2011	9	Flooded								
		5/25/2011	14	Flooded								
	Standpipe	5/25/2011	76-81	15.7	72.8	40	13.4	4.2	0.0	ND	10	29.6
		5/25/2011	95-100	15.6	82.7		16.1	1.2	0.0	NA	10	29.6
	Well Casing	6/8/2011	NA	NA	35.8	NA	7	12	0.0	NA	0	29.8
M-110	Gas Probe	6/7/2011	15	NA	47.1	NA	4.1	8.8	0.0	NA	10	29.8
		6/7/2011	23	NA	70	52	2.4	1.5	0.0	ND	0	29.8
	Standpipe	6/7/2011	30-35	33.8	84.7	29	13.7	1.6	0.0	ND	0	29.7
		6/7/2011	40-45	45.4	85.2	NA	12	2.8	0.0	NA	0.25	29.7
M-111	Gas Probe	6/7/2011	10	NA	0.3	NA	0.3	0.9	0.0	NA	0.1	29.6
		6/7/2011	17	NA	0.4	NA	0	9.5	0.0	NA	0	29.6
	Standpipe	6/7/2011	30-35	22.8	0.4	NA	0	20.8	0.0	NA	0.05	29.6
		6/7/2011	45-55	45.5	0.4	0.2	0	19.6	0.0	ND	0.05	29.6
M-112	Gas Probe	7/19/2011	12	NA	31.4	NA	5.5	4.1	1.0	NA	4.0	29.4
		7/19/2011	15	NA	55.0	NA	7.9	4.6	1.0	NA	4.0	29.4
	Standpipe	7/19/2011	30-40	23.4	84.2	NA	13.1	2.7	0.0	NA	2.0	29.4
		7/19/2011	60-70	35.4	81.1	86	17.1	1.8	0.0	0.34	0.5	29.4

Table 3-9: 2011 Field and Lab Measurements of Methane, Hydrogen Sulfide, Oxygen and Carbon dioxide Concentrations in Air Monitoring of Nested Probes and Wells (PE Phase) (continued)

Location		Monitoring Date	Standpipe or Gas Probe Depth (feet)	Depth to Water (feet)	Gas Concentration						Standpipe or Gas Probe Pressure (inches H_2O)	Barometric Pressure (inches Hg)
					CH_4 (%)		CO_2 (%)	O_2 (%)	H_2S (ppm)			
					Field	Lab	Field	Field	Field	Lab		
M-113	Gas Probe	6/7/2011	7	NA	7.8	NA	0.9	0.9	0.0	NA	0	29.6
		6/7/2011	12	NA	9.2	6.8	0.5	0.8	0.0	ND	0	29.6
	Standpipe	6/7/2011	15-25	16.4	2.9	NA	0.5	16.5	0.0	NA	0.5	29.6
		6/7/2011	35-40	39.5	84.6	NA	14.5	0.9	0.0	NA	0	29.6
M-114	Gas Probe	7/11/2011, 11/30/2011	15	NA	51.2/89.2	NA	0.7/2.7	0.1/1.0	0.0/6.0	NA	0.05/0.4	29.8
		7/11/2011, 11/30/2011	25	NA	89.1/92.2	96	10.5/6.6	0.4/1.2	0.0/3.0	ND	12.0/0.0	29.7
	Standpipe	7/11/2011, 11/30/2011	38-53	52.6	86.6/86.5	NA	13.3/13.0	0.1/0.5	0.0/120	NA	14.0/20.0	29.7
M-115	Gas Probe	6/21/2011	15	NA	0.9	NA	0.0	11.1	0.0	NA	0.0	29.7
		6/21/2011	25	NA	99.2	66	0.0	0.8	0.0	ND	0.0	29.7
	Standpipe	6/21/2011	53-63	50.8	1.7	NA	0.2	20.7	0.0	NA	0.0	29.7
		6/21/2011	70-75	58.9	1.1	NA	0.1	20.9	0.0	NA	0.0	29.7
M-116	Gas Probe	6/22/2011	9	NA	0.0	NA	0.3	16.8	0.0	NA	0.0	29.7
		6/22/2011	16.5	NA	0.0	0.0038	0.2	18.3	0.0	ND	0.0	29.7
	Standpipe	6/22/2011	55-60	44.1	0.0	NA	0.0	21.8	0.0	NA	0.0	29.7
		6/22/2011	70-80	32.9	0.0	NA	0.0	22.0	0.0	NA	0.0	29.7
M-119	Gas Probe	6/22/2011	15	NA	0.0	0.0013	0.2	1.8	0.0	ND	0.0	29.5
		6/23/2011		NA	0.2	NA	0.4	1.3	0.0	NA	0.0	29.5
		6/22/2011	25	NA	0.0	4.9	0	0.4	0.0	ND	0.0	29.6
		6/23/2011		NA	0.0	NA	0	0.3	0.0	NA	0.0	29.6
	Standpipe	6/22/2011	45-50	Dry	2.7	NA	4.1	1.0	0.0	NA	0.0	29.6
		6/22/2011	70-75	Dry	12.1	NA	5.7	4.7	0.0	ND	0.0	29.6
M-122	Gas Probe	7/20/2011	20	NA	0.1	NA	9.3	9.6	0.0	NA	0.0	29.6

Table 3-9: 2011 Field and Lab Measurements of Methane, Hydrogen Sulfide, Oxygen and Carbon dioxide Concentrations in Air Monitoring of Nested Probes and Wells (PE Phase) (continued)

Location		Monitoring Date	Standpipe or Gas Probe Depth (feet)	Depth to Water (feet)	Gas Concentration CH_4 (%)		CO_2 (%)	O_2 (%)	H_2S (ppm)		Standpipe or Gas Probe Pressure (inches H_2O)	Barometric Pressure (inches Hg)
					Field	Lab	Field	Field	Field	Lab		
		7/20/2011	40	NA	0.1	ND	2.6	9.4	0.0	ND	0.0	29.6
	Standpipe	7/20/2011	55-70	52.6	0.1	NA	0.7	20.6	0.0	NA	0.0	29.5
M-124	Gas Probe	7/12/2011	20	NA	0.0	NA	0.1	20.6	1.0	NA	0.0	29.5
		7/12/2011	35	NA	0.0	0.1	10.4	10.8	1.0	ND	0.0	29.5
		7/12/2011	55	NA	0.0	NA	3.7	11.7	1.0	NA	0.0	29.5
	Standpipe	7/12/2011	60-80	64.0	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
Field = Data readings taken by Applied GeoKinetics personnel in the field NA – Not Analyzed
ATL = Data readings analyzed by Advanced Technology Laboratories, a fixed laboratory.
CH_4 = Methane
CO_2 = Carbon Dioxide
O_2 = Oxygen
H_2S = Hydrogen Sulfide
"ppm" stands for parts per million

Table 3-10: 2011 Lab Gas Test Data in Water Samples Collected from Monitoring Wells (PE Phase)

Monitoring Well Location		Date	Screen Interval (ft, btoc)	Depth to Water (ft)	Water Volume Extracted from Well (cm^3)	Gas Volume Extracted from Sample (cm^3)	Methane Gas Concentration (%)	Methane Volume Extracted (cm^3)	Methane Mass Extracted (mg)	Methane Dissolved Concentration (mg/L)	Relative Methane Saturation (%)	H_2S Gas Concentration (%)	H_2S Volume Extracted (cm^3)	H_2S Dissolved Concentration (mg/L)	Relative H_2S Saturation (%)	CO_2 Gas Concentration (%)	CO_2 Volume Extracted (cm^3)	CO_2 Mass Extracted (mg)	CO_2 Dissolved Concentration (mg/L)	Relative CO_2 Saturation (%)	O_2 Gas Concentration (%)
M-101	Standpipe	7/22/2011	45-50	15.1	4,948	70	1.4	1	0.7	0.1	0.1	0.40	0.000	0	0	1	49.51	97.3	19.7	1.2	8.8
		7/22/2011	60-80	15.9	6,789	270	69.3	187	134	19.7	86	0.0057	0.4	0.06	0.002	3.9	265	520.7	76.7	4.5	6.4
M-102	Standpipe	5/12/2011	35 to 40	12.31	5,382	120	59	15	10.7	2	9	0.000	0	0	0	5	6	11.8	2.2	0.1	0.4
M-103	Standpipe	5/12/2011	35 to 45		9,050	285	38	119.7	85.5	9.4	41	0.000	0	0	0	45	128	251	27.7	1.6	0.2
		5/10/2011	55 to 60	Tar @ 7.84	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
M-104	Standpipe	5/10/2011	35 to 40	DRY	No Groundwater																
		5/10/2011	55 to 65	Tar at 29'	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
M-105	Standpipe	5/10/2011	40 to 45	Tar at 26'	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		5/12/2011	65 to 70	11.33'	5,930	275	35	159.5	114	19.2	83	0.000	0	0	0	42	116	228	38.4	2.3	0.1
M-106	Standpipe	5/25/2011	25 to 30	Dry	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		5/25/2011	60 to 70	16.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
M-107	Standpipe	5/26/2011	78-83	69.0	8,180	620	12.5	366	261	31.9	139	0.000	0	0	0	41	254	499	61	3.6	0.2
		5/24/2011	90 to 100	58.5	No Sample	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
M-108	Standpipe	7/13/2011	40 to 50	Tar at 5'	No Sample	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		7/11/2011	65 to 70	Shallow tar	No Sample	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
M-109	Standpipe	5/26/2011	76-81	15.7	7,140	365	42	139	99	13.9	60	0.000	0	0	0	62	226	444	62	3.6	0.1
		5/26/2011	95-100	15.6	5,360	435	58	152	109	20.3	88	0.000	0	0	0	65	283	556	104	6.1	0.1
M-110	Standpipe	6/7/2011	30 to 35	33.8	No Sample	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		6/7/2011	40 to 45	45.4	No Sample	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
M-111	Standpipe	6/7/2011	30 to 35	22.8	11,025	130	0.0	0	0	0	0	0.000	0	0	0	0.0	0	0	0	0	2.6
		6/7/2011	45 to 55	45.5	8,680	60	1.4	0.8	0.6	0.07	0.3	0.000	0	0	0	0.6	0.4	0.8	0.09	0.005	16.5
M-112	Standpipe	7/22/2011	40	23.4	4,289	95	28.5	27.1	19.4	4.5	20	0.000	0	0	0	24.3	23.1	45.4	10.6	0.6	6.4
		7/22/2011	70	35.37	3,895	330	45	148.5	106.1	27.2	118	0.000	0	0	0	41.9	138.3	271.7	69.8	4.1	5.2
M-113	Standpipe	6/7/2011	15 to 25	16.4	No Sample	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		6/7/2011	35 to 40	39.5	No Sample	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
M-114	Standpipe	7/11/2011	38-53	52.6	No Sample	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
M-115	Standpipe	6/23/2011	53-63	50.8	10,870	270	37.4	101	72.2	6.6	29	0.0138	0.0373	0.005	0.001	12.9	34.8	68.4	6.3	0.3	3.3
		6/23/2011	70-75	58.9	9,090	340	9.30	31.6	22.6	2.5	11	0.0016	0.0054	0.0009	0.00002	2.6	8.8	17.3	1.9	0.10	14.6
M-116	Standpipe	6/23/2011	55-60	44.1	5,025	195	0.0	0	0	0	0	0.000	0	0	0	0.4	0.8	1.5	0.3	0.02	14.5

Monitoring Well Location		Date	Screen Interval (ft, btoc)	Depth to Water (ft)	Water Volume Extracted from Well (cm^3)	Gas Volume Extracted from Sample (cm^3)	Methane Gas Concentration (%)	Methane Volume Extracted (cm^3)	Methane Mass Extracted (mg)	Methane Dissolved Concentration (mg/L)	Relative Methane Saturation (%)	H_2S Gas Concentration (%)	H_2S Volume Extracted (cm^3)	H_2S Dissolved Concentration (mg/L)	Relative H_2S Saturation (%)	CO_2 Gas Concentration (%)	CO_2 Volume Extracted (cm^3)	CO_2 Mass Extracted (mg)	CO_2 Dissolved Concentration (mg/L)	Relative CO_2 Saturation (%)	O_2 Gas Concentration (%)
	e	6/23/2011 80	70-80	32.9	9,895	88	0.0	0	0	0	0	0.000	0	0	0	8.9	8.8	17.3	1.9	0.1	5.4
M-119	Standpipe	7/22/2011	45-50	Dry	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		7/22/2011	70- 75	Dry	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
M-122	Standpipe	7/22/2011	55-70	52.6	3,341	75	0.0	0	0	0	0	0.000	0	0	0	3.7	2.8	5.5	1.6	0.1	14.5
M-124	Standpipe	7/22/2011	60-80	64.0	5,068	195	0.0	0	0	0	0	0.000	0	0	0	8.7	17.0	33.4	6.6	0.4	14.9

Notes;
btoc – below top of casing in feet
cm^3 = cubic centimeters
mg = milligrams
mg/L = milligrams per liter
H_2S = hydrogen sulfide
CO_2 = carbon dioxide
0_2 = oxygen
ppm = parts per million
Analysis performed by GeoKinetics using an infrared gas analyzer.

3.4.4 Summary of Results

3.4.4.1 Depth to Groundwater in Gas Monitoring Wells:

Groundwater depth measurements in the shallow screened wells (i.e., screened generally from 25 to 45 feet bgs) in the area between Cochran Avenue and Curson Avenue (M-101 through M-109) indicated shallow groundwater at depths of 12 to 29.8 feet below ground surface (in some cases tar had entered the hole and groundwater could not be measured, i.e., at M-105A).

In the deeper wells (i.e., screened at 60 to 100 feet bgs) groundwater depths can be quite variable in this area as indicated by a groundwater depth of 16.5 feet in well M-106B (deep) which was screened from 60 to 70 feet deep, and groundwater was measured at a depth of 69.0 feet in M-107A, screened at 78-83 feet bgs (Table 3-7). Well M-107B (screened from 90-100 feet bgs) had a groundwater measurement of 58.5 which is slightly shallower than the shallower well 107A, likely due to the deeper zone being under more in-situ pressure. Reasons for this variability in groundwater depth is likely due to the variability of soil type within the San Pedro and Fernando Formations which can vary from a tight silt that would not tend to produce water to sandy zones that are saturated and have higher transmissivities. The soil consists of interbedded sand and silt zones and the sand and silt layers are discontinuous laterally, i.e., since water tends to accumulate in these sand lenses, the depth to water along the alignment is somewhat variable, with layers of unsaturated soils below the saturated zone(s). These conditions are referred to as “perched” or “semi-perched,” depending on the extent of the sand lenses bearing water, and the degree of contrast in saturation between the different soil layers.

Groundwater depths in the Fairfax Avenue area varied from 16 to 34 feet below ground surface for the shallower (A) wells and 40 to 45 feet for the deeper (B) wells.

At M-119 on Constellation Boulevard in Century City groundwater was not encountered down to 80 feet.

3.4.4.2 Results of Vapor Probe and Well Headspace Measurements

Field monitoring of gas from vapor probes and headspace of 2-inch wells indicated varying results for methane and hydrogen sulfide (see Table 3-8).

Field measurements of methane levels in the PE phase wells showed patterns similar to the preliminary assessment study with higher levels of methane between Dunsmuir Avenue and La Jolla Avenue. These results are borne out by the higher levels of methane detected in wells M-103 through M-115 along the Wilshire Boulevard Alignment. The other areas to the west and east of this segment and at the San Diego Freeway area had significantly lower to no levels of methane based on the field readings. Some of the higher levels of methane from vapor probes were measured at M-104 (Wilshire Boulevard near Houser Boulevard)at 10 feet bgs (59.1% methane), at M-106 (Wilshire Boulevard between Court Yard Place and Curson Avenue)at 20 feet (79.1% methane), at M-107 (Curson Avenue, south of Wilshire Boulevard) at 15 feet (77.7% methane), at M-108 (Curson Avenue, north of Wilshire) at 10 feet and 18 feet (86.8% each), and at M-110 (Wilshire Boulevard, 100 feet west of Fairfax Avenue)at 23 feet (70% methane). Methane at shallow depths decreases west of M-110 with concentrations of methane in vapor probes at M-113 much lower (i.e., 7.8 to 9.2% in field). These readings are consistent with previous findings in the preliminary assessment phases along Wilshire Boulevard between Fairfax Avenue and Dunsmuir Avenue (High Methane Zone).

At M-119 located in Century City on Constellation Avenue, the vapor probe readings at 15 feet and 25 feet showed trace to no amounts of methane , whereas the wells screened at 45-50 and 70-75 feet bgs had detections of methane of 2.7 and 12.1 percent respectively. At M-122 and M-124, which are located at the west end of the alignment near the San Diego Freeway, the vapor probe readings of methane were 0.1 and 0.0 percent, respectively, for both probes and standpipes (i.e., wells).

The headspace measurements from gas wells (i.e., 2-inch diameter PVC wells a.k.a. “standpipes”), which are deeper than the probes, in the area of Dunsmuir Avenue to Fairfax Avenue showed similar levels of methane to the probe readings such as at M-104 the methane level was 64.1% in the shallow well and 63.9% in the deep well and the vapor probe reading at 10 feet was 59.1%. At M-110 and M-112, the well readings were slightly higher than the vapor probe readings suggesting a slight increase in methane with depth at that location.

In the PE Phase wells, the highest hydrogen sulfide readings measured in the field were from M-106 and M-108 (near the corner of Curson Avenue and Wilshire Boulevard). At M-106, a measurement of 66 parts per million (ppm) hydrogen sulfide was taken from the 20-foot deep vapor probe and a measurement of 179 ppm hydrogen sulfide was measured from the shallow well (screened at 25-30 feet bgs). 134 ppm hydrogen sulfide was measured from the deep well of M-106. At M-108, hydrogen sulfide was detected at 79.0 ppm hydrogen sulfide in the vapor probe screened at 10 feet deep bgs while the shallow well (screened at 40-50 feet bgs yielded a reading of 56.0 ppm hydrogen sulfide. At M-104 located near Houser Boulevard, the deep well (65 feet bgs) yielded a relatively higher hydrogen sulfide reading at 36 ppm. The majority of the locations tested resulted in not detectable levels of hydrogen sulfide concentrations (see Table 3-9). When including all wells, (ACE Phase and PE Phase) M-13 had the highest levels of hydrogen sulfide and methane (6,500 ppm H_2S and 100% methane) from readings taken in December, 2011; A laboratory sample from M-13 in May, 2011 resulted in a concentration of 3,600 ppm H_2S following EPA Method 15/16.

The gas readings in a profile view in Farifax and Century City are are illustrated in Plates 4-1 and 4-2, respectively. These figures illustrate the highest reading obtained from the wells by either the field measurements or the laboratory measurements. As shown on Plate 4-1, along Wilshire Boulevard between Fremont Place (Station 422+00) and San Vicente Boulevard (Station 560+00) within the former Salt Lake and South Salt Lake oil fields, the following information can be summarized pertaining to subsurface gas data collected to date.

- Within this stretch between South Burnside Avenue (Station 493+00) and South La Jolla Avenue (Station 550+60) [Approximately 1.1 mile long portion of the alignment] displayed higher levels of gas pressure, methane, and hydrogen sulfide recorded in between 2009 and 2011.
- Maximum recorded gas pressures in probes / wells reached 844 inches of water in 2009 and 730 inches of water in 2011 at M-7. Maximum recorded methane levels reached 100% in 2009 at well M-13 and 99% in 2011 at well M-114. Maximum recorded hydrogen sulfide levels reached 1,000 parts per million [ppm] in 2009 and 6,500 in 2011 at well M-13.
- This portion of Wilshire Boulevard near the La Brea Tar Pits, also is characterized by having extensive tar sands, with tar seeps (i.e., to the surface) in the area. The tar sands and associated gases are located primarily in the San Pedro Formation and overlying soils (alluvium, or Lakewood Formation). The presence of tar sands between South Ridgeley Drive and Fairfax Avenue limited the ability to place wells at depth (i.e., below 45 feet) at locations such as M-113 because the tar sands are present down to approximately 110 feet bgs.

- Elsewhere within this stretch of the alignment (i.e. east of Station 493+00 and west of 550+60), no sample point in six installed wells displayed a pressure greater than 0.7 inches of water, recorded greater than 2.3% methane, or indicated greater than 1 ppm of hydrogen sulfide.

As shown on Plate 4-2, at Century City in the vicinity of Constellation station within the former Beverly Hills oil field, the following information can be summarized pertaining to subsurface gas data collected to date.

- Within this stretch between Moreno Drive (Station 692+50) and South Avenue of the Stars (Station 550+60) no sample point in installed wells/probes displayed a pressure greater than 0.3 inches of water, recorded greater than 24.3% methane, or indicated greater than 0.02 ppm of hydrogen sulfide.
- BAT sampling tests performed underneath the Beverly Hills High School indicated negligible quantities of methane.

3.4.4.3 Vapor Probes Air Samples – Laboratory Test Results

Air samples collected from vapor probes were tested by ATL analytical laboratory. The test data (Table 3-9) indicated highest methane levels in vapor probes as 45% at 10 feet at M-104 (near Houser Boulevard on Wilshire Boulevard), 43% at 20 feet at M-106 (between Court Yard Place and Curson Avenue on Wilshire Boulevard), and 43% at 15 feet at M-107 (on Curson Avenue, south of Wilshire Boulevard). At M-110 a methane concentration from the 23 foot deep gas probe measured 52%. The highest hydrogen sulfide readings were measured in the laboratory at 0.029 parts per million at 20 feet at M-106.

3.4.4.4 Dissolved Gases in Large Volume Groundwater Sample - GeoKinetics Results

Results of the dissolved gases in large volume groundwater are presented in Table 3-10. These groundwater samples were not exposed to atmospheric conditions and were collected through downhole tubing directly into a collapsed large volume tedlar bag. The highest concentration of dissolved methane was observed in monitoring well M-107 (from 83 feet bgs), at 31.9 percent methane. The second highest concentration of dissolved methane was from M-112 at 27.2 percent. M-107 is located at the eastern end of the “gassy area” while M-112 is located toward the west end of the “gassy area.” The percentage relative methane saturation was 139%, indicating that the methane levels exceeded the solubility limit at atmospheric pressure. The reason is that there is greater pressure at depth and with the increased pressure more gas can be dissolved. No dissolved hydrogen sulfide was detected in the ground water from any well, although each sample contained trace levels of oxygen that probably would have oxidized any hydrogen sulfide.

3.4.4.5 Potential Off-gassing During Dewatering Operations

Based upon the available monitoring results, the following soil gas concentrations have been adopted as a reasonable worst case scenario for the vadose zone immediately above the groundwater table:

- Methane @ 999,000 ppm (99.3% by volume)
- Hydrogen Sulfide @ 6,500 ppm (0.65% by volume)

The solubility limits for methane and hydrogen sulfide in groundwater at 18° C and one atmosphere of pressure are approximately 25 mg/L and 3,900 mg/L, respectively. If it is assumed that the dissolved gas concentrations in groundwater are in equilibrium with the soil gas concentrations measured in the vadose zone, the following approximate dissolved gas concentrations are calculated using Henry's Law:

- Dissolved Methane Concentration: 25 mg/L
- Dissolved Hydrogen Sulfide Concentration: 25 mg/L

If it is assumed that groundwater will be extracted from a depth of approximately 80 feet bgs within the station excavations with the static groundwater level at approximately 20 feet bgs, the initial groundwater pressure prior to extraction will be approximately three atmospheres (1 atm barometric pressure + about 2 atm hydrostatic pressure). Under these conditions, the following approximate dissolved gas concentrations would exist:

- Dissolved Methane Concentration: 75 mg/L
- Dissolved Hydrogen Sulfide Concentration: 75 mg/L

The reduction in the hydrostatic pressure for the groundwater that is extracted will be approximately two atmospheres. Accordingly, approximately two-thirds of the dissolved gas can be expected to evolve as a result of the change in hydrostatic pressure. This corresponds to the following off-gassing volumes:

- Methane: 71 cm^3 per liter of groundwater
- Hydrogen Sulfide: 36 cm^3 per liter of groundwater

If the rate of dewatering is assumed to be 1000 liters per minute (lpm), the associated potential rates of off-gassing would be approximately:

- Methane: 71 LPM
- Hydrogen Sulfide: 36 LPM

The Lower Explosive Level (LEL) for methane is approximately 5.5% by volume. Ventilation systems are typically designed to maintain methane levels below 10% LEL. Accordingly, under these conditions, the minimum required ventilation rate in the area where dewatering is occurring would be approximately 13 m^3/min.

However, the ventilation requirements for hydrogen sulfide are likely to be more stringent due to the very low odor threshold for this gas. As discussedpreviously, hydrogen sulfide has a strong, rotten-egg like odor that is detectable, and objectionable, to many people at concentrations as low as approximately 1 ppm. If this is adopted as the maximum acceptable concentration in ambient air, the required ventilation rate would be extremely high (i.e. approximately 36,000 m^3/min). Accordingly, pre-treatment of the groundwater prior to its extraction, and/or treatment of the groundwater during the dewatering process, to remove the hydrogen sulfide before, or as, it evolves may represent more cost effective alternatives for odor control.

3.5 Hydrogeologic Investigation

A hydrogeologic investigation was planned to provide information for planning temporary groundwater pumping along the alignment during construction. Typically, the tunnels would not require groundwater pumping, but cut-and-cover excavations for stations, cross-over structures, or vent shafts would potentially require temporary groundwater pumping where the depth of excavation extends below the groundwater level. Pump tests were originally proposed to be performed at three locations along the alignment to provide data to be used in the hydrogeologic analysis. Two of the locations are Wilshire/La Cienega and Westwood/UCLA stations; a third location is yet to be determined.

The locations selected for the hydrogeologic investigations for PE phase were the Westwood/UCLA Station (on-street location) and the Wilshire/La Cienega Station. At this time only the Westwood/UCLA Station (off-street location) hydrogeologic investigation has been completed. Three groundwater wells have been installed at the Wilshire/La Cienega Station location and a pumping test has been completed; the results will be presented in an addendum.

Groundwater wells were installed for the purpose of performing pumping tests. The data from the pumping test was used to estimate hydraulic parameters of the aquifer in the area of the proposed excavation. The data was be used for estimating flow rates, evaluate dewatering options, and to provide design parameters for a dewatering program.

3.5.1 Summary of Explorations

3.5.1.1 Westwood/UCLA Station

The site is currently occupied by a paved parking lot located at 11020 Kinross Avenue on the northeast corner of Wilshire Boulevard and Veteran Avenue. The site is owned and operated by UCLA as Lot 36.

The bottom of the Westwood/UCLA station will be established at about Elevation 230 or approximately 75 to 80 feet below ground surface (bgs). Based on previous geotechnical borings in this area, groundwater was known to occur at a depth of approximately 45 feet. Prior to well drilling, applications for well permits for three wells were submitted to and approved by the Los Angeles County Department of Public Health.

Pumping Well P-103 was completed in Boring S-114. Boring S-114 was drilled to 120 feet using a sonic drilling rig on May 27-28, 2011 by Boart Longyear. The shallow stratigraphy at this location consists primarily of brown to grayish green clayey silt and gravelly sandy silt/silty sand from the surface to approximately 48 feet bgs, where groundwater was encountered. The first water-bearing zone is approximately 20 feet thick from 48 to 68 feet bgs and consists primarily of brown silty clay with sand and gravel. The soil at 48 feet is wet, brown silty clay with a trace of gravel. At approximately 58 feet, the soil transitioned to wet, silty clay with sand and at approximately 65 feet, there is 2- to 3-inch gravel. The sediments from 68 feet to approximately 108 feet bgs are primarily moist, orange brown silty clay. The second water-bearing zone is encountered from approximately 108 feet to 120 feet, where the lithology consists primarily of wet, orange brown sand.

The well was installed to a depth of 84 feet bgs after placing approximately 49 feet of hydrated bentonite chips in the borehole and is constructed of 4-inch-diameter Schedule 40-PVC with 0.02-

inch slotted screen. The screen interval is 20 feet in length, from approximately 48 feet to 68 feet. Fifteen feet of blank casing was placed below the screened interval to provide a reservoir sump for the pumping test.

Observation well OB-105 was completed in the G-186 bore hole using a rotary-wash drilling rig on May 27, 2011 by C&L Drilling. The well was installed to a depth of 84 feet. The well was constructed of 2-inch-diameter Schedule 40-PVC with 0.02-inch slotted screen from approximately 48 feet to 68 feet. Well OB-105 is located approximately 150 feet east of P-103.

Observation well OB-106 was completed using a hollow-stem auger drilling rig on June 3, 2011 by Tri-County Drilling. The well is constructed of 2-inch-diameter Schedule 40-PVC with 0.02-inch slotted screen from approximately 48 feet to 68 feet. Well OB-106 is located approximately 25 feet east of P-103.

During drilling, the borings were logged following the United Soil Classification System (USCS) and the screen intervals were selected based upon the findings during drilling, including the stratigraphy (e.g., soil types and layering) and the presence of saturated conditions. Saturated conditions were observed from approximately 48 feet to 68 feet. The wells were screened across the vertical extent of the aquifer located within the proposed station excavation.

Refer to the boring logs in Volume 2 for further details on drilling and well construction, including soil sampling, screen interval, blank casing, sand pack, and seal.

3.5.1.2 Groundwater Well Development

Following groundwater well installation, the wells were developed using surge, swab, bail, and pumping techniques. P-103 and OB-105 were developed on June 3, 2011, by Gregg Drilling and Testing and OB-106 was developed by Tri-County Drilling on June 17, 2011. Approximately 130 gallons were removed from P-103 (over 5 casing volumes) until the water was generally clear and the groundwater parameters stabilized (within 10 percent for three consecutive readings). During development of P-103, the pumping rate ranged from 1.2 to 1.3 gallons per minute (gpm). Approximately 80 gallons were removed from OB-105 until the water was generally clear and the groundwater parameters stabilized. OB-106 went dry after removing approximately 100 gallons.

3.5.1.3 Groundwater Sampling – June 2011

A grab groundwater sample was collected from P-103 on June 3, 2011 and OB-106 on June 17, 2011 that would be representative of the effluent discharge to surface waters as required for the National Pollution Discharge Elimination System (NPDES) application supplemental requirements. The sample was analyzed by Advanced Technology Laboratories (ATL) for the pollutants listed in the NPDES application supplemental requirements. A list of the analytes and analytical methodology is included in Table 3-11.

The analytical results were submitted to the California Regional Water Quality Control Board – Los Angeles Region (RWQCB) with the Notice of Intent (NOI) to comply with General Waste Discharge Requirements (WDR) and NPDES permit on July 5, 2011. A copy of the NOI is attached as Appendix C.

Table 3-11: List of Analytes and Test Methodology

Analyte	Method
Volatile Organic Compounds (VOCs) + Oxygenates	EPA 8260 B
Semi Volatile Organic Compounds (SVOCs)	EPA 8270 C
1, 4 – Dioxane (Isotope Dilution Technique)	EPA 8270C (M)
Total Recoverable Petroleum Hydrocarbons (TRPH)	EPA 1664
Oil & Grease	EPA 1664
Total Petroleum Hydrocarbons (TPH) as Gasoline Range Organics (GRO)	EPA 8015B / 503 SA
TPH as Diesel Range Organics (DRO) and Oil Range Organics (ORO)	EPA 8015 B
Polychlorinated Biphenyls (PCBs) and Pesticides	EPA 8082 A
Methanol and Ethanol	EPA 8015 M
Title 22 Metals + Boron	EPA 200.7,200.8,245.1
Total Hardness (as calcium carbonate)	SM 2340 C
Total Cyanide	SM 4500
Perchlorate	EPA 314.0
pH	SM 4500
Total Suspended Solids (TSS)	SM 2540 D
Turbidity	180.1
Hexavalent Chromium	EPA 7199
Settleable Matter	SM 2540 F
Total Dissolved Solids (TDS)	SM 2540 C
BOD 520 C	SM5210 B
Chlorides, Sulfates, Nitrites + Nitrates (as N)	EPA 300.0

3.5.1.4 Step-Drawdown Pumping Test

A step-drawdown pumping test was conducted on July 8, 2011 to estimate hydraulic properties of the aquifer and establish a pumping rate for the 24-hour constant rate pumping test. Prior to conducting the test, groundwater was measured from the top of casing in Well P-103, Well OB-105 and Well OB-106 using an electronic water-level meter. All groundwater levels were measured using an electronic water-level meter.

Well P-103 was pumped using a 2-inch Grundfos pump at four different pumping rates: 0.5 gallon per minute (gpm) for 30 minutes, 1 gpm for 30 minutes, 2 gpm for 1 hour, and 3 gpm for 20 minutes. Groundwater was allowed to recover to the static water level between steps.

The pumped groundwater was contained in 55-gallon drums and subsequently removed from the site by Belshire Environmental Services, Inc. (BESI).

3.5.1.5 WDR and NPDES Permit No. CAG994004

The WDR and NPDES permit was issued by the RWQCB on August 4, 2011 and later revised on August 22, 2011 to correct the contact information. The permit contained a table of potential constituents that may be present in the discharge. The discharge would flow to Westwood Channel and then to Ballona Creek, which is designated as potential beneficial use. Ballona Creek mandatory heavy metals Total Maximum Daily Limitations (TMDL) are applicable to the discharge. A list of the specific constituents and effluent limitations are presented in Table 3-12.

Table 3-12: List of Analytes and Effluent Limits

Constituents	Units	Daily Maximum	Monthly Average
Total Suspended Solids	mg/L	150	50
Turbidity	NTU	150	50
BOD_5 20°C	mg/L	30	20
Settleable Solids	mg/L	0.3	0.1
Residual Chlorine	mg/L	0.1	---
Methylene Blue Active Substances	mg/L	0.5	---
Ballona Creek Heavy Metals TMDL			
Copper	µg/L	24	12.5
Lead	µg/L	13	6.5
Selenium	µg/L	5	2.5
Zinc	µg/L	304	152

A copy of the NPDES permit and WDR is attached as Appendix C.

3.5.1.6 Groundwater Sampling – August 2011

On August 19, 2011, a representative groundwater sample of the potential effluent was obtained from Well P-103, prior to any discharge, and analyzed by ATL to determine compliance with the discharge limitations for the constituents shown on the table above, in accordance with general permit No. CAG994004.

Based on the analytical results, all the analytes were below NPDES screening levels except for selenium. A discharge into the storm drain without treatment to reduce the selenium concentration below the effluent limitation would constitute a violation. Based on the low volume of groundwater expected to be generated during the 24-hour pumping test, it was decided that it would be more practical to pump the groundwater into a storage tank and dispose of the water offsite at a recycling facility.

3.5.1.7 Constant-Rate Pumping Test

A 24-hour constant-rate pumping test was conducted on September 9 and 10, 2011. Well P-103 was pumped using a 2-inch Grundfos pump at a constant rate of 1.5 gpm. Pressure transducers were placed in the pumping well and the nearest observation well, OB-106 to record pressure readings, barometric pressure and temperature. Groundwater was measured from the top of casing every 15 minutes for 45 minutes prior to conducting the test. In Wells P-103 and OB-106 groundwater was measured at 48.64 feet and 46.22 feet, respectively, using an electronic water-level meter. Groundwater was initially pumped into a poly drum and transferred to a 4,000 gallon tank via a sump pump.

3.5.1.8 Summary of Results

3.5.1.9 Analytical Results of Groundwater – June 2011

Based on the analytical results, all the analytes were below NPDES screening level except for selenium. Selenium was detected above the screening level of 5 micrograms per liter (µg/L) at 7.5 µg/L. The analytical report is attached in Appendix F of Volume 3 of this report.

3.5.1.10 Analytical Results of Groundwater – August 2011

Based on laboratory analytical results and field measurement readings, no constituents of concern were above effluent permit limitations except for selenium. Selenium was detected in the sample at 6.9 µg/L which exceeds the daily maximum of 5 µg/L. The analytical report is attached in Appendix F of Volume 3 of this report.

3.5.1.11 Step-Drawdown Pumping Test Results

On July 8, 2011, prior to conducting the step-drawdown test, groundwater was measured in Well P-103 at 48.96 feet, Well OB-105 at 47.22 feet, and Well OB-106 at 48.55 feet below top of casing. Well OB-106 and OB-105 are located 25 feet and 150 feet from pumping well P-103, respectively.

At 0.5 gpm, the maximum drawdown in Well P-103 was 1.13 feet after 30 minutes, at 1 gpm, 2.81 feet after 30 minutes, and at 2 gpm, 16.48 feet after 1 hour. At 3 gpm, the drawdown was measured at over 5 feet below the screened interval and at 20 minutes, the drawdown was over 33 feet, or over 14 feet below the screened interval.

The highest drawdown measured in observation Well OB-106 was 0.08 feet during the 2 gpm and 3 gpm tests. No measurable drawdown was measured in Well OB-105.

3.5.1.12 Analysis of the Step-Drawdown Test

Pumping stress at the nearest monitoring well (OB-106) most likely was not significant because of the relatively short test at relatively low pumping rates. Consequently, a constant-rate pumping test was performed, wherein the well is pumped for 24 hours or longer to yield more useful results with respect to permeability (K) and Storativity (S) estimation; the results of the 24-hour test are presented below. Pumping stress at the nearest observation well needs to be more significant, so sustained pumping over many hours is probably necessary to develop a drawdown curve for which an analytical solution can be developed. Curve-fitting to data from monitoring wells is generally preferable to relying on pumping well data alone, as disturbances due to unsteady flow can affect the quality of data from the pumping well.

Constant-Rate Pumping Test Results

Groundwater was measured from the top of casing prior to conducting the constant-rate test in the pumping well (P-103) and observation well (OB-106) at 48.64 feet and 46.22 feet, respectively. The maximum drawdown measured in the pumping well was 5.6 feet and in the observation well, 0.5 feet. The pumping well was fully recovered within 20 minutes after the pumping stopped. The discharge water was observed to be clear with no odor.

The data from the constant-rate test was inputted into the AQTESOLV aquifer analysis software that uses curve matching procedures to calculate the value of aquifer parameters.

Drawdown curve data was analyzed via the Neumann (1974) solution (for an unconfined aquifer) and the Theis solution (for an unconfined aquifer). The analysis yielded the following estimates for K and S at OB-106.

Results for observation well OB-106		
Solution method	K (ft/d)	S
Theis (1935)	14.65	0.0026
Neumann (1974)	12.5	0.0019

K estimates were internally consistent for each solution method. S values were also much lower than what is usually encountered at an unconfined system. It is possible that an overlaying fine-grained unit above the OB-106 well screen caused this discrepancy. Pumping from the screened interval of P-103 may have drawn in flow from less-consolidated overlaying units, which may account for the higher S value at that well.

3.5.1.13 Conclusions

Three groundwater wells were installed within the UCLA parking lot 36 (proposed Westwood/UCLA Station) where groundwater extraction for dewatering purposes would be expected. The first water-bearing zone was encountered from 48 feet to 68 feet bgs in unconfined alluvial aquifer materials consisting of clay, silt, sand and gravel. One pumping well and two observation wells were installed at this location.

Based on a step-drawdown pumping test conducted in July 2011, a pumping rate for the 24-hour constant rate pumping test was established at 1.5 gpm.

A 24-hour constant-rate pumping test was conducted on September 9 and 10, 2011. Drawdown curve data from observation well OB-106 was analyzed. The analysis by two solution methods yielded estimates for K at 12.65 ft/day and 14.65 ft/day and S at 0.0019 and 0.0026.

An NPDES permit was issued by the RWQCB to allow discharge into the storm drain as long as daily maximum limitations for selected constituents were met. Based on analytical results of representative groundwater samples, all analytes were below maximum limitations except for selenium. Since discharge into the storm drain without treatment to reduce the selenium concentration would be a violation, the pumped groundwater generated during the constant-rate pumping test was stored on site and transported to a recycling facility

3.6 Environmental Site Assessment

The Environmental Site Assessment scope of the investigation consisted of advancing a total of 31 borings along the proposed alignment between Western Avenue on the east to just east of the I-405 (San Diego Freeway) on the west. The boring locations were selected based on the findings of previous preliminary environmental site assessment reports that identified suspect sources of environmental concern with the highest likelihood to impact the alignment. Each boring location was initially marked as close as possible to the suspect source of concern (e.g., existing dry cleaner or former gasoline station facility) while staying within the public street area under which the proposed tunnel alignment is being considered. In several cases, the boring locations had to be moved further away from the suspect source due to the presence of underground utilities and/or traffic control issues. Table 3-13 lists the boring number and the associated suspect source that the boring was meant to address:

3.6.1 Summary of Explorations

The field sampling activities were conducted between June 21 and September 22, 2011. Gregg Drilling & Testing, Inc. (Gregg), Kehoe Testing and Engineering, Inc. (Kehoe) and Fugro Consultants, Inc. (Fugro), environmental drilling subcontractors were retained to collect soil and groundwater samples from the 31 boring locations along the alignment. The drilling subcontractors used direct-push sampling methodologies (30-ton cone penetrometer test rig) to collect soil and groundwater samples from discreet depths at each boring location. In some cases, due to dense soils, the CPT rig operators were unable to advance the sampling rods to the proposed depth. Therefore, Gregg was retained to provide a hollow-stem auger rig crew to collect soil samples below where refusal was encountered with the CPT rigs.

The borings were advanced to depths ranging from approximately 55 to 135 feet below ground surface. In most cases, the upper 10 feet of each boring was hand augered prior to conducting sampling activities with the CPT/hollow-stem rigs. Soil sampling was typically started at depths of approximately 15 to 20 feet bgs in the borings located within the proposed station locations while soil sampling was started approximately 10 to 15 feet above the top of the proposed tunnel in the tunnel locations.

The environmental boring locations are presented on Plates 1-01 through 1-21. A summary of each boring and the respective soil sampling depth intervals from which soil samples were collected is provided in Table 3-14.

Prior to commencing the sampling activities, the drilling subcontractors cored the asphalt/concrete road surface. They then used hand auger equipment to check for the presence of underground utilities that may not have been marked by USA or may not have been identified during the field screening process (i.e., geophysical survey and visual observations). The hand augering activities were typically performed down to a depth of approximately 10 feet bgs or until natural soils were encountered.

The CPT rig operator collected soil samples by pushing the stainless steel sampler, which was lined with two stainless steel sleeves, a distance of approximately 1 foot at the desired sampling depth. The hollow stem rig operator used a split-spoon sampling barrel lined with three stainless steel/brass sleeves to collect soil samples. Once the sampler was retrieved, the two ends of the lower sleeve were covered with Teflon® sheets and capped with plastic end-caps. Depending on the amount of recovery, some of the soil in the upper sleeve was placed in a resealable plastic bag so that soil headspace readings could be obtained using a photoionization detector (PID) field instrument for qualitatively measuring for the presence of volatile organic compounds (VOCs). The lower sleeve was labeled and placed into a chilled ice chest.

Table 3-13: Summary of Suspect Sources for Environmental Site Assessment

Boring No.	Plate No.	Suspect Source
E-101	1-01	Spills, Leaks, Investigations and Cleanups [SLIC] case (former dry cleaners at 3807 Wilshire)
E-102	1-01	Closed LUST case (3855 Wilshire)
E-103	1-01	Closed LUST case (3875 Wilshire)
E-104	1-01	Existing dry cleaners (4001 Wilshire) and closed LUST (4006 Wilshire)
E-105	1-02	Former service station on SWC and SEC of intersection. Vent shaft location
E-106	1-04	SLIC case (former service station at 5020 Wilshire) and SLIC case (dry cleaners at 5034 Wilshire)
E-107	1-04	SLIC case (former service station at 5020 Wilshire) and SLIC case (dry cleaners at 5034 Wilshire)
E-108	1-04	LUST case (former auto dealership at 5151 Wilshire)
E-109	1-04	SLIC case (5220 Wilshire)
E-110	1-04	Former services stations at intersection and SLIC case (5220 Wilshire)
E-111	1-04	Former service stations/dry cleaners (5347-5351 Wilshire)
E-112	1-05	Petroleum/Tar Deposits
E-113	1-05	Petroleum/Tar Deposits
E-114	1-06	Petroleum/Tar Deposits
E-115	1-06	Former service station property and current UST site at 6100 Wilshire Boulevard.
E-116	1-06	Former oil production well
E-117	1-06	Former auto gas & oil/ car wash
E-118	1-06	Existing dry cleaning facility (6250 Wilshire)
E-119	1-06	Former oil production well
E-120	1-07	Former LUST site (8383 Wilshire), cleaners, hazardous materials spill (Wilshire/San Vicente) and background
E-121	1-07	Auto sales-repair/gas
E-122	1-07	Former gasoline stations
E-123	1-08	Closed LUST with residual groundwater contamination (8567 Wilshire)
E-124	1-08	Two dry cleaning facilities on both sides of street (8621 and 8624 Wilshire)
E-125	1-09	Former LUST and dry cleaning facilities (9055 and 9045 Wilshire)
E-126	1-10	Former dry cleaners
E-127	1-11	Open LUST case (9815 Wilshire)
E-128*	-	Existing cleaners (9925 Santa Monica)
E-129*	-	Former leaking underground storage tank [LUST] (9975 Santa Monica)
E-130*	-	Former oil production well
E-131*	-	Open SLIC case (dry cleaners at 10301 Santa Monica)
E-132	1-12	Former oil exploration activities
E-133	1-12	Former oil exploration activities
E-134	1-12	Former oil exploration activities
E-135	1-16	Former LUST/soil remediation cases (10936 and 10951 Wilshire)

*Borings E-128 and E-129 were not drilled because of access issues associated with being located on private property. E-130 and E-131 were initially located on the alignment. However, due to route modifications, the borings were no longer located on the alignment.

Table 3-14: Summary of Explorations for Environmental Site Assessment

Boring No.	Soil Sample Depths (feet)
E-101	45, 50 and 55
E-102	30, 40, 45, 50 and 55
E-103	20, 30, 40, 45, 50 and 55
E-104	20, 30, 40, 45, 50, 55 and 60
E-105	30, 40, 50, 60, 65, and 70
E-106	30, 40, 50, 55, 60, and 65
E-107	30, 40, 50, 55, 60, and 65
E-108	10, 15, 20, 25, 30, 35, 40, 45, 50, 60 and 70
E-109	15, 20, 25, 30, 35, 45, 55,65, and 75
E-110	15, 20, 25, 30, 35, 40, 50, 55, 60, 65, 70 and 75
E-111	10, 15, 20, 25, 30, 35, 45, 50, 55, 60, 65, 70 and 75
E-112	40, 50, 60, 70, 75, and 80
E-113	40, 50, 60, 70, 75, 80, and 85
E-114	30, 35, 40, 50, 55 and 60
E-115	10, 15, 20, 30, 40, 50, and 60
E-116	15, 25, 35, 45, 55, and 65
E-117	20, 30, 42.5, 50, and 55
E-118	30, 40, 45, 50, 55, 60 and 65
E-119	30, 40, 45, 50, 55, 60 and 65
E-120	30, 40, 50, 55, 60, 65 and 70
E-121	10, 15, 20, 25, 35, 45, 50, 55, 60 and 65
E-122	10, 15, 20, 25, 30, 35, 40, 50, 55, 60, 65 and 70
E-123	30, 40, 50, 55, 60, 65 and 70
E-124	50, 55, 60, 65, 70 and 75
E-125	30, 40, 50, 55, 60, 65, 70 and 75
E-126	10, 15, 20, 25, 30, 35, 45, 50, 55, 60, 65, 70 and 75
E-127	60, 80, 100, 110, 120, 125, and 130
E-128	Boring Not Drilled and Sampled
E-129	Boring Not Drilled and Sampled
E-130*	Boring Not Drilled and Sampled
E-131*	Boring Not Drilled and Sampled
E-132	10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 and 85
E-133	10, 15, 20, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85 and 90
E-134	10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85 and 90
E-135	10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65 and 75

*Not required. Tunnel alignment was changed subsequent to identifying boring locations.

Based on the presence of unusual discoloration/odors and PID readings, in most cases, three samples from each boring were selected for laboratory analyses. The three selected samples, if scheduled to be analyzed for volatile constituents, were preserved in the field using EPA Method 5035. Approximate 5 gram aliquots of soil sample were collected from the sleeve of the sample scheduled to be analyzed using a "T" handle sampler. The 5 gram samples were then deposited into glass vials containing either sodium bisulfate or methanol preservative. The glass vials were then stored in resealable plastic bags and placed in a chilled ice chest. The remaining samples not scheduled to be analyzed were also stored in resealable plastic bags and placed in an ice chest for transport to the analytical laboratory. A chain-of-custody form was completed for each sample that was collected during the day. Those samples not scheduled for analysis were placed "on-hold" with the analytical laboratory.

If groundwater was encountered, a set of water samples were collected from each boring. The CPT rig operator used a stainless steel sampler that was advanced to the desired depth and then retracted to allow water to infill into the screened section. A small stainless steel bailer was then lowered down the interior of the sampling rods and a "grab" groundwater sample was collected. At the boring locations where a hollow-stem auger drill rig was used, the subcontractor typically installed temporary slotted PVC well screen and then a "grab" groundwater sample was collected by lowering a disposable bailer inside the well screen casing.

The groundwater from the bailer (either CPT or hollow-stem auger sampling) was decanted into glass vials and jars. The glass containers were labeled, placed in resealable plastic bags and stored in a chilled ice chest for transport to the analytical laboratory.

Upon completion of the field activities, the borings were backfilled with a cement/bentonite grout. The ground surface was then patched with a quick setting concrete mix that was typically dyed black to match the surrounding asphalt road surface.

3.6.2 Summary of Explorations

The field observations for each of the 31 boring locations are discussed below in Table 3-15.

Table 3-15: Summary of Explorations

Boring No.	Notes	Findings
E-101	E-101 was advanced to assess potential impacts to the site from a former dry cleaning facility located at 3807 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 55 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 43 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 2.1 to 2.9 parts per million (ppm).
E-102	E-102 was advanced to assess potential impacts of a closed LUST case located at 3855 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 55 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 20 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.7 to 2.4 ppm.

Table 3-15: Summary of Explorations (continued)

Boring No.	Notes	Findings
E-103	E-103 was advanced to assess potential impacts of a closed LUST case located at 3875 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 55 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 50 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 4.3 ppm.
E-104	E-104 was advanced to assess potential impacts of an existing dry cleaners located at 4001 Wilshire Boulevard, as well as a closed LUST site located at 4006 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 60 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 43 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 1.4 ppm.
E-105	E-105 was advanced to assess potential impacts of former service stations that were located on the southwest and southeast corners of the intersection of Wilshire Boulevard and Crenshaw. The boring was drilled using a CPT rig to a depth of 70 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 63 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings were all 0.0 ppm.
E-106	E-106 was advanced to assess potential impacts of a former service station located at 5020 Wilshire Boulevard, as well as an existing dry cleaners located at 5034 Wilshire Boulevard. Both locations are SLIC cases. The boring was drilled using a CPT rig to a depth of 70 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 55 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 1.8 to 6.7 ppm.
E-107	E-107 was advanced to assess potential impacts of a former service station located at 5020 Wilshire Boulevard, as well as an existing dry cleaners located at 5034 Wilshire Boulevard. Both locations are SLIC cases. The boring was drilled using a CPT rig to a depth of 65 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 60 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 1.4 to 4.0 ppm.
E-108	E-108 was advanced to assess potential impacts of a LUST case, which is a former auto dealership, located at 5151 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 70 feet bgs. A grab groundwater sample was attempted from this boring at a depth of approximately 50 feet bgs, but there was no recovery.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 1.0 to 2.0 ppm.
E-109	E-109 was advanced to assess potential impacts of a SLIC case located at 5220 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 75 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 30 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 0.1 ppm.
E-110	E-110 was advanced to assess potential impacts of a SLIC case located at 5220 Wilshire Boulevard and former service stations that were located at the intersection of Wilshire Boulevard and Manhattan Place. The boring was drilled using a CPT rig to a depth of 75 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 45 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.3 to 4.4 ppm.

Table 3-15: Summary of Explorations (continued)

Boring No.	Notes	Findings
E-111	E-111 was advanced to assess potential impacts of a former service stations and dry cleaners located between 5347 and 5351 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 75 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 40 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 2.7 ppm.
E-112	E-112 was advanced to assess for the presence of tar sand deposits located between Burnside and Ridgeley on Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 80 feet bgs. A groundwater sample was not collected during the advancement of this boring.	Petroliferous sediments were encountered during the advancement of this boring. The PID readings ranged from 5.1 to 125 ppm.
E-113	E-113 was advanced to assess for the presence of tar sand deposits located at Stanley and Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 85 feet bgs. Groundwater was not encountered during the advancement of this boring.	Petroliferous sediments were encountered during the advancement of this boring. The PID readings ranged from 6.0 to 27.1 ppm.
E-114	E-114 was advanced to assess for the presence of tar sand deposits located between Spaulding and Ogden on Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 60 feet bgs. A groundwater sample was not collected during the advancement of this boring.	Petroliferous sediments were encountered during the advancement of this boring. The PID readings ranged from 51.2 to 156 ppm.
E-115	E-115 was advanced to assess potential impacts of a former service station and a current UST site located at 6100 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 60 feet bgs. Groundwater was encountered but the attempt to collect a sample was unsuccessful.	Petroliferous sediments were encountered during the advancement of this boring. The PID readings ranged from 4.8 to 314 ppm.
E-116	E-116 was advanced to assess potential impacts of a former oil production well located at Hayward and Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 65 feet bgs. A groundwater sample was not collected during the advancement of this boring.	Petroliferous sediments were encountered during the advancement of this boring. The PID readings ranged from 6.7 to 58.2 ppm.
E-117	E-117 was advanced to assess potential impacts of a former auto gas and oil station and a car wash located on Wilshire Boulevard, approximately 300 feet west of Hayworth. The boring was drilled using a CPT rig to a depth of 55 feet bgs. Groundwater was not encountered during the advancement of this boring.	Petroliferous sediments were encountered during the advancement of this boring. The PID readings ranged from 7.0 to 51.5 ppm.
E-118	E-118 was advanced to assess potential impacts of an existing dry cleaning facility located at 6250 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 65 feet bgs. Groundwater was not encountered during the advancement of this boring.	Petroliferous sediments were encountered during the advancement of this boring. The PID readings ranged from 1.4 to 42.5 ppm.
E-119	E-119 was advanced to assess potential impacts of a former oil production well located Wilshire Boulevard and Crescent Heights. The boring was drilled using a CPT rig to a depth of 65 feet bgs. Groundwater was not encountered during the advancement of this boring.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 2.0 to 5.3 ppm.

Table 3-15: Summary of Explorations (continued)

Boring No.	Notes	Findings
E-120	E-120 was advanced to assess potential impacts of a former LUST site located at 8383 Wilshire Boulevard, a dry cleaners facility and a previous hazardous materials spill. The boring was drilled using a CPT rig to a depth of 70 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 63 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.4 to 2.4 ppm.
E-121	E-121 was advanced to assess potential impacts of an existing auto sales and gas station located at Hamilton and Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 65 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 63 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.2 to 2.8 ppm.
E-122	E-122 was advanced to assess potential impacts of former gas stations located at La Cienega and Wilshire Boulevards. The boring was drilled using a CPT rig to a depth of 65 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 43 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 2.6 ppm.
E-123	E-123 was advanced to assess potential impacts of a closed LUST site with residual groundwater contamination located at 8567 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 70 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 30 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 3.0 ppm.
E-124	E-124 was advanced to assess potential impacts of two existing dry cleaning facilities located on both sides of the street at 8621 and 8624 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 75 feet bgs. A groundwater sample was not collected during the advancement of this boring.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 2.8 ppm.
E-125	E-125 was advanced to assess potential impacts of a former LUST site and dry cleaning facilities located at 9045 and 9055 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 75 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 42 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 0.3 ppm.
E-126	E-126 was advanced to assess potential impacts of a former dry cleaning facility located at Reeves and Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 75 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 64 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings were all recorded as 0.0 ppm.
E-127	E-127 was advanced to assess potential impacts of an open LUST case located at 9815 Wilshire Boulevard. The boring was drilled using a hollow-stem auger rig to a depth of 130 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 70 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 1.4 ppm.
E-128*	Not Applicable	Not Applicable
E-129*	Not Applicable	Not Applicable
E-130*	Not Applicable	Not Applicable
E-131*	Not Applicable	Not Applicable

Table 3-15: Summary of Explorations (continued)

Boring No.	Notes	Findings
E-132	E-132 was advanced to assess potential impacts of former oil exploration activities located in the vicinity of Constellation Boulevard and Avenue of the Stars. The boring was drilled using a CPT rig to a depth of 40 feet bgs. A hollow-stem auger rig was subsequently used to drill down to a depth of 85 feet bgs. A groundwater sample was not collected from this boring.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 1.0 ppm.
E-133	E-133 was advanced to assess potential impacts of former oil exploration activities located in the vicinity of Constellation Boulevard and Avenue of the Stars. The boring was drilled using a CPT rig to a depth of 35 feet bgs. A hollow-stem auger rig was subsequently used to drill to a depth of 85 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 27 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 1.1 ppm.
E-134	E-134 was advanced to assess potential impacts of former oil exploration activities located in the vicinity of Constellation Boulevard and Avenue of the Stars. The boring was drilled using a CPT rig to a depth of 40 feet bgs. A hollow-stem auger rig was used to drill to a depth of 90 feet bgs. A grab groundwater sample was collected from this boring at a depth of approximately 85 feet bgs.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 0.1 ppm.
E-135	E-135 was advanced to assess potential impacts of former LUST and soil remediation cases located at 10936 and 10951 Wilshire Boulevard. The boring was drilled using a CPT rig to a depth of 75 feet bgs. A grab groundwater sample was not collected from this boring.	No evidence of unusual soil discoloration or odors were documented during the field activities. The PID readings ranged from 0.0 to 1.5 ppm.
*Borings E-128 and E-129 were not drilled because of access issues associated with being located on private property. E-130 and E-131 were initially located on the alignment. However, due to route modifications, the borings were no longer located on the alignment.		

3.6.3 Laboratory Test Program

The soil and groundwater samples collected during the ESA field investigation were transported under standard chain-of-custody protocol and delivered to Advanced Technology Laboratories (ATL), a laboratory certified by the California Department of Public Health - Environmental Laboratory Accreditation Program (DPH-ELAP) located in Signal Hill, California. Depending on the suspect source near which a boring was drilled, the soil and groundwater samples were analyzed for one or more of the following constituents:

- Total petroleum hydrocarbons as gasoline/diesel/oil (TPH-g/d/o) by EPA Method 8015B
- Volatile organic compounds and fuel oxygenates (VOCs+Oxy) by EPA Method 8260B
- Polynuclear aromatic hydrocarbons (PAHs) by EPA Method 8270C
- Title 22 metals by EPA Methods 6010B/7471A

Table 3-16 below provides a summary of the analytical test program planned for each boring.

Table 3-16: Analytical Test Program for ESA

Boring No.	Sample Analyses (3 samples per boring)
E-101	VOCs+Oxy (8260B)
E-102	TPH-g/d/o (8015B),VOCs+Oxy (8260B)
E-103	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-104	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-105	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-106	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-107	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-108	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-109	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-110	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-111	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-112	TPH-g/d/o (8015B), VOCs+Oxy (8260B), PAHs (8270C)
E-113	TPH-g/d/o (8015B), VOCs+Oxy (8260B), PAHs (8270C)
E-114	TPH-g/d/o (8015B), VOCs+Oxy (8260B), PAHs (8270C)
E-115	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-116	TPH-g/d/o (8015B), VOCs+Oxy (8260B), PAHs (8270C)
E-117	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-118	VOCs+Oxy (8260B)
E-119	TPH-g/d/o (8015B), VOCs+Oxy (8260B), PAHs (8270C)
E-120	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-121	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-122	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-123	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-124	VOCs+Oxy (8260B)
E-125	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-126	VOCs+Oxy (8260B)
E-127	TPH-g/d/o (8015B), VOCs+Oxy (8260B)
E-128*	N/A
E-129*	N/A
E-130**	N/A
E-131**	N/A
E-132	TPH-g/d/o (8015B), VOCs+Oxy (8260B), PAHs (8270C)
E-133	TPH-g/d/o (8015B), VOCs+Oxy (8260B), PAHs (8270C)
E-134	TPH-g/d/o (8015B), VOCs+Oxy (8260B), PAHs (8270C)
E-135	TPH-g/d/o (8015B), VOCs+Oxy (8260B)

* Not drilled since they were located on private property
** Not drilled since tunnel alignment was changed
Note: One sample from each boring was analyzed for Title 22 Metals

3.6.4 Summary of Laboratory Test Results

The analytical laboratory results of soil samples for VOCs/SVOCs/TPH and Title 22 metals are presented in Table 3-17 and Table 3-18, respectively. The analytical laboratory results of groundwater samples are presented in Table 3-19.

Boring E-101

The 45-, 50- and 55-foot soil samples, and the one groundwater sample, were analyzed for volatile organic compounds and oxygenates (VOCs+Oxy) by EPA Method 8260B. Additionally, the 50-foot soil sample was analyzed for Title 22 Metals by EPA Methods 6010B/7471A. A review of the analytical results showed the following:

- VOCs+Oxy were not detected above the analytical laboratory practical quantitation limits (PQLs) in the samples submitted for analysis.
- Title 22 Metals: Eight of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-102

The 40-, 45- and 55-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and Total Petroleum Hydrocarbons as gasoline, diesel and oil(TPH-g/d/o) by EPA Method 8015B(M). Additionally, the 50-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil samples submitted for analysis. In the groundwater sample three VOC's and TPH-g were detected above the respective PQLs.
- Title 22 Metals: Eight of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-103

The 40-, 50- and 55-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d. Additionally, the 50-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- In the 50-foot soil sample, there was one detection of a VOC compound (benzene) above the PQL in the sample submitted for analysis.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-104

The 40-, 50- and 60-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d. Additionally, the 50-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d were not detected above the PQLs in the soil and groundwater samples submitted for analysis.
- Title 22 Metals: Ten of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-105

The 40-, 60- and 70-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d. Additionally, the 50-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d were not detected above the PQLs in the soil and groundwater samples submitted for analysis.
- Title 22 Metals: Ten of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-106

The 55-, 60- and 65-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 55-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil samples submitted for analysis. In the groundwater sample five VOC's, TPH-d, and TPH-o were detected above the PQL.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-107

The 55-, 60- and 65-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 60-foot sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil samples submitted for analysis. In the groundwater sample four VOC's, TPH-d, and TPH-o were detected above the PQL.
- Title 22 Metals: Eight of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-108

The 15-, 30-, 50-, and 70-foot soil samples were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 40-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil samples submitted for analysis.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-109

The 20-, 45- and 75-foot soil samples were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 55-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil samples submitted for analysis.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-110

The 15-, 30-, 40-, 50-, and 60-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d/o Additionally, the 20-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- One VOC compound (methyl tert butyl ether [MTBE]) was detected in the 15-, and 30-foot soil sample, and two VOCs were detected in the groundwater sample above the respective laboratory PQLs. TPH-g/d/o was not detected in the soil samples submitted for analysis. In the groundwater sample, TPH-d and TPH-o were detected.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-111

The 15-, 30-, 45-, 55-, and 70-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 30-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- MTBE was detected in the 15-and 30-foot soil sample while three VOCs were detected in the groundwater sample. TPH-g/d/o was not detected in the soil and groundwater samples submitted for analysis.

- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-112

The 70-, 75- and 80-foot soil samples were analyzed for VOCs+Oxy, semi-volatile organic compounds (SVOCs), and TPH-g/d/o. Additionally, the 80-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and SVOCs were not detected above the PQLs in the samples submitted for analysis. However, TPH-g/d/o were detected in all of the soil samples submitted for analysis.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-113

The 75-, 80- and 85-foot soil samples were analyzed for VOCs+Oxy, SVOCs, and TPH-g/d/o. Additionally, the 85-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and SVOCs were not detected above the PQLs in the samples submitted for analysis. However, TPH-g/d/o were detected in all of the soil samples submitted for analysis.
- Title 22 Metals: Ten of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-114

The 50- and 60-foot soil samples, were analyzed for VOCs+Oxy, SVOCs, and TPH-g/d/o. Additionally, the 60-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- One VOC (xylenes) was detected in the 60-foot soil sample. SVOCs were not detected above the PQLs in the samples submitted for analysis. TPH-g/d/o was detected in all of the soil samples submitted for analysis.
- Title 22 Metals: Ten of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-115

The 20-, 40- and 60-foot soil samples were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 60-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy were not detected above the PQLs in the samples submitted for analysis. However, TPH-g/d/o were detected in all of the soil samples submitted for analysis.

- Title 22 Metals: Eight of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-116

The 25-, 45-, 55- and 65-foot soil samples were analyzed for VOCs+Oxy, SVOCs, and TPH-g/d/o. Additionally, the 65-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and SVOCs were not detected above the PQLs in the samples submitted for analysis. However, TPH-g/d/o was detected above the laboratory PQLs in all of the soil samples submitted for analysis.
- Title 22 Metals: Seven of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-117

The 42.5-, 50- and 55-foot soil samples were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 50-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- One VOC (xylenes) was detected above the laboratory PQL in the 50-foot soil sample submitted for analysis. TPH-g/d/o was detected in all of the soil samples submitted for analysis.
- Title 22 Metals: Eight of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-118

The 45-, 55- and 60-foot soil samples were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 55-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- There were nine VOCs detected above the PQLs in the 45-foot soil sample, six in the 55-foot soil sample and none in the 60-foot soil sample. TPH-g/d/o was only detected in the 55-foot soil sample.
- Title 22 Metals: Eight of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-119

The 45-, 55- and 60-foot soil samples were analyzed for VOCs+Oxy, SVOCs, and TPH-g/d/o. Additionally, the 50-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy, SVOCs, and TPH-g/d/o were not detected above the PQLs in the soil samples submitted for analysis.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-120

The 55-, 60- and 70-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 55-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil samples submitted for analysis. There was one VOC detected above the laboratory PQLs in the groundwater sample that was submitted for analysis.
- Title 22 Metals: Seven of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-121

The 15-, 45- and 65-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 35-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil and groundwater samples submitted for analysis.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-122

The 20-, 40- and 60-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 55-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil and groundwater samples submitted for analysis.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-123

The 55-, 60- and 70-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 55-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil and groundwater samples submitted for analysis.
- Title 22 Metals: Eight of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-124

The 55-, 65- and 70-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy. Additionally, the 60-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy were not detected above the PQLs in the soil samples submitted for analysis. Two VOCs and TPH-d were present above the respective laboratory PQLs in the groundwater sample submitted for analysis.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-125

The 60-, 70- and 75-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 65-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil and groundwater samples submitted for analysis.
- Title 22 Metals: Eight of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-126

The 25-, 45- and 70-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy. Additionally, the 30-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy were not detected above the PQLs in the soil samples submitted for analysis. One VOC was detected above the laboratory PQL in the groundwater sample that was submitted for analysis.
- Title 22 Metals: Ten of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-127

The 120-, 125- and 130-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 120-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil samples submitted for analysis. One VOC and TPH-d/o were present above the respective laboratory PQLs in the groundwater sample that was submitted for analysis.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-132

The 15-, 30-, 60- and 80-foot soil samples were analyzed for VOCs+Oxy, SVOCs, and TPH-g/d/o. Additionally, the 35-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy, SVOCs, and TPH-g/d/o were not detected above the PQLs in the soil samples submitted for analysis except for low concentrations of TPH-d/o in the 80-foot sample.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-133

The 35-foot soil sample was analyzed for VOCs+Oxy, SVOCs, and TPH-g/d/o. The one groundwater sample was analyzed for VOCs+Oxy and TPH-g/d/o. A review of the analytical results showed the following:

- VOCs+Oxy, SVOCs, and TPH-g/d/o were not detected above the PQLs in the soil samples submitted for analysis. TPH-d/o were present above the respective laboratory PQLs in the groundwater sample that was submitted for analysis.
- Title 22 Metals: Seven of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-134

The 20-, and 40-foot soil samples, and the one groundwater sample, were analyzed for VOCs+Oxy and TPH-g/d/o while the 80-foot sample was analyzed for VOCs+Oxy, TPH-g/d/o and SVOCs. Additionally, the 25-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy, TPH-g/d/o and SVOCs were not detected above the PQLs in the soil samples submitted for analysis. In the groundwater sample, two VOC's were detected above the PQLs.

- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Boring E-135

The 20-, 40- and 60-foot soil samples were analyzed for VOCs+Oxy and TPH-g/d/o. Additionally, the 35-foot soil sample was analyzed for Title 22 Metals. A review of the analytical results showed the following:

- VOCs+Oxy and TPH-g/d/o were not detected above the PQLs in the soil samples submitted for analysis.
- Title 22 Metals: Nine of the 17 metals were present with concentrations above the analytical laboratory PQLs. However, the reported concentrations are not elevated and are likely representative of typical background concentrations for soils in the vicinity of the boring location.

Groundwater samples were also collected from two wells that were installed as part of the groundwater investigation for the project. The analytical results for these samples is summarized below:

Boring M-112

This well is located approximately 200-250 feet northeast of Borings E-115 and E-116. The groundwater sample was analyzed for VOCs and TPH-g/d/o. VOCs and TPH-g were not detected above the PQLs. Low concentrations of TPH-d/o were detected in the groundwater sample.

Boring M-114

This well is located approximately 300 feet west of E-117 and 100 feet east of Boring E-118. The groundwater sample was analyzed for VOCs. Only one VOC (benzene) was detected above the respective PQL.

Table 3-17: Soil Sample Analytical Laboratory Results (VOCs/SVOCs/TPH)

SAMPLE ID	DATE	DEPTH (feet)	Volatile Organic Compounds (µg/Kg) and Oxygenates via EPA METHOD 8260B and 8021B											Semi-Volatile Organic Compounds (µg/kg) via EPA METHOD 8270C	Total Petroleum Hydrocarbons (mg/Kg) via EPA Method 8015B(M)		
			Benzene	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	Ethylbenzene	n-Propylbenzene	Naphthalene	MTBE	m,p-Xylene	o-Xylene	Toluene	All Other VOCs	All SVOCs	GRO	DRO	ORO
E-101-45	6/21/2011	45	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<7.8)	ND (<3.9)	ND (<3.9)	ND	NA	NA	NA	NA
E-101-50	6/21/2011	50	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<7.3)	ND (<3.6)	ND (<3.6)	ND	NA	NA	NA	NA
E-101-55	6/21/2011	55	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<7.2)	ND (<3.6)	ND (<3.6)	ND (89 Tert-Butanol)	NA	NA	NA	NA
E-102-40	7/26/2011	40	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<8.1)	ND (<4.1)	ND (<4.1)	ND	NA	ND (<0.82)	ND (<10)	ND (<10)
E-102-45	7/26/2011	45	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<7.8)	ND (<3.9)	ND (<3.9)	ND	NA	ND (<0.75)	ND (<10)	ND (<10)
E-102-55	7/26/2011	55	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<7.5)	ND (<3.7)	ND (<3.7)	ND	NA	ND (<0.76)	ND (<10)	ND (<10)
E-103-40	6/22/2011	40	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<7.3)	ND (<3.6)	ND (<3.6)	ND	NA	ND (<0.74)	ND (<10)	NA
E-103-50	6/22/2011	50	8.7	ND (<3.7)	ND (<3.7)	ND (<3.6)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<7.3)	ND (<3.6)	ND (<3.6)	ND	NA	ND (<0.73)	ND (<10)	NA
E-103-55	6/22/2011	55	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<7.0)	ND (<3.5)	ND (<3.5)	ND	NA	ND (<0.71)	ND (<10)	NA
E-104-40	6/23/2011	40	ND (<4.7)	ND (<7.6)	ND (<7.6)	ND (<4.7)	ND (<7.6)	ND (<7.6)	ND (<7.6)	ND (<9.4)	ND (<4.7)	ND (<4.7)	ND	NA	ND (<0.94)	ND (<10)	NA
E-104-50	6/23/2011	50	ND (<5.4)	ND (<5.4)	ND (<5.4)	ND (<5.4)	ND (<5.4)	ND (<5.4)	ND (<5.4)	ND (<11)	ND (<5.4)	ND (<5.4)	ND	NA	ND (<1.4)	ND (<10)	NA
E-104-60	6/23/2011	60	ND (<4.5)	ND (<5.1)	ND (<5.1)	ND (<4.5)	ND (<5.1)	ND (<5.1)	ND (<5.1)	ND (<9.0)	ND (<4.5)	ND (<4.5)	ND	NA	ND (<0.90)	ND (<10)	NA
E-105-40	6/24/2011	40	ND (<5.4)	ND (<5.4)	ND (<5.4)	ND (<5.4)	ND (<5.4)	ND (<5.4)	ND (<5.4)	ND (<11)	ND (<5.4)	ND (<5.4)	ND	NA	ND (<1.2)	ND (<10)	NA
E-105-60	6/24/2011	60	ND (<4.1)	ND (<5.0)	ND (<5.0)	ND (<4.1)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<8.3)	ND (<4.1)	ND (<4.1)	ND	NA	ND (<0.83)	ND (<10)	NA
E-105-70	6/24/2011	70	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<7.5)	ND (<3.8)	ND (<3.8)	ND	NA	ND (<0.86)	ND (<10)	NA
E-106-55	7/19/2011	55	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<7.1)	ND (<3.5)	ND (<3.5)	ND	NA	ND (<0.70)	ND (<10)	ND (<10)
E-106-60	7/19/2011	60	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<7.3)	ND (<3.6)	ND (<3.6)	ND	NA	ND (<0.69)	ND (<10)	ND (<10)
E-106-65	7/19/2011	65	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<7.5)	ND (<3.7)	ND (<3.7)	ND	NA	ND (<0.73)	ND (<10)	ND (<10)
E-107-55	7/20/2011	55	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<7.0)	ND (<3.5)	ND (<3.5)	ND	NA	ND (<0.72)	ND (<10)	ND (<10)
E-107-60	7/20/2011	60	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<7.8)	ND (<3.9)	ND (<3.9)	ND	NA	ND (<0.75)	ND (<10)	ND (<10)
E-107-65	7/20/2011	65	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<7.4)	ND (<3.7)	ND (<3.7)	ND	NA	ND (<0.72)	ND (<10)	ND (<10)
E-108-15	7/22/2011	15	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<7.5)	ND (<3.7)	ND (<3.7)	ND	NA	ND (<0.74)	ND (<10)	ND (<10)
E-108-30	7/22/2011	30	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<7.6)	ND (<3.8)	ND (<3.8)	ND	NA	ND (<0.74)	ND (<10)	ND (<10)
E-108-50	7/22/2011	50	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<7.8)	ND (<3.9)	ND (<3.9)	ND	NA	ND (<0.75)	ND (<10)	ND (<10)
E-108-70	7/22/2011	70	ND (<3.4)	ND (<3.4)	ND (<3.4)	ND (<3.4)	ND (<3.4)	ND (<3.4)	ND (<3.4)	ND (<6.9)	ND (<3.4)	ND (<3.4)	ND	NA	ND (<0.70)	ND (<10)	ND (<10)
E-109-20	8/24/2011	20	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<9.5)	ND (<4.7)	ND (<4.7)	ND	NA	ND (<0.83)	ND (<10)	ND (<10)
E-109-45	8/24/2011	45	ND (<4.2)	ND (<4.2)	ND (<4.2)	ND (<4.2)	ND (<4.2)	ND (<4.2)	ND (<4.2)	ND (<8.4)	ND (<4.2)	ND (<4.2)	ND	NA	ND (<0.81)	ND (<10)	ND (<10)
E-109-75	8/24/2011	75	ND (<4.0)	ND (<4.0)	ND (<4.0)	ND (<4.0)	ND (<4.0)	ND (<4.0)	ND (<4.0)	ND (<7.9)	ND (<4.0)	ND (<4.0)	ND	NA	ND (<0.71)	ND (<10)	ND (<10)
E-110-15	7/26/2011	15	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	9.6	ND (<8.3)	ND (<4.1)	ND (<4.1)	ND	NA	ND (<0.79)	ND (<10)	ND (<10)
E-110-30	7/26/2011	30	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	7.9	ND (<8.1)	ND (<4.1)	ND (<4.1)	ND	NA	ND (<0.83)	ND (<10)	ND (<10)
E-110-60	7/26/2011	60	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<7.7)	ND (<3.8)	ND (<3.8)	ND	NA	ND (<0.71)	ND (<10)	ND (<10)

Table 3-17: Soil Sample Analytical Laboratory Results (VOCs/SVOCs/TPH) (continued)

			Volatile Organic Compounds (µg/Kg) and Oxygenates via EPA METHOD 8260B and 8021B											Semi-Volatile Organic Compounds (µg/kg) via EPA METHOD 8270C	Total Petroleum Hydrocarbons (mg/Kg) via EPA Method 8015B(M)		
SAMPLE ID	DATE	DEPTH (feet)	Benzene	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	Ethylbenzene	n-Propylbenzene	Naphthalene	MTBE	m,p-Xylene	o-Xylene	Toluene	All Other VOCs	All SVOCs	GRO	DRO	ORO
E-110-40	7/27/2011	40	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<10)	ND (<5.0)	ND (<5.0)	ND	NA	NA	ND (<10)	ND (<10)
E-110-50	7/27/2011	50	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<10)	ND (<5.0)	ND (<5.0)	ND	NA	NA	ND (<10)	ND (<10)
E-111-15	7/28/2011	15	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	4.9	ND (<7.1)	ND (<3.6)	ND (<3.6)	ND	NA	ND (<0.81)	ND (<10)	ND (<10)
E-111-55	7/28/2011	55	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<7.6)	ND (<3.8)	ND (<3.8)	ND	NA	ND (<0.80)	ND (<10)	ND (<10)
E-111-70	7/28/2011	70	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<8.3)	ND (<4.1)	ND (<4.1)	ND	NA	ND (<0.82)	ND (<10)	ND (<10)
E-111-30	7/28/2011	30	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	11	ND (<10)	ND (<5.0)	ND (<5.0)	ND	NA	NA	NA	NA
E-111-45	7/28/2011	45	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<10)	ND (<5.0)	ND (<5.0)	ND	NA	NA	NA	NA
E-112-70	7/21/2011	70	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<430)	ND (<210)	ND (<210)	ND	ND	33	32,000	37,000
E-112-75	7/21/2011	75	ND (<220)	ND (<220)	ND (<220)	ND (<220)	ND (<220)	ND (<220)	ND (<220)	ND (<450)	ND (<220)	ND (<220)	ND	ND	17	44,000	58,000
E-112-80	7/21/2011	80	ND (<220)	ND (<220)	ND (<220)	ND (<220)	ND (<220)	ND (<220)	ND (<220)	ND (<440)	ND (<220)	ND (<220)	ND	ND	29	48,000	61,000
E-113-75	8/3/2011	75	ND (<230)	ND (<230)	ND (<230)	ND (<230)	ND (<230)	ND (<230)	ND (<230)	ND (<450)	ND (<230)	ND (<230)	ND	ND	1.1	15,000	20,000
E-113-80	8/3/2011	80	ND (<200)	ND (<200)	ND (<200)	ND (<200)	ND (<200)	ND (<200)	ND (<200)	ND (<410)	ND (<200)	ND (<200)	ND	ND	1.3	14,000	20,000
E-113-85	8/3/2011	85	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<430)	ND (<210)	ND (<210)	ND	ND	1.1	15,000	23,000
E-114-50	7/6/2011	50	ND (<4.3)	ND (<14)	ND (<14)	ND (<4.3)	ND (<14)	ND (<14)	ND (<14)	ND (<8.6)	ND (<4.3)	ND (<4.3)	ND	ND	10	42,000	61,000
E-114-60	7/7/2011	60	ND (<4.0)	ND (<4.1)	ND (<4.1)	ND (<4.0)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<8.3)	77	ND (<4.0)	ND	ND	8.0	32,000	45,000
E-115-20	7/8/2011	20	ND (<3.9)	ND (<4.1)	ND (<4.1)	ND (<3.9)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<7.8)	ND (<3.9)	ND (<3.9)	ND	NA	ND (<0.78)	660	1,900
E-115-40	7/8/2011	40	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<7.6)	ND (<3.8)	ND (<3.8)	ND	NA	16	17,000	20,000
E-115-60	7/8/2011	60	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<7.7)	ND (<3.8)	ND (<3.8)	ND	NA	7.3	39,000	56,000
E-116-25	7/11/2011	25	ND (<3.9)	ND (<4.0)	ND (<4.0)	ND (<3.9)	ND (<4.0)	ND (<4.0)	ND (<4.0)	ND (<7.9)	ND (<3.9)	ND (<3.9)	ND	ND	2.3	3,200	4,600
E-116-45	7/11/2011	45	ND (<3.8)	ND (<4.0)	ND (<4.0)	ND (<3.8)	ND (<4.0)	ND (<4.0)	ND (<4.0)	ND (<7.6)	ND (<3.8)	ND (<3.8)	ND	ND	6.9	4,700	6,600
E-116-65	7/11/2011	65	ND (<4.1)	ND (<4.2)	ND (<4.2)	ND (<4.1)	ND (<4.2)	ND (<4.2)	ND (<4.2)	ND (<8.3)	ND (<4.1)	ND (<4.1)	ND	ND	4.1	56,000	79,000
E-116-55	7/11/2011	55	ND (<25)	ND (<250)	ND (<250)	ND (<25)	ND (<250)	ND (<250)	ND (<250)	ND (<50)	ND (<25)	ND (<25)	ND	NA	36	40,000	58,000
E-117-42.5	7/13/2011	42.5	ND (<3.7)	ND (<3.8)	ND (<3.8)	ND (<3.7)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<7.3)	ND (<3.7)	ND (<3.7)	ND	NA	1.5	7,600	12,000
E-117-50	7/13/2011	50	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	53	ND (<3.9)	ND (<3.9)	ND	NA	2.5	37,000	57,000
E-117-55	7/13/2011	55	ND (<3.7)	ND (<3.9)	ND (<3.9)	ND (<3.7)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<7.4)	ND (<3.7)	ND (<3.7)	ND	ND	4.0	49,000	70,000
E-118-45	7/15/2011	45	4.1	31	8.1	8.4	3.9	20	ND (<3.7)	42	15	6.4	ND	NA	ND (<1.0)	ND (<10)	ND (<10)
E-118-55	7/15/2011	55	ND (<4.0)	26	6.8	5.9	ND (<4.0)	14	ND (<4.0)	30	11	ND (<4.0)	ND	NA	2.5	5,200	9,300
E-118-60	7/15/2011	60	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<210)	ND (<420)	ND (<210)	ND (<210)	ND	NA	NA	NA	NA
E-119-45	7/14/2011	45	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<7.8)	ND (<3.9)	ND (<3.9)	ND	ND	ND (<0.81)	ND (<10)	ND (<10)
E-119-55	7/14/2011	55	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<3.5)	ND (<7.1)	ND (<3.5)	ND (<3.5)	ND	ND	ND (<0.74)	ND (<10)	ND (<10)
E-119-60	7/14/2011	60	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<7.9)	ND (<3.9)	ND (<3.9)	ND	ND	ND (<0.78)	ND (<10)	ND (<10)
E-120-50	7/20/2011	50	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<7.5)	ND (<3.7)	ND (<3.7)	ND	NA	ND (<0.79)	ND (<10)	ND (<10)
E-120-60	7/20/2011	60	ND (<7.6)	ND (<7.6)	ND (<7.6)	ND (<7.6)	ND (<7.6)	ND (<7.6)	ND (<7.6)	ND (<15)	ND (<7.6)	ND (<7.6)	ND	NA	ND (<1.1)	ND (<10)	ND (<10)

Table 3-17: Soil Sample Analytical Laboratory Results (VOCs/SVOCs/TPH) (continued)

SAMPLE ID	DATE	DEPTH (feet)	Volatile Organic Compounds (µg/Kg) and Oxygenates via EPA METHOD 8260B and 8021B											Semi-Volatile Organic Compounds (µg/kg) via EPA METHOD 8270C	Total Petroleum Hydrocarbons (mg/Kg) via EPA Method 8015B(M)		
			Benzene	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	Ethylbenzene	n-Propylbenzene	Naphthalene	MTBE	m,p-Xylene	o-Xylene	Toluene	All Other VOCs	All SVOCs	GRO	DRO	ORO
E-120-70	7/20/2011	70	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<11)	ND (<5.7)	ND (<5.7)	ND	NA	ND (<1.1)	ND (<10)	ND (<10)
E-121-15	7/21/2011	15	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<3.9)	ND (<7.8)	ND (<3.9)	ND (<3.9)	ND	NA	ND (<0.89)	ND (<10)	ND (<10)
E-121-45	7/21/2011	45	ND (<8.6)	ND (<8.6)	ND (<8.6)	ND (<8.6)	ND (<8.6)	ND (<8.6)	ND (<8.6)	ND (<17)	ND (<8.6)	ND (<8.6)	ND	NA	ND (<0.88)	ND (<10)	ND (<10)
E-121-65	7/21/2011	65	ND (<6.6)	ND (<6.6)	ND (<6.6)	ND (<6.6)	ND (<6.6)	ND (<6.6)	ND (<6.6)	ND (<13)	ND (<6.6)	ND (<6.6)	ND	NA	ND (<0.79)	ND (<10)	ND (<10)
E-122-20	7/22/2011	20	ND (<10)	ND (<10)	ND (<10)	ND (<10)	ND (<10)	ND (<10)	ND (<10)	ND (<21)	ND (<10)	ND (<10)	ND	NA	ND (<0.87)	ND (<10)	ND (<10)
E-122-40	7/22/2011	40	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<7.4)	ND (<3.7)	ND (<3.7)	ND	NA	ND (<0.88)	ND (<10)	ND (<10)
E-122-60	7/22/2011	60	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<8.9)	ND (<4.5)	ND (<4.5)	ND	NA	ND (<0.93)	ND (<10)	ND (<10)
E-123-55	8/4/2011	55	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<7.3)	ND (<3.7)	ND (<3.7)	ND	NA	ND (<0.72)	ND (<10)	ND (<10)
E-123-60	8/4/2011	60	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<3.8)	ND (<7.5)	ND (<3.8)	ND (<3.8)	ND	NA	ND (<0.77)	ND (<10)	ND (<10)
E-123-70	8/4/2011	70	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<7.2)	ND (<3.6)	ND (<3.6)	ND	NA	ND (<0.74)	ND (<10)	ND (<10)
E-124-55	7/19/2011	55	ND (<4.9)	ND (<4.9)	ND (<4.9)	ND (<4.9)	ND (<4.9)	ND (<4.9)	ND (<4.9)	ND (<9.8)	ND (<4.9)	ND (<4.9)	ND	NA	NA	NA	NA
E-124-65	7/19/2011	65	ND (<5.5)	ND (<5.5)	ND (<5.5)	ND (<5.5)	ND (<5.5)	ND (<5.5)	ND (<5.5)	ND (<11)	ND (<5.5)	ND (<5.5)	ND	NA	NA	NA	NA
E-124-70	7/19/2011	70	ND (<4.8)	ND (<4.8)	ND (<4.8)	ND (<4.8)	ND (<4.8)	ND (<4.8)	ND (<4.8)	ND (<9.6)	ND (<4.8)	ND (<4.8)	ND	NA	NA	NA	NA
E-125-60	8/5/2011	60	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<3.7)	ND (<7.4)	ND (<3.7)	ND (<3.7)	ND	NA	ND (<0.75)	ND (<10)	ND (<10)
E-125-70	8/5/2011	70	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<7.1)	ND (<3.6)	ND (<3.6)	ND	NA	ND (<0.72)	ND (<10)	ND (<10)
E-125-75	8/5/2011	75	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<3.6)	ND (<7.3)	ND (<3.6)	ND (<3.6)	ND	NA	ND (<0.73)	ND (<10)	ND (<10)
E-126-25	8/11/2011	25	ND (<5.8)	ND (<5.8)	ND (<5.8)	ND (<5.8)	ND (<5.8)	ND (<5.8)	ND (<5.8)	ND (<12)	ND (<5.8)	ND (<5.8)	ND	NA	NA	NA	NA
E-126-45	8/11/2011	45	ND (<6.7)	ND (<6.7)	ND (<6.7)	ND (<6.7)	ND (<6.7)	ND (<6.7)	ND (<6.7)	ND (<13)	ND (<6.7)	ND (<6.7)	ND	NA	NA	NA	NA
E-126-70	8/11/2011	70	ND (<9.0)	ND (<9.0)	ND (<9.0)	ND (<9.0)	ND (<9.0)	ND (<9.0)	ND (<9.0)	ND (<18)	ND (<9.0)	ND (<9.0)	ND	NA	NA	NA	NA
E-127-120	8/18/2011	120	ND (<9.1)	ND (<9.1)	ND (<9.1)	ND (<9.1)	ND (<9.1)	ND (<9.1)	ND (<9.1)	ND (<18)	ND (<9.1)	ND (<9.1)	ND	NA	ND (<0.81)	ND (<10)	ND (<10)
E-127-125	8/18/2011	125	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<9.4)	ND (<4.7)	ND (<4.7)	ND	NA	ND (<0.81)	ND (<10)	ND (<10)
E-127-130	8/18/2011	130	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<4.1)	ND (<8.1)	ND (<4.1)	ND (<4.1)	ND	NA	ND (<0.74)	ND (<10)	ND (<10)
E-132-15	8/12/2011	15	ND (<10)	ND (<10)	ND (<10)	ND (<10)	ND (<10)	ND (<10)	ND (<10)	ND (<20)	ND (<10)	ND (<10)	ND	ND	ND (<0.90)	ND (<10)	ND (<10)
E-132-30	8/12/2011	30	ND (<6.4)	ND (<6.4)	ND (<6.4)	ND (<6.4)	ND (<6.4)	ND (<6.4)	ND (<6.4)	ND (<13)	ND (<6.4)	ND (<6.4)	ND	ND	ND (<1.1)	ND (<10)	ND (<10)
E-133-35	8/19/2011	35	ND (<4.8)	ND (<4.8)	ND (<4.8)	ND (<4.8)	ND (<4.8)	ND (<4.8)	ND (<4.8)	ND (<9.5)	ND (<4.8)	ND (<4.8)	ND	ND	ND (<0.95)	ND (<10)	ND (<10)
E-132-60	9/20/2011	60	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND	ND	ND (<1.1)	ND (<10)	ND (<10)
E-132-80	9/20/2011	80	ND (<6.3)	ND (<6.3)	ND (<6.3)	ND (<6.3)	ND (<6.3)	ND (<6.3)	ND (<6.3)	ND (<13)	ND (<6.3)	ND (<6.3)	ND	ND	ND (<0.97)	12	13
E-133-55	9/21/2011	55	ND (<4.3)	ND (<4.3)	ND (<4.3)	ND (<4.3)	ND (<4.3)	ND (<4.3)	ND (<4.3)	ND (<8.7)	ND (<4.3)	ND (<4.3)	ND	ND	ND (<0.93)	ND (<10)	ND (<10)
E-133-80	9/21/2011	80	ND (<5.9)	ND (<5.9)	ND (<5.9)	ND (<5.9)	ND (<5.9)	ND (<5.9)	ND (<5.9)	ND (<12)	ND (<5.9)	ND (<5.9)	ND	ND	ND (<0.85)	ND (<10)	ND (<10)
E-134-20	9/6/2011	20	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<10)	ND (<5.0)	ND (<5.0)	ND	NA	ND (<1.0)	ND (<10)	ND (<10)
E-134-40	9/6/2011	40	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<10)	ND (<5.0)	ND (<5.0)	ND	NA	ND (<1.0)	ND (<10)	ND (<10)

Table 3-17: Soil Sample Analytical Laboratory Results (VOCs/SVOCs/TPH) (continued)

SAMPLE ID	DATE	DEPTH (feet)	Volatile Organic Compounds (µg/Kg) and Oxygenates via EPA METHOD 8260B and 8021B											Semi-Volatile Organic Compounds (µg/kg) via EPA METHOD 8270C	Total Petroleum Hydrocarbons (mg/Kg) via EPA Method 8015B(M)		
			Benzene	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	Ethylbenzene	n-Propylbenzene	Naphthalene	MTBE	m,p-Xylene	o-Xylene	Toluene	All Other VOCs	All SVOCs	GRO	DRO	ORO
E-134-80	9/22/2011	80	ND (<4.3)	ND (<4.3)	ND (<4.3)	ND (<4.3)	ND (<4.3)	ND (<4.3)	ND (<4.3)	ND (<8.6)	ND (<4.3)	ND (<4.3)	ND	ND	ND (<0.97)	ND (<10)	ND (<10)
E-135-20	9/12/2011	20	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<8.9)	ND (<4.5)	ND (<4.5)	ND	ND	ND (<0.93)	ND (<10)	ND (<10)
E-135-40	9/12/2011	40	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<4.5)	ND (<9.1)	ND (<4.5)	ND (<4.5)	ND	ND	ND (<0.82)	ND (<10)	ND (<10)
E-135-60	9/12/2011	60	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<4.7)	ND (<4.7)	` ND (<4.7)	ND (<4.7)	ND (<9.4)	ND (<4.7)	ND (<4.7)	ND	ND	ND (<1.0)	ND (<10)	ND (<10)

Notes:
1,1-DCA = 1,1-dichloroethane
1,1-DCE = 1,1-dichloroethene
PCE = tetrachloroethene
1,1,1-TCA = 1,1,1-trichloroethane
TCE = trichloroethene
ND <1.0 = Analyte not detected; below the laboratory Reporting Limit indicated
µg/L = micrograms per liter
NA = Not analyzed

Table 3-18: Soil Sample Analytical Laboratory Results - Title 22 Metals

SAMPLE ID	DATE	DEPTH (feet)	Title 22 Metals (mg/Kg) via EPA METHOD 6010B/7471A																Mercury (mg/Kg) via EPA Method 7471A
			Antimony	Arsenic	Barium	Berylium	Cadmium	Chromium	Cobalt	Copper	Lead	Molyb-denum	Nickel	Selenium	Silver	Thalium	Vanadium	Zinc	Mercury
E-101-50	6/21/2011	50	ND (<2.0)	ND (<1.0)	58	ND (<1.0)	ND (<1.0)	12	5.9	9.4	2.7	ND (<1.0)	10	ND (<1.0)	ND (<1.0)	ND (<1.0)	17	28	ND (<0.10)
E-102-50	7/26/2011	50	ND (<2.0)	ND (<1.0)	42	ND (<1.0)	ND (<1.0)	17	8.7	14	2.1	ND (<1.0)	23	ND (<1.0)	ND (<1.0)	ND (<1.0)	16	29	ND (<0.10)
E-103-50	6/22/2011	50	ND (<2.0)	ND (<1.0)	34	ND (<1.0)	1.3	15	6.8	12	1.7	ND (<1.0)	17	ND (<1.0)	ND (<1.0)	ND (<1.0)	20	28	ND (<0.10)
E-104-50	6/23/2011	50	ND (<2.0)	8.0	60	ND (<1.0)	1.9	20	9.6	3.9	1.7	ND (<1.0)	24	ND (<1.0)	ND (<1.0)	ND (<1.0)	22	24	ND (<0.10)
E-105-65	6/24/2011	65	ND (<2.0)	2.7	19	ND (<1.0)	ND (<1.0)	16	4.6	6.5	1.7	1.9	15	ND (<1.0)	ND (<1.0)	ND (<1.0)	15	19	ND (<0.10)
E-106-55	7/19/2011	55	ND (<2.0)	ND (<1.0)	14	ND (<1.0)	ND (<1.0)	15	2.5	3.8	1.3	ND (<1.0)	9.8	1.1	ND (<1.0)	ND (<1.0)	29	11	ND (<0.10)
E-107-60	7/20/2011	60	ND (<2.0)	ND (<1.0)	120	ND (<1.0)	ND (<1.0)	6.9	11	14	1.8	ND (<1.0)	3.5	ND (<1.0)	ND (<1.0)	ND (<1.0)	47	44	ND (<0.10)
E-108-40	7/22/2011	40	ND (<2.0)	ND (<1.0)	54	ND (<1.0)	2.2	17	8.4	16	3.3	ND (<1.0)	18	ND (<1.0)	ND (<1.0)	ND (<1.0)	29	47	ND (<0.10)
E-109-55	8/24/2011	55	ND (<2.0)	ND (<1.0)	110	ND (<1.0)	1.1	19	13	24	6.8	ND (<1.0)	21	ND (<1.0)	ND (<1.0)	ND (<1.0)	28	62	ND (<0.10)
E-110-20	7/26/2011	20	ND (<2.0)	ND (<1.0)	37	ND (<1.0)	1.0	21	9.4	12	3.5	ND (<1.0)	20	ND (<1.0)	ND (<1.0)	ND (<1.0)	37	37	ND (<0.10)
E-111-30	7/28/2011	30	ND (<2.0)	ND (<1.0)	66	ND (<1.0)	1.1	25	10	12	1.9	ND (<1.0)	23	ND (<1.0)	ND (<1.0)	ND (<1.0)	24	34	ND (<0.10)
E-112-80	7/21/2011	80	ND (<2.0)	3.0	54	ND (<1.0)	ND (<1.0)	12	6.0	7.3	1.6	ND (<1.0)	9.5	ND (<1.0)	ND (<1.0)	ND (<1.0)	21	21	ND (<0.10)
E-113-85	8/3/2011	85	ND (<2.0)	ND (<1.0)	190	ND (<1.0)	1.2	20	8.2	25	3.2	2.1	37	ND (<1.0)	ND (<1.0)	ND (<1.0)	41	56	ND (<0.10)
E-114-60	7/7/2011	60	ND (<2.0)	1.2	45	ND (<1.0)	ND (<1.0)	31	2.1	5.5	1.2	2.1	18	ND (<1.0)	ND (<1.0)	ND (<1.0)	19	28	ND (<0.10)
E-115-60	7/8/2011	60	ND (<2.0)	ND (<1.0)	16	ND (<1.0)	ND (<1.0)	6.7	2.0	2.4	ND (<1.0)	1.7	22	ND (<1.0)	ND (<1.0)	ND (<1.0)	24	8.7	ND (<0.10)
E-116-65	7/11/2011	65	ND (<2.0)	ND (<1.0)	29	ND (<1.0)	ND (<1.0)	9.5	6.5	ND (<2.0)	1.6	ND (<1.0)	34	ND (<1.0)	ND (<1.0)	ND (<1.0)	26	20	ND (<0.10)
E-117-50	7/13/2011	50	ND (<2.0)	ND (<1.0)	23	ND (<1.0)	ND (<1.0)	9.6	2.4	3.3	1.3	ND (<1.0)	13	ND (<1.0)	ND (<1.0)	ND (<1.0)	20	7.2	ND (<0.10)
E-118-55	7/15/2011	55	ND (<2.0)	ND (<1.0)	29	ND (<1.0)	ND (<1.0)	4.6	1.0	4.6	1.1	ND (<1.0)	5.0	ND (<1.0)	ND (<1.0)	ND (<1.0)	9.0	5.6	ND (<0.10)
E-119-50	7/14/2011	50	ND (<2.0)	ND (<1.0)	65	ND (<1.0)	2.1	35	18	18	3.0	ND (<1.0)	44	ND (<1.0)	ND (<1.0)	ND (<1.0)	36	54	ND (<0.10)
E-120-55	7/20/2011	55	ND (<2.0)	ND (<1.0)	31	ND (<1.0)	ND (<1.0)	9.5	2.9	ND (<2.0)	1.0	ND (<1.0)	26	ND (<1.0)	ND (<1.0)	ND (<1.0)	28	13	ND (<0.10)
E-121-35	7/21/2011	35	ND (<2.0)	3.2	83	ND (<1.0)	ND (<1.0)	7.8	1.7	7.5	6.0	ND (<1.0)	4.6	ND (<1.0)	ND (<1.0)	ND (<1.0)	9.5	21	ND (<0.10)
E-122-25	7/22/2011	25	ND (<2.0)	ND (<1.0)	110	ND (<1.0)	1.7	24	9.9	12	2.6	ND (<1.0)	15	ND (<1.0)	ND (<1.0)	ND (<1.0)	29	47	ND (<0.10)
E-123-55	8/4/2011	55	ND (<2.0)	ND (<1.0)	130	ND (<1.0)	ND (<1.0)	21	6.5	8.5	2.0	ND (<1.0)	16	ND (<1.0)	ND (<1.0)	ND (<1.0)	14	23	ND (<0.10)
E-124-60	7/19/2011	60	ND (<2.0)	4.1	130	ND (<1.0)	ND (<1.0)	43	16	18	4.2	ND (<1.0)	23	ND (<1.0)	ND (<1.0)	ND (<1.0)	73	60	ND (<0.10)
E-125-65	8/5/2011	65	ND (<2.0)	ND (<1.0)	110	ND (<1.0)	ND (<1.0)	20	7.8	10	2.6	ND (<1.0)	19	ND (<1.0)	ND (<1.0)	ND (<1.0)	20	30	ND (<0.10)
E-126-30	8/11/2011	30	ND (<2.0)	9.6	89	ND (<1.0)	1.3	26	11	17	4.7	ND (<1.0)	24	ND (<1.0)	ND (<1.0)	ND (<1.0)	45	46	ND (<0.10)
E-127-120	8/18/2011	120	ND (<2.0)	6.4	62	ND (<1.0)	ND (<1.0)	22	6.8	16	3.2	ND (<1.0)	16	ND (<1.0)	ND (<1.0)	ND (<1.0)	35	59	ND (<0.10)
E-132-35	8/12/2011	35	ND (<2.0)	1.3	59	ND (<1.0)	ND (<1.0)	19	5.4	14	3.0	ND (<1.0)	17	ND (<1.0)	ND (<1.0)	ND (<1.0)	30	50	ND (<0.10)
E-133-65	9/21/11	65	ND (<4.0)	ND (<2.0)	27	ND (<2.0)	ND (<2.0)	14	7.9	7.7	ND (<2.0)	ND (<2.0)	15	ND (<2.0)	ND (<2.0)	ND (<2.0)	18	47	ND (<0.10)
E-134-25	9/6/2011	25	ND (<2.0)	7.2	85	ND (<1.0)	ND (<1.0)	24	6.7	14	4.8	ND (<1.0)	17	ND (<1.0)	ND (<1.0)	ND (<1.0)	45	36	ND (<0.10)
E-135-35	9/12/2011	35	ND (<2.0)	15	110	ND (<1.0)	ND (<1.0)	31	7.6	20	6.4	ND (<1.0)	21	ND (<1.0)	ND (<1.0)	ND (<1.0)	47	51	ND (<0.10)

Explanation:
ND (<1.0) = Analyte not detected; below the laboratory Reporting Limit indicated
mg/Kg = milligrams per kilogram

Table 3-19: Groundwater Sample Analytical Results

SAMPLE ID	DATE	DEPTH (feet)	Volatile Organic Compounds (µg/L) and Oxygenates via EPA METHOD 8260B										Total Petroleum Hydrocarbons (mg/L) via EPA Method 8015B(M)		
			1,1-Dichloroethane	1,1-Dichloroethene	Chloroform	Chloromethane	MTBE	n-Propylbenzene	cis-1,2-Dichloroethene	TCE	Toluene	All Other VOCs	GRO	DRO	ORO
E-101-40-45	6/21/2011	40-45	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	NA	NA	NA
E-102-GW	7/26/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	67	ND (<0.50)	1.0	0.59		ND	0.22	ND (<0.24)	ND (<0.24)
E-103-50	6/22/2011	50	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	ND (<0.20)	NA
E-104-GW	6/23/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	ND (<0.20)	NA
E-105-GW	6/24/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	ND (<0.20)	NA
E-106-GW	7/19/2011		0.61	2.2	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	0.75	1.3	0.52	ND	ND (<0.20)	1.2	0.63
E-107-GW	7/20/2011		ND (<0.50)	0.51	ND (<0.50)	ND (<0.50)	ND (<0.50)	0.78	ND (<0.50)	0.53	0.63	ND	ND (<0.20)	0.39	0.29
E-109-GW-30	8/24/2011	30	ND (<0.50)	0.87	ND (<0.50)	ND (<0.50)	4.8	ND (<0.50)	0.6	6.3	ND (<0.50)	ND	ND (<0.20)	ND (<0.20)	ND (<0.20)
E-110-GW	7/27/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	21	ND (<0.50)	7.6	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	0.60	0.52
E-111-GW	7/28/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	14	ND (<0.50)	3.4	1.0	ND (<0.50)	ND	ND (<0.20)	ND (<0.20)	ND (<0.20)
E-120-GW	7/20/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	1.8	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	ND (<0.25)	ND (<0.25)
E-121-GW	7/21/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	ND (<0.20)	ND (<0.20)
E-122-GW	7/22/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	ND (<0.20)	ND (<0.20)
E-123-GW	8/4/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	ND (<0.25)	ND (<0.25)
E-124-GW	7/19/2011		ND (<0.50)	0.89	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	1.0	ND (<0.50)	ND	ND (<0.20)	0.36	ND (<0.29)
E-125-GW	8/5/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	ND (<0.20)	ND (<0.20)
E-126-GW	8/11/2011		ND (<0.50)	ND (<0.50)	0.60	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	NA	NA	NA
E-127-GW	8/18/2011		ND (<0.50)	ND (<0.50)	0.64	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	0.87	1.1
E-133-GW-25	8/19/2011	25	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	0.21	0.24
M-112 S	7/21/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	5.3	6.2
E-134-GW	9/22/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	5.9	ND (<0.50)	ND (<0.50)	1.6	ND (<0.50)	ND (<0.50)	ND	ND (<0.20)	ND (<0.20)	ND (<0.20)
M-114	7/12/2011		ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (<0.50)	ND (3.4 Benzene)	NA	NA	NA

Explanations:
1,1-DCA = 1,1-dichloroethane
PCE = tetrachloroethene
TCE = trichloroethene
MTBE = methylter-butyl ether
GRO = gasoline range organics
DRO = diesel range organics
ORO = oil range organics
µg/L = micrograms per liter
NA = Not analyzed
J = Estimated value. Refer to laboratory report for details.
1,1-DCE = 1,1-dichloroethene
1,1,1-TCA = 1,1,1-trichloroethane
ND <1.0 = Analyte not detected; below the laboratory Reporting Limit indicated

3.6.5 Findings Discussion

The environmental investigation findings (field observations and analytical laboratory results) suggest that in a majority of the areas investigated, the subsurface soils and groundwater within the proposed tunnel/station excavation areas are adversely impacted from the suspect sources or other nearby possible sources. A summary of the findings for soil and groundwater contamination is presented as bulleted items below:

Soil

- Soil samples from ten of the 31 borings contained some constituents of concern in concentrations above the laboratory reporting limits. The ten borings where the suspect constituents were identified were E-103, E-110, E-112 through E-118, and E-132.
- VOCs were detected in nine of the 99 soil samples that were analyzed. One VOC constituent was detected in seven of these nine samples. The VOC constituents that were detected included benzene, MTBE, ethylbenzene and xylenes. The concentrations of the detected VOCs ranged from 3.9 to 77 micrograms per kilogram (µg/kg). The specific VOCs that were detected suggest that the impacted areas were associated with fuel (gasoline or diesel) releases.
- TPH-g was detected in 18 of the 85 soil samples submitted for analysis. The concentrations of the detected TPH-g ranged from 1.1 to 36 milligrams per kilogram (mg/kg).
- TPH-d was detected in 20 of the 87 soil samples submitted for analysis. The concentrations of the detected TPH-d ranged from 12 to 56,000 mg/kg.
- TPH-o was detected in 20 of the 78 soil samples submitted for analysis. The concentrations of the detected TPH-o ranged from 13 to 79,000 mg/kg.
- SVOCs were not detected in the 23 soil samples submitted for analysis.
- Certain metals were detected in each of the 31 soil samples were analyzed. The reported concentrations were not elevated and appear to be representative of background concentrations for soils in the area from which each sample was collected.

Groundwater

- Groundwater samples were collected from 20 of the 31 boring locations plus two of the soil gas groundwater wells ("M-" wells). Fourteen of these 22 groundwater samples contained some detectable concentrations of the suspect constituents of concern. These 14 borings are identified as E-102, E-106, E-107, E-109 through E-111, E-120, E-124, E-126, E-127, E-133, E-134, M-112 and M-114.
- VOCs were detected in eleven of the 22 groundwater samples that were analyzed. The VOC constituents that were detected included MTBE, trichloroethylene (TCE) and toluene. The concentrations of the detected VOCs ranged from 0.51 to 67 micrograms per liter (µg/L). The specific VOCs that were detected suggest that the impacted areas were associated with fuel (gasoline or diesel) releases or chlorinated solvent releases.
- TPH-g was detected in only one of the 19 groundwater samples submitted for analysis. The concentrations of the detected TPH-g ranged were reported as 0.22 milligrams per liter (mg/L).
- TPH-d was detected in seven of the 19 groundwater samples submitted for analysis. The concentrations of the detected TPH-d ranged from 0.21 to 5.3 mg/L.

- TPH-o was detected in 5 of the 16 groundwater samples submitted for analysis. The concentrations of the detected TPH-o ranged from 0.24 to 6.2 mg/L.

Specific Boring Locations

Table 3-20 below presents a discussion of the borings where suspect constituents were detected in the soil and/or groundwater samples and also provides a summary of the analytical laboratory findings with respect to the threshold as defined by the California Code of Regulation with regard to waste characterization for disposal.

Table 3-20: Impacted Soil and/or Groundwater Boring Locations

Boring No.	Location	Media Affected	Discussion	Constituents Detected	Lab Results	Disposal Threshold Levels*
E-102	Wilshire/St. Andrews	Groundwater	E-102: The groundwater sample collected from this boring contained detectable concentrations of fuel-related compounds and chlorinated solvents (MTBE and TCE). The suspect source is a former LUST property located at 3855 Wilshire Boulevard (between Manhattan Place and St. Andrews Place).	MTBE	67 µg/L[1]	—[2]
				Cis-1,2 Dichloroethene	1.0 µg/L	—[2]
				TCE	0.59 µg/L	500 µg/L
				TPH-G	0.22 mg/L[3]	5,000-20,000 mg/L[4]
E-103	Wilshire/St. Andrews	Soil	Benzene was detected in the 50-foot soil sample. However, this constituent was not detected in either the 40- or 55-foot samples. The suspect source is a former LUST property located at 3875 Wilshire Boulevard (between Manhattan Place and St. Andrews Place).	Benzene	8.7 µg/kg[5] (at 50')	20 x TCLP[6] (or, 10,000 µg/L)

Table 3-20: Impacted Soil and/or Groundwater Boring Locations (continued)

Boring No.	Location	Media Affected	Discussion	Constituents Detected	Lab Results	Disposal Threshold Levels*
E-106	Wilshire/Between Highland and Citrus	Groundwater	The groundwater sample collected from this boring contained detectable concentrations of chlorinated solvents and one fuel-related constituent (including TCE and toluene). The suspect sources consisted of a former service station and a dry cleaning facility.	1,1-Dichloroethane	0.61 µg/L	500 µg/L
				1,1-Dichloroethene	2.2 µg/L	700 µg/L
				Cis-1,2 Dichloroethene	0.75 µg/L	—[2]
				TCE	1.3 µg/L	500 µg/L
				Toluene	0.52 µg/L	—[2]
				TPH-D	1.2 mg/L	5,000-20,000 mg/L
				TPH-O	0.63 mg/L	5,000-20,000 mg/L
E-107	Wilshire/Citrus	Groundwater	The groundwater sample collected from this boring contained detectable concentrations of chlorinated solvents and fuel-related constituents (including TCE and toluene). The suspect sources consisted of a former service station and a dry cleaning facility.	1,1-Dichloroethene	0.51 µg/L	700 µg/L
				n-Propylbenzene	0.78 µg/L	—[2]
				TCE	0.53 µg/L	500 µg/L
				Toluene	0.63 µg/L	—[2]
				TPH-D	0.39 mg/L	5,000-20,000 mg/L
				TPH-O	0.29 mg/L	5,000-20,000 mg/L
E-109	Wilshire/La Brea	Groundwater	The groundwater sample collected from this boring contained detectable concentrations of chlorinated solvents and fuel-related constituents (including TCE and MTBE). The suspect source consisted of a SLIC facility.	1,1-Dichloroethene	0.87 µg/L	700 µg/L
				MTBE	4.8 µg/L	—[2]
				Cis-1,2 Dichloroethene	0.6 µg/L	—[2]
				TCE	6.3 µg/L	500 µg/L

Table 3-20: Impacted Soil and/or Groundwater Boring Locations (continued)

Boring No.	Location	Media Affected	Discussion	Constituents Detected	Lab Results	Disposal Threshold Levels*
E-110	Wilshire/Manhattan	Soil Groundwater	The 15- and 30-foot soil samples from this boring contained detectable concentrations of MTBE. However, MTBE was not detected in the soil samples collected from the 40-, 50- and 60-foot depths. The groundwater sample collected from this boring contained detectable concentrations of a chlorinated solvent and a fuel-related constituent. The suspect sources consisted of a (Spills, Leaks, Investigation and Cleanup) SLIC facility and former service stations.	MTBE	9.6 µg/kg (at 15') 7.9 µg/kg (at 30') 21 µg/L (Groundwater)	—[2]
				Cis-1,2 Dichloroethene	7.6 µg/L (Groundwater)	—[2]
				TPH-D	0.60 µg/L (Groundwater)	5,000-20,000 µg/L
				TPH-O	0.52 µg/L (Groundwater)	5,000-20,000 µg/L
E-111	Wilshire/Detroit	Soil Groundwater	The groundwater sample collected from this boring contained detectable concentrations of chlorinated solvents and one fuel-related constituent (including TCE and MTBE). The suspect sources consisted of a former service stations and a dry cleaning facility located between 5347 and 5351 Wilshire Boulevard (Wilshire Boulevard and Detroit Street).	MTBE	4.9 µg/kg (at 15') 11 µg/kg (at 30') 14 µg/L (Groundwater)	—[2]
				Cis-1,2 Dichloroethene	3.4 µg/L	—[2]
				TCE	1.0 µg/L	500 µg/L
E-112	Wilshire/Between Burnside and Ridgeley	Soil	All three soil samples submitted for analysis from the boring contained detectable levels of TPH-g/d/o. The suspect source is the naturally occurring tar sands located within the mid-Wilshire District.	TPH-G	33 mg/kg (at 70') 17 mg/kg (at 75') 29 mg/kg (at 80')	5,000-20,000 mg/kg[4,7]
				TPH-D	32,000 mg/kg (at 70') 44,000 mg/kg (at 75') 48,000 mg/kg (at 80')	5,000-20,000 mg/kg

Table 3-20: Impacted Soil and/or Groundwater Boring Locations (continued)

Boring No.	Location	Media Affected	Discussion	Constituents Detected	Lab Results	Disposal Threshold Levels*
				TPH-O	37,000 mg/kg (at 70') 58,000 mg/kg (at 75') 61,000 mg/kg (at 80')	5,000-20,000 mg/kg
E-113	Wilshire/Stanley	Soil	All three soil samples submitted for analysis from the boring contained detectable levels of TPH-g/d/o. The suspect source is the naturally occurring tar sands located within the mid-Wilshire District.	TPH-G	1.1 mg/kg (at 75') 1.3 mg/kg (at 80') 1.1 mg/kg (at 85')	5,000-20,000 mg/kg
				TPH-D	15,000 mg/kg (at 75') 14,000 mg/kg (at 80') 15,000 mg/kg (at 85')	5,000-20,000 mg/kg
				TPH-O	20,000 mg/kg (at 75' and 80') 23,000 mg/kg (at 85')	5,000-20,000 mg/kg
E-114	Wilshire/Between Spaulding and Ogden	Soil	Both soil samples submitted for analysis from the boring contained detectable levels of TPH-g/d/o. Additionally, one fuel-related constituent (xylenes) was present in one of the soil samples. The suspect source is the naturally occurring tar sands located within the mid-Wilshire District.	TPH-G	10.0 mg/kg (at 50') 8.0 mg/kg (at 60')	5,000-20,000 mg/kg
				TPH-D	42,000 mg/kg (at 50') 32,000 mg/kg (at 60')	5,000-20,000 mg/kg
				TPH-O	61,000 mg/kg (at 50') 45,000 mg/kg (at 60')	5,000-20,000 mg/kg
				Xylenes	77 µ/kg (at 60')	—[8]
E-115	Wilshire/Fairfax	Soil	All three soil samples submitted for analysis from this boring contained detectable levels of TPH-g/d/o. The suspect sources are a former service station property and an existing	TPH-G	16 mg/kg (at 40') 7.3 mg/kg (at 60')	5,000-20,000 mg/kg
				TPH-D	660 mg/kg (at 20') 17,000 mg/kg (at 40')	5,000-20,000 mg/kg

Table 3-20: Impacted Soil and/or Groundwater Boring Locations (continued)

Boring No.	Location	Media Affected	Discussion	Constituents Detected	Lab Results	Disposal Threshold Levels*
			underground storage tank (UST) property. However, based on the findings, it appears that the main source may be the naturally occurring tar sands located within the mid-Wilshire District.		39,000 mg/kg (at 60')	
				TPH-O	1,900 mg/kg (at 20') 20,000 mg/kg (at 40') 56,000 mg/kg (at 60')	5,000-20,000 mg/kg
E-116	Wilshire/Hayworth	Soil	All four soil samples submitted for analysis from this boring contained detectable levels of TPH-g/d/o. The suspect sources are a former oil production well. However, based on the findings, it appears that another source may be the naturally occurring tar sands located within the mid-Wilshire District.	TPH-G	2.3 mg/kg (at 25') 6.9 mg/kg (at 45') 36.0 mg/kg (at 55') 4.1 mg/kg (at 65')	5,000-20,000 mg/kg
				TPH-D	3,200 mg/kg (at 25') 4,700 mg/kg (at 45') 40,000 mg/kg (at 55') 56,000 mg/kg (at 65')	5,000-20,000 mg/kg
				TPH-O	4,600 mg/kg (at 25') 6,600 mg/kg (at 45') 58,000 mg/kg (at 55') 79,000 mg/kg (at 65')	5,000-20,000 mg/kg
E-117	Wilshire Approximately 300 Feet West of Hayworth	Soil	All three soil samples submitted for analysis from the boring contained detectable levels of TPH-g/d/o. Additionally, one fuel-related constituent (xylenes) was present in one of the soil samples. The suspect source is a former auto service station and car wash facility. However, based on the findings, it appears that another source may be the naturally occurring	TPH-G	1.5 mg/kg (at 42.5') 2.5 mg/kg (at 50') 4.0 mg/kg (at 55')	5,000-20,000 mg/kg
				TPH-D	7,600 mg/kg (at 42.5') 37,000 mg/kg (at 50') 49,000 mg/kg (at 55')	5,000-20,000 mg/kg
				TPH-O	12,000 mg/kg (at 42.5') 57,000 mg/kg (at 50')	5,000-20,000 mg/kg

Table 3-20: Impacted Soil and/or Groundwater Boring Locations (continued)

Boring No.	Location	Media Affected	Discussion	Constituents Detected	Lab Results	Disposal Threshold Levels*
			tar sands located within the mid-Wilshire District.		70,000 mg/kg (at 55')	
				Xylenes	53 µg/kg (at 50')	—[8]
E-118	Wilshire/McCarthy Vista-Crescent Heights	Soil	Both soil samples submitted for analysis from the boring contained detectable levels of VOCs. One of the samples also contained detectable concentrations of TPH-g/d/o. The suspect source consists of an existing dry cleaning facility located at 6250 Wilshire Boulevard. However, the VOCs that were identified are more consistent with a fuel release than a chlorinated solvent release.	TPH-G	2.5 mg/kg (at 55')	5,000-20,000 mg/kg
				TPH-D	5,200 mg/kg (at 55')	5,000-20,000 mg/kg
				TPH-O	9,300 mg/kg (at 55')	5,000-20,000 mg/kg
				Benzene	4.1 µg/kg (at 45')	20 x TCLP (or, 10,000 µg/L)
				1,2,4-Trimethylbenzene	31 µg/kg (at 45') 26 µg/kg (at 55')	—[2]
				1,3,5-Trimethylbenzene	8.1 µg/kg (at 45') 6.8 µg/kg (at 55')	—[2]
				Ethylbenzene	8.4 µg/kg (at 45') 5.9 µg/kg (at 55')	—[2]
				n-Propylbenzene	3.9 µg/kg (at 45')	—[2]
				Naphthalene	20 µg/kg (at 45') 14 µg/kg (at 55')	—[2]
				m,p-Xylenes	42 µg/kg (at 45') 30 µg/kg (at 55')	—[8]
				o-Xylenes	15 µg/kg (at 45') 11 µg/kg (at 55')	—[8]
				Toluene	6.4 µg/kg (at 45')	—[2]
E-120	Wilshire/San Vicente	Groundwater	The groundwater sample collected from this boring contained a detectable concentration of a chlorinated solvent. The suspect sources consisted of a former LUST property, a dry cleaning facility and a hazardous	Cis-1,2 Dichloroethene	1.8 µg/L	—[2]

Table 3-20: Impacted Soil and/or Groundwater Boring Locations (continued)

Boring No.	Location	Media Affected	Discussion	Constituents Detected	Lab Results	Disposal Threshold Levels*
			materials release.			
E-124	Wilshire/Carson	Groundwater	The groundwater sample collected from this boring contained detectable concentrations of VOCs (including TCE) and TPH-d. The suspect sources consisted of two dry cleaning facilities located on opposite sides of the street in the vicinity of the boring.	1,1-Dichloroethene	0.89 µg/L	700 µg/L
				TCE	1.0 µg/L	500 µg/L
				TPH-D	0.36 mg/L	5,000-20,000 mg/L
E-126	Wilshire/Reeves	Groundwater	The groundwater sample collected from this boring contained one detectable VOC (chloroform). No other suspect constituents were detected. The suspect source consists of a dry cleaning facility.	Chloroform	0.60 µg/L	6,000 µg/L
E-127	Wilshire/Santa Monica	Groundwater	The groundwater sample collected from this boring contained detectable concentrations of a VOC (chloroform) and TPH-o/d. The suspect source consists of an open LUST case located at 9815 Wilshire Boulevard.	Chloroform	0.64 µg/L	6,000 µg/L
				TPH-D	0.87 mg/L	5,000-20,000 mg/L
				TPH-O	1.1 mg/L	5,000-20,000 mg/L
E-132	Constellation/Avenue of the Stars	Soil	The soil sample from the 80-foot depth from this boring contained detectable levels of TPH-d/o. The suspect source consists of former oil exploration activities.	TPH-D	12 mg/kg (at 80')	5,000-20,000 mg/kg
				TPH-O	13 mg/kg (at 80')	5,000-20,000 mg/kg
E-133	Constellation/Avenue of the Stars	Groundwater	The groundwater sample collected from this boring contained detectable concentrations of TPH-d/o. The suspect source consists of former oil exploration activities.	TPH-D	0.21 mg/L	5,000-20,000 mg/L
				TPH-O	0.24 mg/L	5,000-20,000 mg/L
E-134	Constellation/Avenue of the Stars	Groundwater	The groundwater sample collected from this boring contained detectable concentrations of VOCs (cis-1,2 dichloroethene and chloromethane). The	Chloromethane	5.9 µg/L	—[2]
				Cis-1,2 Dichloroethene	1.6 µg/L	—[2]

Table 3-20: Impacted Soil and/or Groundwater Boring Locations (continued)

Boring No.	Location	Media Affected	Discussion	Constituents Detected	Lab Results	Disposal Threshold Levels*
			suspect source consists of former oil exploration activities.			
M-112	Wilshire/Fairfax	Groundwater	The groundwater sample collected from this boring contained detectable concentrations of TPH-d/o. The suspect sources are a former service station property, an existing UST property and a former oil production well. However, based on the findings, it appears that another source may be the naturally occurring tar sands located within the mid-Wilshire District.	TPH-D	5.3 mg/L	5,000-20,000 mg/L
				TPH-O	6.2 mg/L	5,000-20,000 mg/L
M-114	Wilshire/McCarthy Vista	Groundwater	The groundwater sample collected from this boring contained detectable concentrations of one VOC (benzene). TPH-o/d. The suspect sources are a former auto service station, a car wash facility and an existing dry cleaning facility located at 6250 Wilshire Boulevard (between Fairfax Avenue and Crescent Heights Boulevard).	Benzene	3.4 µg/L	500 µg/L

*The listed threshold levels are maximum values above which the respective constituent would be considered a hazardous waste under the Title 22 California Code of Regulations.

Notes
[1] µg/L = milligrams per liter
[2] Not listed as a hazardous constituent of concern based on criteria established under Title 22 California Code of Regulations
[3] mg/L = milligrams per liter
[4] TPH is not regulated under the California Code of Regulations. The maximum TPH values are dependent on the particular disposal facility accepting the waste. Maximum TPH values, independent of the organics range (i.e., gasoline, diesel or oil), generally range from 5,000 to 20,000 mg/kg in soil and 5,000 to 20,000 mg/L in groundwater. However, additional testing (e.g., fish bioassay) may be required at lower levels depending on the source of contamination (e.g., tar sands) or at higher levels in order to better characterize the waste.
[5] µg/kg = micrograms per kilogram
[6] TCLP =Toxicity Characteristic Leaching Procedure
[7] mg/kg = milligrams per kilogram
[8] Not considered a RCRA Hazardous Waste under Article 4 of the Title 22 California Code of Regulations

3.6.6 Conclusions and Recommendations

A review of the field findings and analytical laboratory results shows that suspect constituents of concern were detected in some of the soil and/or the groundwater samples in 21 of the 31 borings advanced during this investigation (in addition to both of the groundwater samples collected from the two "M" borings). The constituents identified were related to releases of fuel compounds and/or chlorinated solvents or naturally occurring petroleum compounds.

Note that the "E-" borings advanced during this assessment, and the soil and groundwater samples that were analyzed from the specific borings, are indicative of the conditions at a precise location. In several cases, the borings had to be moved further away from the suspect sources due to underground utility and/or traffic control reasons. Therefore, further investigation would be necessary to better delineate the possible extent of impacted areas along the proposed alignment.

Considering the relatively lengthy history of retail/commercial (and some light industrial) development along a majority of the proposed subway alignment, combined with the findings of this investigation, it is readily apparent that impacted soils and groundwater will be encountered along certain portions of the alignment during tunneling and excavation activities. A soil and groundwater management plan is recommended to address these issues.

Table 3-21 below presents a summary of boring locations drilled within the proposed station locations where impacted groundwater was identified.

Table 3-21: Impacted Groundwater Boring Locations at Stations

Station	Boring Number	Constituents Detected
Wilshire/La Brea	E-109, E-110 and E-111	TPH-D/O VOCs
Wilshire/Fairfax	M-112	TPH-D/O
Wilshire/La Cienega	E-120	VOCs
Wilshire/Rodeo	E-126	VOCs
Century City Constellation	E-133 and E-134	VOCs

3.7 Oil Well Surveys

In accordance with the December 10, 2010 work plan, AMEC conducted oil well investigations at three study areas: "Salt Lake" 10, "Wolfskill" 23 and "Aladdin" Wells 25E-1, 26, and 28. Three areas were later added at Beverly Hills High School : the football field, the lacrosse field, and the tennis court area (including a grassy area to the northwest).

The investigations consisted of a review of California Department of Conservation Division of Oil, Gas and Geothermal Resources (DOGGR) and performing geophysical surveys. For each subject well discussed above, AMEC obtained DOGGR records on the well. From these records the following information was noted:

- "Salt Lake" 10 was not shown to be formally abandoned.

- "Wolfskill" 23 was drilled in 1908 and 1909 and abandoned in 1916. According to the records, as part of the abandonment, the casing was shot at depths of 2,203 feet, 2,201 feet and 420 feet before plugging each zone with 20-sack cement. Then the hole was filled with unknown materials and tamped to surface.
- According to DOGGR records, "Rodeo" 107 (also owned by ChevronTexaco Exploration & Production Company) was drilled in 1909 and abandonment occurred in 1916. The hole was "filled to top – all casing pulled" in 1916.
- For "Rodeo" 114 (mapped in the football field) no records are available on the drilling and logging of the hole. The owner is Chevron U.S.A. Inc.
- The "Rodeo" wells were originally called that because they were located in the Rancho Rodeo de La Aguas property, which encompassed hundreds of acres east of Century Park East in Beverly Hills. Other "Rodeo" wells include 101 through 106 which are mapped as located south of the alignment in a line parallel with the Century Park East (northwest-southeast) starting 400 feet south of 107 over a three block area (approximately 400 feet apart). "Rodeo" 112 lies to the north of 107 approximately 500 feet. "Rodeo" 115 through 117 are located south east of 114 at about 400 feet southeast of 114 approximately 400 feet apart. The California Mining Bureau Bulletin #63 from 1913 notes on page 233 that there were seven productive and five abandoned wells on the property.

Geophysical surveys were performed by GeoVision, Inc. (GeoVision) under AMEC supervision, using non-invasive imaging equipment. The geophysical techniques used during the investigation were the magnetic method and the electromagnetic (EM) method. A magnetometer and an electromagnetic detector were used to scan over the surface of the ground in a grid pattern. The magnetic method is the most commonly used geophysical technique for locating abandoned oil wells and the EM method is used to scan selected areas for metallic pipes and to further characterize anomalies found in the magnetic data. The geophysical survey was designed to map abandoned wells with ferrous metallic pipe in the upper 15 feet.

Areas of study were as follows:

1. "Salt Lake" 10. According to DOGGR records, "Salt Lake" 10 is an idle oil well located in the South Salt Lake Oil Field. An "idle" oil well is an industry term to define a well that is out of production and inactive, but has not been decommissioned. DOGGR has plotted its approximate location at the northwest quadrant of the intersection of Fairfax Avenue and Wilshire Boulevard with an approximate location west of the Johnnie's Restaurant building (closed). The area investigated by the geophysical survey on May 31, 2011 was the parking lot located west of the restaurant building and the adjacent alley that separates the parking lot and a beauty school. There was a manhole cover located in the alley that most likely is associated with an underground vault or utility. The survey GeoVision report is provided in Appendix E of Volume 2.

2. "Wolfskill" 23. According to DOGGR records, this is a plugged oil well located in the Wolfskill lease of the Beverly Hills Oil Field. DOGGR has plotted its approximate location in Century City at 1950 Century Park East, a property known as Meridian's Bodies in Motion. The oil well appears to be located beneath the parking structure (on the west end) based upon available records. The well is owned by ChevronTexaco Exploration & Production Company. The survey report by GeoVision is provided in Appendix E of Volume 2.

3. "Aladdin" 25E-1, "Aladdin" 26, "Aladdin" 28. According to DOGGR records, these three oil well are plugged and abandoned and are plotted in Century City at the intersection of Constellation Boulevard and Avenue of the Stars, northeast quadrant vacant lot and adjacent parking lot. "Aladdin" 25E-1, "Aladdin" 26, and "Aladdin" 28 appear to be the three oil wells in closest proximity to the proposed alignment alternative associated with Constellation Boulevard based upon available DOGGR maps. Based on the results of the geophysical investigation conducted on July 1, 2011, there was no indication of an oil well within or immediately adjacent to the proposed alignment. The survey GeoVision report is provided in Appendix E of Volume 2.

4. Beverly Hills High School: The lacrosse field was studied as an extension to the "Wolfskill" 23 oil well study (immediately east of the 1950 Century Park East property). Based on DOGGR information, "Rodeo" 114 was mapped on the football field area (northern 1/3rd) and "Rodeo" 107 mapped near the southeast corner of the lacrosse field study area. All three areas were scanned by GeoVision in March 2011 and the report is provided in Volume 2. Refer to the report for a map indicating the study area boundaries, and geophysical presentation data.

In the area consisting of the tennis courts and the front lawn, there was no indication of any abandoned oil wells in the magnetic data. In the football field area there was no indication of any abandoned oil wells in the magnetic and EM data.

At the lacrosse field, four large magnetic anomalies (A1 through A4) were present in the total magnetic field data that may be related to steel-cased abandoned oil wells (or its infrastructure) or other buried metallic debris. Two of the anomalies (A1 and A2) may be related to a pipe segment or previous building infrastructure. Three (A1, A2, and A3) are located on or near the grass lacrosse field, which is surrounded by a metallic chain-link fence and a block retaining wall. The other anomaly (A4) is located southeast of the lacrosse field, in a small area adjacent to an asphalt road with utility vaults, chain-link fencing, reinforced concrete, a building and a retaining wall.

A-1 is the westernmost anomaly and is located within the the tunnel envelope. A-1 presents a strong dipolar magnetic response and a strong EM-61 response. Although this anomaly may be related to a pipe segment or previous building infratructure, it cannot be fully discounted that this anomaly is related to an abandoned oil well or its infrastructure.

A-2 also presents a strong, dipolar response but a weaker EM-61 response, which may indicate that this anomaly is deeper than the source of the A-1 anomaly. Although this anomaly may be related to a pipe segment or previous building infratructure, it cannot be fully discounted that this anomaly is related to an abandoned oil well or its infrastructure.

Due to the large magnetic response in A-3, it cannot be fully discounted that this anomaly is related to a steel-cased abandoned oil well. It is estimated that the source of this anomaly is east of the the fencing and retaining wall surrounding the lacrosse field. An additional survey would be needed to further characterize this anomaly, but due to its proximity to surface metallic features, there would be no guarantee that results from a further investigation would be conclusive..

The suspected location of abandoned oil well "Rodeo" 107 was surveyed and marked on the ground near the retaining wall where anomaly A-4 was located. Due to the large magnetic response in A-4, it cannot be fully discounted that this anomaly is related to a steel-cased abandoned oil well. An additional gridded survey would need to be conducted on the asphalt road to further characterize this anomaly.

Based upon the results of the study, no definitive indications of any abandoned oil wells or associated infrastructure could be located at the "Wolfskill" 23, "Salt Lake" 10, "Rodeo" 107, and "Rodeo" 114 study areas and associated surveyed areas. Therefore, to further study the anomalies and possibly locate the abandoned oil wells at "Wolfskill" 23, horizontal directional drilling (HDD) will be conducted at the tunnel level in the Advanced Preliminary Engineering phase.

THIS PAGE INTENTIONALLY LEFT BLANK

4.0 LABORATORY TESTING

4.1 Geotechnical Exploration Testing

Eighteen geotechnical rotary-wash borings drilled during the ACE phase are relevant for the Project alignment. In addition, 87 geotechnical rotary-wash borings and 17 geotechnical sonic core borings were drilled for the PE phase. Samples collected from these borings were transported to the laboratory for visual inspection and testing. Various tests were performed on the samples to estimate strength, compressibility, and other relevant soil properties to assist with soil classification. A list of the laboratory tests performed for the ACE and PE phases is presented in Table 4-1. The laboratory testing program was pre-approved by Parsons Brinckerhoff, Metro, and TAP.

Table 4-1: Laboratory Tests Performed for ACE and PE Phases

Laboratory Test	Laboratory	ASTM Designation (or) other	ACE Phase	PE Phase
Field Moisture Content	AMEC/AP Engineering	D 2216	X	X
Field Dry Density	AMEC/AP Engineering	D 2937	X	X
Sieve Analysis	AMEC/AP Engineering	D 422	X	X
Passing No. 200 Sieve	AMEC/AP Engineering	D 1140	X	X
Atterberg Limits	AMEC/AP Engineering	D 4318	X	X
Tar Content	AMEC	Modified D 6307	-	X
Direct Shear	AMEC/AP Engineering	D 3080	X	X
Consolidation	AMEC/AP Engineering	D 2435	X	X
Expansion/Collapse	AMEC/AP Engineering	D 2435	-	X
Triaxial Unconsolidated-Drained	AP Engineering	D 4767	-	X
Soil Abrasion	University of Texas, Austin	NTNU-SINTEF	-	X
Specific Gravity	AMEC	D 854	-	X
Soil/Water Quality	Orange Coast Analytical, Inc. and ATL	Various EPA methods	-	X
Corrosion	HDR-Schiff Associates	Caltrans method	X	X
Unconfined Compression	AP Engineering	D 2166		X

4.1.1 Field Moisture Content and Dry Density

Field moisture content and dry density of undisturbed ring samples were determined in the laboratory in accordance with ASTM D 2216. For disturbed samples obtained from SPT sampling and sonic core borings, only moisture content was determined. The results of the tests are shown on the boring logs.

4.1.2 Sieve Analysis and Passing No. 200 Sieve

Sieve analysis and tests to determine the percentage of fines (material passing through No. 200 sieve) were performed on selected samples collected from the rotary-wash and sonic core borings to determine the size of the different particles in the samples, in accordance with ASTM D 422. The percentage of fines passing No. 200 sieve is shown to the left on the boring logs. The gradation curves obtained from sieve tests are presented in Appendix F of Volume 3, Laboratory Test Results.

4.1.3 Atterberg Limits

Atterberg Limits were performed on selected samples collected from rotary-wash borings and sonic core borings to determine the plasticity of the materials in accordance with ASTM D 4318. The results of the tests are presented in Appendix F of Volume 3, Laboratory Test Results.

4.1.4 Tar Content

A portion of the tunnel traverses through tar-impacted soils. Therefore, it was desired to determine the percentage of tar in the soil samples collected from the borings. Soil samples collected from rotary-wash and sonic core borings drilled between Wilshire/La Brea and Wilshire/La Cienega were used for tar content tests.

4.1.4.1 Test Procedure

An ASTM standard for determining tar content on soil samples was not available. Therefore, a modified version of ASTM D 6307 (Asphalt Content of Hot-Mix Asphalt by Ignition Method) was used. About 600 grams of sample were placed in steel pans, weighed, and put in an oven. The temperature of the oven was set to 250 degrees Fahrenheit and the sample was left in the oven for about 24 hours. During this period, the majority of the fluids (water and volatile compounds) from the samples evaporated. The sample was removed from the oven and weighed to estimate its moisture content. Next, the sample was placed in a sample tray with a catch pan and the initial weight was recorded before placing it in an N-Cat oven. The temperature inside the oven was set to 995 degrees Fahrenheit to burn off the tar and other hydrocarbons present in the sample. The N-cat oven has an automatic read out for sample weight during the burning process. When the dry weight reached a nearly constant value, the tray was removed from the oven and weighed to estimate the percentage of tar content in the sample.

4.1.4.2 Test Results

The results of 69 tar content tests are presented in Table 4-2. The tar content represents the percentage of tar by weight of the total dry weight of soil.

Table 4-2: Tar Content Test Results

Boring No.	Depth (feet)	USCS Soil Classification	Tar Content
G-118	31.5	Silty Sand	7.9%
	37.5	Silty Sand	13.6%
	52	Silty Sand	13.6%
	61.5	Silty Sand	16.9%
	73.5	Sandy Silt/Silty Sand	16.9%
G-119	25.5	Poorly Graded Sand with Silt	13.6%
G-119	30.5	Silt	17.4%
	35.5	Silty Sand	8.8%
	50.5	Poorly Graded Sand with Silt	16.5%
	60.5	Poorly Graded Sand with Silt	14.8%

Table 4-2: Tar Content Test Results (continued)

Boring No.	Depth (feet)	USCS Soil Classification	Tar Content
	85.5	Siltstone	17.5%
G-123	15.5	Silty Clay	4.6%
	33.5	Silt	4.1%
	44.5	Silty Sand	10.0%
	55.5	Silty Sand	11.4%
	69.5	Silty Sand	16.4%
G-124	15.5	Lean Clay	4.0%
	30.5	Lean Clay	9.6%
	45.5	Poorly Graded Sand	7.1%
	60.5	Poorly Graded Sand	12.5%
	80.5	Poorly Graded Sand	11.7%
	100.5	Silt	4.9%
S-105	11-12	Silty Sand	10.5%
	17-18	Silty Sand	12.0%
	26-27	Silty Sand	20.4%
	32-33	Poorly Graded Sand with Silt	13.5%
	42-43	Poorly Graded Sand with Silt	16.8%
	52-53	Poorly Graded Sand with Silt	10.5%
	57-58	Poorly Graded Sand with Silt	12.3%
	72-73	Siltstone	18.7%
	82-83	Siltstone	18.4%
	96-97	Siltstone	19.3%
S-106	18-19	Silty Sand	5.7%
	21-22	Silty Sand	9.2%
	26-27	Silty Sand	3.7%
	36-37	Silty Sand	9.1%
	51-52	Silty Sand	15.1%
	57-58	Silty Sand	16.5%
	66-67	Silty Sand	18.5%
	71.5-72.5	Poorly Graded Sand with Silt	12.9%
	81-82	Silty Sand	17.6%
	106-107	Poorly Graded Sand with Silt	9.2%
	117-118	Siltstone	6.4%
S-116	18-19	Poorly Graded Sand with Silt	18.5%
	39-40	Poorly Graded Sand with Silt	17.1%
	48-49	Silty Sand	17.7%
	57-58	Silty Sand	12.2%
	62-63	Silt	18.0%
	76-77	Siltstone	20.2%

Table 4-2: Tar Content Test Results (continued)

Boring No.	Depth (ft)	USCS Soil Classification	Tar Content
	91-92	Siltstone	17.9%
	98-99	Siltstone	16.9%
S-117	16-17	Silt	13.1%
	24-25	Silty Sand	16.0%
	36-37	Poorly Graded Sand with Silt	16.1%
	39-40	Silty Sand	17.8%
	47-48	Poorly Graded Sand with Silt	13.9%
	55-56	Poorly Graded Sand with Silt	13.4%
	62-63	Silty Sand	17.6%
	67-68	Siltstone	19.7%
	92-93	Siltstone	18.2%
S-118	40-41	Fat Clay	4.0%
	46-47	Silty Sand	12.2%
	49-50	Silty Sand	11.2%
	60-61	Silty Sand	15.4%
	69-70	Poorly Graded Sand with Silt	12.0%
	72-73	Poorly Graded Sand with Silt	17.4%
	79-80	Silty Sand	18.4%
	84-85	Siltstone	18.7%
	94-95	Siltstone	29.5%

Based on the test results presented in Table 4-2, the tar content varies from about 5% to 30%, with an average value of about 15%. The percentage of tar appears to increase with depth and averages about 20% tar in siltstone bedrock, about 15% tar in sands and about 7% tar in clay and silts of alluvium overlying the bedrock.

For purposes of classifying the soil samples based on the percentage of tar content, a classification scheme was developed as presented in Table 4-3.

Table 4-3: Tar Content Classification Scheme

Tar Content	Classification
< 5%	Slightly Infused Tar
5% - 15%	Moderately Infused Tar
>15%	Saturated with Tar

This scheme was used in classifying the remaining tar-impacted samples in which tar content tests were not performed. The percentage of tar was estimated based on visual inspection and using the qualifiers presented in the above table.

Out of 69 samples tested within a depth range of 10 to 120 feet, about 10% were slightly infused with tar; about 45% were moderately infused with tar, and the remaining 45% of the samples were satarated with tar.

4.1.4.3 Analytical Test Results

Analytical tests were performed on two samples of tar-impacted soils for VOCs/SVOCs/TPH and Title 22 metals by American Scientific Labs. The results are included in Appendix F of Volume 3, Laboratory Test Results. In addition, soil samples from drill cuttings stored in the drums were also analyzed. Based on the test results, the tar-impacted soils were determined to be non-hazardous waste per the Resource Conservation and Recovery Act (RCRA). Therefore, tar sands are not considered a concern with respect to environmental transportation and disposal requirements. These tar sands from exploratory borings have been sent to the Soil Safe (formerly TPST) facility in Adelanto, California for thermal treatment and reuse.

4.1.5 Direct Shear

Direct shear tests were performed on selected undisturbed samples obtained from rotary-wash borings to determine the strength of the soils in accordance with ASTM D 3080. The tests were performed after soaking to near-saturated moisture content and at three surcharge pressures. The yield-point values determined from the tests were taken as the shear strength of the sample. The direct shear test results are presented in Appendix F of Volume 3, Laboratory Test Results.

The rate of shearing varied depending on the type of soil tested (fine-grained versus granular material). The rate of shearing was estimated using the time-consolidation rate reading taken from one-dimensional laboratory consolidation tests performed in accordance with ASTM D 2435. The rate of shearing for different materials is listed in Table 4-4.

Table 4-4: Direct Shear Rate of Shearing

Test Material	Rate of Shearing (inch/minute)	Test Duration (minutes)
Fine-Grained	0.01	45
Coarse-Grained	0.02	25
Tar Sand	0.005	100
Petroliferous Silt/Clay	0.002	180

4.1.6 Consolidation

Confined consolidation tests were performed on undisturbed (ring) samples obtained from rotary-wash borings to determine the compressibility of the soils in accordance with ASTM D 2435. Water was added to the samples during the tests to illustrate the effect of moisture on the compressibility. The results of the tests are presented in Appendix F of Volume 3, Laboratory Test Results.

4.1.7 Expansion/Collapse

In addition to the confined consolidation tests, "quick" consolidation tests were performed on selected undisturbed samples obtained from rotary-wash borings to determine the hydrocompaction potential of the soils in accordance with ASTM D 2435. The tests were performed by confining the sample under a surcharge pressure of 1,800 pounds per square foot, allowing the sample to consolidate at its field moisture content, and then saturating the sample and measuring the consolidation resulting from the addition of water. The results of the tests are presented in Appendix F of Volume 3, Laboratory Test Results.

4.1.8 Triaxial Consolidation-Undrained

Triaxial consolidated-undrained (CU) tests with pore pressure measurements were performed on selected undisturbed samples obtained from rotary-wash borings to determine the strength of the soils in accordance with ASTM D 4767. A three-stage load test method was used by testing the sample at three confining pressures. The results of the Triaxial CU tests are presented in Appendix F of Volume 3, Laboratory Test Results.

4.1.9 Unconfined Compression

Unconfined compression strength (UCS) tests were performed on selected undisturbed samples of siltstone bedrock of the Fernando Formation to determine the strength of the soils in accordance with ASTM D 2166. The results of the UCS tests are presented in Appendix F of Volume 3, Laboratory Test Results. The unconfined compression strength values (Q_u) are presented in Table 4-5.

Table 4-5: Unconfined Compression Strength Test Results

Boring No.	Sample Depth (feet)	Rock Description	Q_u (ksf)
G-105	85.5	Siltstone	16.4
	105.5	Siltstone	13.92
G-106	89.5	Siltstone	14.1
G-107	90.5	Siltstone (with calcium carbonate nodules)	18.34
G-109	70.5	Siltstone (poorly-cemented)	8.97
G-110	125.5	Siltstone (poorly-cemented)	14.3
G-111	105.5	Siltstone (poorly-cemented)	14.07
G-114	98.5	Siltstone (poorly-cemented)	8.68
G-118	82.5	Siltstone (with tar)	8.44
	88.5	Siltstone (with tar)	10.33
	100.5	Siltstone (with tar)	6.69
G-207	100	Siltstone (poorly-cemented)	10.82

4.1.10 Soil Abrasion

Soil abrasion testing (SAT) was performed on selected samples of predominately granular material collected from sonic core borings. Samples obtained from rotary-wash borings did not provide sufficient quantity of sample to perform abrasion testing. The soil abrasion tests were performed in accordance with the Norwegian University of Science and Technology (NTNU) test procedure by the rock mechanics laboratory at the University of Texas, Austin..

Test Procedure and Results

The SAT method was developed by the NTNU and the associated SINTEF organization as a modification of the Abrasion Value Steel (AVS) test. The purpose of the test is to quantify the abrasivity of soils in soft ground tunneling. The test consists of measuring the weight loss in a steel piece caused by soil grinding. Transported by a wheel that rotates at 20 revolutions per minute, the soil passes underneath the test piece, which is subject to one kilogram (about 2.5 pounds) of soil or rock. The SAT value is the weight loss in milligrams (e.g., SAT = 5 means that the steel test piece lost 5 milligrams (mg) after 20 revolutions. Therefore, a higher SAT value indicates that the soil or rock is more abrasive.

Based on the NTNU/SINTEF test database, a classification of abrasivity of soil and rock was developed by the University of Texas, Austin, as presented in Table 4-6, to provide guidance on evaluating the SAT test values.

Table 4-6: Classification of Abrasivity of Soil and Rock

Abrasivity Category	SAT Value
Extremely Low	< 1
Very Low	2 – 3
Low	4 – 12
Medium	13 – 25
High	26 – 35
Very High	36 – 44
Extremely High	> 45

A summary of the abrasion test results is presented in Table 4-7. The laboratory test sheets and additional details are presented in Appendix F of Volume 3, Laboratory Test Results.

Table 4-7: Abrasion Test Results

Boring No.	Depth (feet)	Soil Description	Geologic Formation	SAT Value
S-101	42.5-43.5	Clayey Sand (SC)	San Pedro (Qsp)	20
	53-54	Silty Sand (SM)	San Pedro (Qsp)	38
	60-61	Silty Sand (SM)	San Pedro (Qsp)	31
S-102	64-65	Silty Sand (SM)	San Pedro (Qsp)	25.5
	67-68	Poorly Graded Sand with Silt (SP-SM)	San Pedro (Qsp)	22.5
	71-72	P. G. Sand with Silt and Gravel (SP-SM)	San Pedro (Qsp)	31.5
S-103A	71-72	Silty Sand (SM)	San Pedro (Qsp)	21
	91-92	Siltstone	Fernando (Tf)	1.5
	96-97	Siltstone	Fernando (Tf)	2.5
	101-102	Siltstone	Fernando (Tf)	1.5
	113-114	Siltstone	Fernando (Tf)	2

Table 4-7: Abrasion Test Results (continued)

Boring No.	Depth (ft)	Soil Description	Geologic Formation	SAT Value
S-104	59.5-60.5	Poorly Graded Sand with Silt (SP-SM)	San Pedro (Qsp)	14.5
	64-65.5	Poorly Graded Sand with Silt (SP-SM)	San Pedro (Qsp)	28.4
	73-74	Poorly Graded Sand with Silt (SP-SM)	San Pedro (Qsp)	28.9
	81-82	Well Graded Sand w/Silt and Gravel (SW-SM)	San Pedro (Qsp)	35
S-105	96-97	Sandy Siltstone	Fernando (Tf)	6.5
S-106	45-46	Poorly Graded Sand with Silt (SP-SM)	San Pedro (Qsp)	31
	52-53	Silty Gravel with Sand (GM)	San Pedro (Qsp)	22
S-107	48-49	Silty Sand (SM)/Clayey Sand (SC)	San Pedro (Qsp)	9.4
	57-57.9	Well Graded Sand w/Silt and Gravel (SW-SM)	San Pedro (Qsp)	23.5
	64-65	Silty Clayey Sand (SC-SM)	San Pedro (Qsp)	5.9
S-108	69-70	Elastic Silt (MH)	Older Alluvium (Qalo)	2.5
	82-83	Fat Clay with Sand (CH)	Older Alluvium (Qalo)	5
	86-87	Clayey Sand with Gravel (SC)	Older Alluvium (Qalo)	8
	91-92	Silty Sand with Gravel (SM)	Older Alluvium (Qalo)	13.5
S-109	61-62	Sandy Lean Clay (CL)	Older Alluvium (Qalo)	3.6
	68-69	Sandy Lean Clay (CL)	Older Alluvium (Qalo)	1.6
	80-81	Clayey Sand (SC)	Older Alluvium (Qalo)	11.5
S-110	40.5-41.5	Sandy Silt (ML)/Silty Clayey Gravel with Sand (GC_GM)	Older Alluvium (Qalo)	10
	44-45	Lean Clay (CL)	Older Alluvium (Qalo)	5
	71-72	Silty Sand with Gravel (SM)	Older Alluvium (Qalo)	7
	81-82	Silty Sand (SM)	Older Alluvium (Qalo)	4.5
S-111	59-60	Silty Sand (SM)	Lakewood (Qlw)	25.5
	65-66	Poorly Graded Sand with Silt (SP-SM)	Lakewood (Qlw)	27.5
	59-60	Silty Sand (SM)	Lakewood (Qlw)	25.5
	78.5-79.5	Poorly Graded Gravel with Silt and Sand (GP-GM)	Lakewood (Qlw)	16
S-114	53-54	Sandy Lean Clay (CL)	Older Alluvium (Qalo)	8
	61-62	Silty Clay with Sand (CL)	Older Alluvium (Qalo)	8.2
	67-68	Sandy Silt with Gravel (ML)	Older Alluvium (Qalo)	38
S-115	62-63	Silty Gravel with Sand (GM)	Older Alluvium (Qalo)	10.5
	68-69	Sandy Silt (ML)	Older Alluvium (Qalo)	4
	89-90	Poorly Graded Gravel with Silt and Sand (GP-GM)	Older Alluvium (Qalo)	5.5
S-116	76-77	Siltstone (20% Tar)	Fernando (Tf)	2
	91-92	Siltstone (18% Tar)	Fernando (Tf)	5.5
S-117	64-65	Poorly Graded Sand (SP)	San Pedro (Qsp)	27
S-118	89-90	Siltstone (20% Tar)	Fernando (Tf)	4

Abrasion test results were also classified by formation and soil type (fine and coarse-grained) and the results are summarized in Table 4-8.

Table 4-8: Abrasion Test Results by Geologic Formations

Geologic Formation	Soil Type	Data Points	Median	Standard Deviation	Minimum	Maximum
Older Alluvium (Qalo)	Fine-Grained	9	4.0	2.7	1.6	8.2
	Coarse-Grained	8	10.3	3.7	4.5	16.0
Lakewood (Qlw)	Fine-Grained	1	4.0	*	4.0	4.0
	Coarse-Grained	3	25.5	1.2	25.5	27.5
San Pedro (Qsp)	Fine-Grained	**	**	**	**	**
	Coarse-Grained	18.0	24.5	9.5	5.5	38.0
Fernando (Tf)	Fine-Grained	7	2.0	2.0	1.5	6.5
	Coarse-Grained	**	**	**	**	**

* Only one data point, **No test data

4.1.11 Analytical Testing of Groundwater

Groundwater samples were collected from BAT® CPTs at locations CB-101 and C-119B for analytical testing to determine concentrations of dissolved VOCs, hydrogen sulfide (H_2S), and fixed gases in the water samples. The samples were stored in an ice chest and were transported to Orange Coast Analytical for testing. The results of the analytical testing are presented in Appendix F of Volume 3, Laboratory Test Results. The tests indicate that samples of groundwater collected at these locations are contaminated and would require treatment prior to disposal.

Water samples from groundwater monitoring wells installed in geotechnical borings were not collected because the percentage of dissolved gases in water samples could vary due to the nature of conventional water sampling.

A more comprehensive analytical testing of water samples was performed as part of the Gas Investigation and Phase II Environmental Site Assessment, as discussed in Sections 4.3 and 4.5, respectively.

4.1.12 Corrosion

To evaluate the potential for deleterious effects of the on-site soils on structural concrete and steel and on metal piping, chemical testing was performed on selected soil samples from rotary-wash and sonic core borings. The corrosion tests were performed by HDR-Schiff Associates. The results of the corrosion tests are presented in Appendix F of Volume 3, Laboratory Test Results.

The corrosion test results were reviewed for each station, and a separate report for each station summarizing the test results, conclusions regarding the corrosivity, and recommendations for mitigation procedures were prepared by HDR-Schiff Associates. The reports are included in Appendix F of Volume 3, Laboratory Test Results.

An evaluation of corrosion potential of soils within the tunnel zone was performed within each tunnel reach. The test results are presented in Section 11.

4.2 Fault Exploration Testing

No laboratory testing was performed for the PE phase. Carbon dating testing may still be performed as part of the Advanced Preliminary Engineering (APE) phase to evaluate rupture dates of the faults.

4.3 Subsurface Gas Exploration Testing

The samples of gas collected from soil gas wells were analyzed at a state-certified laboratory for hydrogen sulfide, methane, longer chain hydrocarbons (e.g. butane, propane, etc.), and fixed gases using standard EPA testing procedures. The results of these analyses are summarized in Table 3-9 while the associated laboratory analytical reports are provided in Appendix G of Volume 3.

Laboratory results for analysis of vapor samples for methane showed similar levels to the measurements taken in the field using hand-held instruments. For hydrogen sulfide, the concentrations reported by the fixed laboratory were much lower than those obtained in the field using handheld instruments (see Table 3-8). It is common for the laboratory sample analyses to be lower than a field measurement for hydrogen sulfide.

For testing of groundwater sampled from the soil gas wells, the sampling container remained under pressure until the analytical laboratory extracted the water for analysis through the quick-connect fittings. These groundwater samples were analyzed for dissolved methane, hydrogen sulfide, and other fixed gases using standard EPA analytical procedures. The testing results are summarized in Table 3-9, while the associated laboratory analytical reports are includes in Appendix G of Volume 3. The methane percentages for the extracted gas range from 12.5% (in M-107) to 59% (in M-102). No concentrations of hydrogen sulfide were detected in the extracted gas, because of the low solubility of hydrogen sulfide in water.

The results of analyses of groundwater samples collected from the PE phase wells are presented in Appendix G of Volume 3, Laboratory Test Results. These samples were sampled using a disposable Teflon bailer and were sampled as requested to determine water quality at or near the planned station areas from the existing gas monitoring wells. The only wells that yielded hydrogen sulfide concentrations from groundwater were M-102A and M-106B (at 0.027 and 0.046 mg/L, respectively). The only VOCs detected were bromomethane and dibromochloromethane at M-102B. Methane levels in groundwater samples were highest in the M-107A (shallow well) sample and the M-112B (deep well) sample (31.9 and 27.2milligrams per liter, respectively) with samples analyzed at the fixed laboratory (ATL laboratory) (see Table 3-9).

4.3.1 Conclusions

The results of methane and hydrogen sulfide analyses both in the field and from laboratory analyses indicate methane concentrations are highest near the intersection of Curson Avenue and Wilshire Boulevard, from 15 feet below ground surface to as deep as 100 feet (M-109). Methane concentrations at Fairfax Avenue are also elevated with concentrations of 85% at 45 feet at M-110 and at 40 feet at M-113. These concentrations should be considered during tunnel drilling (i.e., near M-109) and for design considerations of the Wilshire/Fairfax Station.

The presence of tar sands between South Ridgeley Drive and Fairfax Avenue limited the ability to place wells at depth (i.e., below 45 feet) at locations such as M-113 because tar sands are present down to approximately 110 feet bgs. In most cases, a well screened in the San Pedro Formation will eventually fill with oil (in some cases quite rapidly), so it was deemed best to avoid placing screens in zones with a high percentage of tar sands.

Methane along the alignment is generally less than 5% with the exception of the portion of the alignment west of Burnside Avenue and east of La Jolla Avenue, which coincides with the Methane Zone (Plates 1-22 through 1-28). The pressures along this zone are also elevated, although they appear to extend to a slightly smaller zone from Masselin Avenue to Crescent Heights Boulevard with pressures of greater than 150 inches of water at M-106 (Courtyard Place) to 20 inches at M-13 and 14 inches at M-114 (900 feet west of South Fairfax Avenue on Wilshire Boulevard) and 844 inches at M-7. The highest laboratory hydrogen sulfide gas readings were from M-104, M-106, M-108, and M-13 (Plates 1-22 through 1-28) with hydrogen sulfide readings of 47, 290, 38, and 3,600 ppm, respectively.

The gas readings in a profile view in the Farirfax area and Century City are illustrated on Plates 4-1 and 4-2. These figures illustrate the highest reading obtained from the wells by either the field measurements or the laboratory measurements.

4.4 Hydrogeologic Exploration Testing

Based on the analytical results performed by Advanced Technology Laboratories on the groundwater sample collected in well P-103 at the Westwood/UCLA Station, groundwater discharged at this location would require minimal or no treatment systems to meet pollutant limits for the NPDES permit and poses no significant threat to water quality. The analytical test report is attached in Appendix H of Volume 3, Laboratory Test Results.

4.5 Environmental Site Assessment Testing

The soil and groundwater samples collected during the Environmental Site Assessment field investigation were transported under standard chain-of-custody protocol and delivered to Advanced Technology Laboratories (ATL), a laboratory certified by the California Department of Public Health - Environmental Laboratory Accreditation Program and located in Signal Hill, California. Depending on the suspect source near which a boring was drilled, the soil and groundwater samples were analyzed for one or more of the following constituents:

- Total petroleum hydrocarbons as gasoline/diesel/oil (TPH-g/d/o) by EPA Method 8015B
- Volatile organic compounds and fuel oxygenates (VOCs+Oxy) by EPA Method 8260B
- Polynuclear aromatic hydrocarbons (PAHs) by EPA Method 8270C
- Title 22 metals by EPA Methods 6010B/7471A

The laboratory test results are presented in Table 3-16 in Section 3.6.3. A discussion of the test results is also presented in Section 3.6.3.

THIS PAGE INTENTIONALLY LEFT BLANK

5.0 PROJECT GEOLOGY

This section provides an overview of the geologic setting and the stratigraphic conditions, geologic structure, and groundwater conditions encountered along the alignment. Geologic hazards such as liquefaction, fault rupture, and tectonic deformation are presented. Naturally occurring tar and gases are discussed in prior sections.

Based on a review of the additional geotechnical rotary-wash boring data and sonic cores performed during this phase of the investigation, the distribution of geologic units and elevations of the geologic contacts between geologic units have been modified significantly at a few locations along the tunnel alignment, compared to the geologic profiles shown in the ACE phase study.

5.1 Geologic Setting of Study Area

The southern California region is comprised of several tectonomorphic provinces characterized by distinct structural fabrics and geomorphic elements. The 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 elongated 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 Santa Monica and Hollywood faults are considered the boundary between the two geomorphic provinces within the area of the alignment.

The alignment is located in the northern portion of the Los Angeles Basin, approximately 1 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 since the middle Miocene. The geologic time scale is shown in Figure 5-1 for reference.

The La Brea and Santa Monica plains comprise the primary geomorphic surfaces along the Project alignment. These two gently sloping alluvial surfaces extend from the Santa Monica Mountains to south of the alignment and were formed by accumulation of sediments that had been shed out from the mountain front over the course of the late Pleistocene epoch (Poland et al., 1959). This process was accelerated by tectonic uplift along the eastern portion of the Santa Monica Mountain range front, which has resulted in relatively high rates of erosion down-cutting in the mountain range. Repeated tectonic uplift and base level changes caused varying rates of channel incision and aggradations of sediments to areas of gentler topographic gradient. The net result of periodic tectonic uplift was the formation of alluvial surfaces at varying elevations and ages adjacent to the mountain front. Older alluvial surfaces are located at generally higher elevations with respect to younger surfaces due to tectonic uplift and also show greater dissection by stream channels.

Figure 5-1: Geologic Time Scale

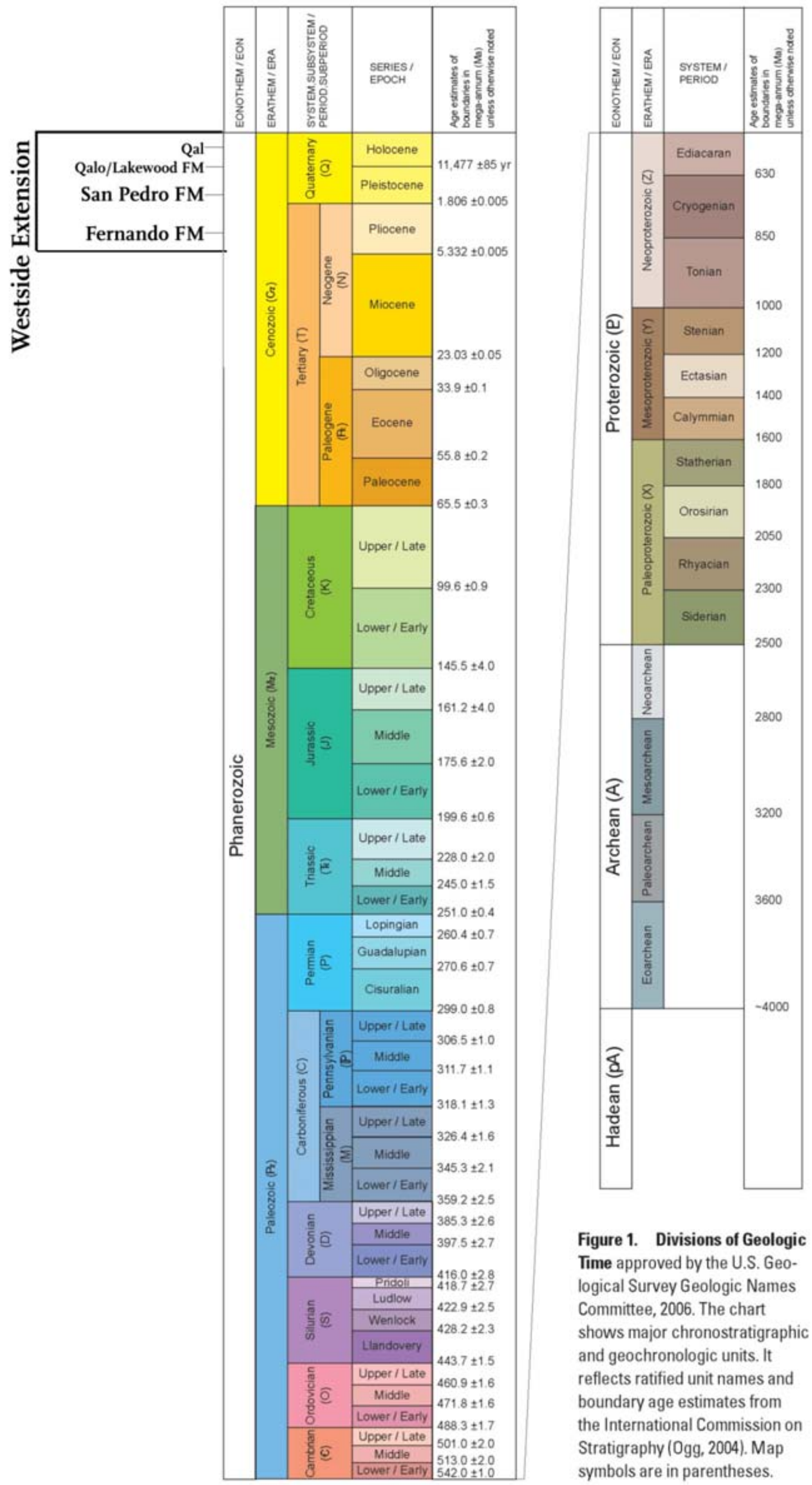


Figure 1. Divisions of Geologic Time approved by the U.S. Geological Survey Geologic Names Committee, 2006. The chart shows major chronostratigraphic and geochronologic units. It reflects ratified unit names and boundary age estimates from the International Commission on Stratigraphy (Ogg, 2004). Map symbols are in parentheses.

5.2 Overview of Stratigraphy

The tunnel and station excavations will encounter several geologic units that range in age from Miocene to Pleistocene. The geologic units that will be encountered in the tunnel excavation along the alignment, from oldest to youngest, are the Pliocene-age sedimentary strata of the Fernando Formation, Pleistocene-age San Pedro and Lakewood Formations, and Pleistocene-age (older) alluvium. The San Pedro and Fernando Formations would be encountered at variable depths in the subsurface beneath a variably thick section of Holocene and late Pleistocene sediments along the alignment. Holocene deposits will be encountered in the station excavations made using cut-and-cover methods.

The areal distribution of geologic units and major Quaternary faults in close proximity to the alignment is shown in Figure 5-2. This map was prepared by downloading GIS files of the Preliminary Geologic Map of the Los Angeles 30 Minute by 60 Minute Quadrangle from the U.S. Geological Survey (http://pubs.usgs.gov/of/2005/1019/) and the Digital Database of Quaternary and Younger Faults from the Fault Activity Map prepared by CGS (http://www.conrv.ca.gov/CGS/information/publications/Quaternary Faults ver2.htm). The digital files were then imported as layers onto the U.S. Geological Survey 7.5-minute topographic maps of the Hollywood and Beverly Hills Quadrangles.

Holocene and late Pleistocene-age sediments form the surficial cover along the study alignments. The Holocene-age materials, where present, are underlain by variably thick, older alluvial deposits of late Pleistocene age, which in turn are underlain by semi-consolidated continental and marine sediments of the late Pleistocene-age Lakewood Formation. The Lakewood Formation materials are underlain by sediments of the early Pleistocene-age San Pedro Formation. Tertiary-age sedimentary rock of the Fernando Formation underlies the Pleistocene sequence of sediments.

Older Alluvium, Lakewood Formation, and San Pedro Formation are anticipated to be the primary geologic units that will be encountered along the tunnel alignment. The current interpretation of the subsurface contacts between the geologic units along the study alignment is shown on the Geologic Plan and Profiles, Plates 1-1 through 1-21. These profiles were prepared from the current boring data in addition to data from core borings drilled as part of the following investigations:

- 2009, Advanced Conceptual Engineering (MACTEC, 2010)
- 1980-1981, Metro Rail Project Alignment (CWDD/ESA/GRC, 1981)
- Borings drilled for earlier Metro Rail geotechnical studies by Kaiser Engineers (1962)
- Numerous geotechnical borings drilled along or adjacent to the alignment over a period of many years by Woodward-Clyde Consultants and AMEC's predecessor companies LeRoy Crandall and Associates, Law/Crandall, and MACTEC Engineering and Consulting, Inc.

Pertinent sources of geotechnical data are presented in Section 13, References.

As part of the current studies, there has been a reinterpretation of the depth to the top of the San Pedro Formation. This reinterpretation was based on the additional borings, including the sonic core borings, which provided larger-diameter continuous samples, that allowed for more detailed stratigraphic interpretation.

The general lithologic compositions of the geologic units that are shown in the Geologic Profile along the alignment are presented in the following sections.

5.2.1 Younger Alluvium (Regional geologic map symbols: Qyf and Qf; Profile symbol: Qal)

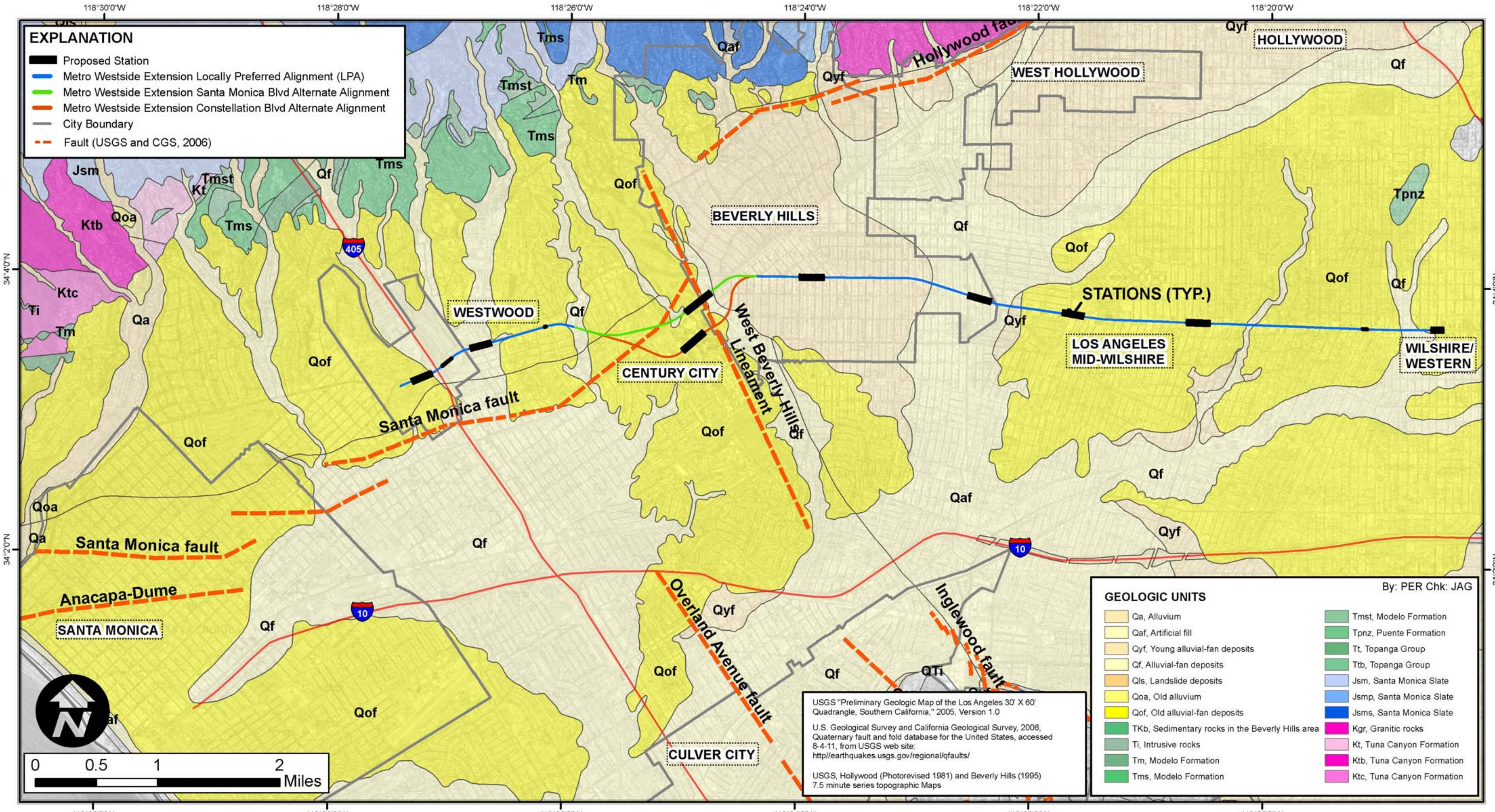
In the eastern portion of the alignment between Western and Fairfax Avenues, Holocene-age stream alluvium is present within two relatively narrow, south-flowing drainage courses that cross Wilshire Boulevard near Sycamore Avenue and between Houser Boulevard and Finley Avenue, respectively. The two drainage courses have incised into the Lakewood and San Pedro Formation, respectively, on an older alluvial surface and appear to flow southwesterly toward Ballona Creek. A local area of Younger Alluvium was encountered in a recent boring at Sycamore Avenue. Where encountered in exploratory borings along Wilshire Boulevard, the Younger Alluvium consisted of brown and dark brown poorly consolidated, interlayered silts, clays, and silty sands with some sand layers and some gravel. The thickness of the young alluvial deposits is estimated to be about 5 to 15 feet.

Broader swaths of Holocene alluvium are present between Lindbrook Drive and the San Diego Freeway in the West Los Angeles area. Other local drainages were encountered in the borings. In this area, the young alluvium was apparently deposited by alluvial fan processes and by streams of low to moderate energy. Most of the western half of the City of Beverly Hills is shown on geologic and geomorphic maps (CGS, 1998, Dolan et al., 2000; Bryant, 2005) to be underlain at the surface by Holocene-age alluvial fan deposits. As encountered in the borings, the composition of the alluvium in the younger fans consists predominantly of mixtures of brown, soft to stiff silts and clays with loose to medium dense silty and sandy to silty clays and clayey sand with subordinate layers and lenses of gravel sandy silt and gravelly sand. Boulders were not encountered in the Younger Alluvium in the borings along the alignment. The thickness of Holocene alluvium along the alignment in the central area of Beverly Hills is estimated to be about 5 to 40 feet. The regional geologic map, Figure 5-2, identifies the areas underlain by younger alluvial deposits with the symbols Qyf and Qf. The geologic profiles show the symbol Qal to indicate the younger alluvial deposits.

5.2.2 Older Alluvium (Regional geologic map symbol: Qof; Profile symbol: Qalo)

The older alluvial deposits consist of sediments deposited by former streams and sheet flow that had once flowed across the La Brea and Santa Monica Plains during late Pleistocene time. These deposits, derived mainly from the Santa Monica Mountains to the north, thicken to the south and west. They are only locally present east of Crescent Height Boulevard. They include channel and overbank deposits, alluvial fan deposits, and marine/estuarine deposits. Their composition ranges from brown and gray, loose to dense sands and gravels in stream channel deposits to predominant gray and brown to olive gray, medium stiff to hard silts and clays and gravelly silts and clays in the fan and overbank deposits. Although local channels with abundant to predominantly gravels are present, boulders were not encountered in the borings along the alignment. Locally in the clays and silts, hard carbonate deposits were occasionally observed. The Older Alluvium depositionally overlies marine and non-marine deposits of the late Pleistocene-age Lakewood Formation. The geologic profiles show the symbol Qalo to indicate the older alluvial deposits.

Figure 5-2: Regional Geologic Map



THIS PAGE INTENTIONALLY LEFT BLANK

5.2.3 Lakewood Formation (Profile symbol: Qlw)

The Lakewood Formation, as encountered in prior borings drilled along Wilshire Boulevard for the Metro Rail alignment (CWDD/ESA/GRC, 1981) and current borings for this investigation, generally consisted of interbedded yellow and brown to light to medium gray silty sands, poorly graded sands, silts, clays, with some clayey sand layers. Although layers of gravel and gravelly zones were encountered in borings, no boulders were encountered during the investigation. The Lakewood Formation is generally dense where granular and very stiff to hard where consisting primarily of silts and clays. Tar was encountered in the lower portion of this unit between Finley and Fairfax Avenues. The geologic profiles show the symbol Qlw to indicate the Lakewood Formation.

5.2.4 San Pedro Formation (Regional geologic map and profile symbol: Qsp)

Primarily marine deposits of the early to mid-Pleistocene age San Pedro Formation unconformably underlie the Older Alluvium and the Lakewood Formation at variable depths below the alignment based on current borings, prior borings drilled along and near the alignment, and water and oil well data. Where encountered in current and prior borings, these materials consisted primarily of light to dark greenish-gray and bluish-gray, fine-grained dense sand and silty sand with interbeds of medium- to course-grained sand and stiff to hard silt layers. Gravelly sand layers and shell fragments at the base of the formation (at the contact with the underlying Fernando Formation) have been reported locally in prior core borings drilled for Metro Rail alignment near the intersection of Wilshire Boulevard and Western Avenue and near the intersection of Wilshire Boulevard and Crenshaw Boulevard (CWDD/ESA/GRC, 1981) and were encountered within the formation elsewhere along the alignment. Concretionary deposits and strongly cemented zones, with strength characteristics similar to that of boulders, were encountered in borings in the San Pedro Formation along the tunnel alignment. Concretionary zones are typically lensoidal and discontinuous, whereas cemented zones are typically more laterally continuous. Current borings drilled for the alignment in some locations encountered San Pedro Formation grading upward to finer layers and lenses of silt and silty clay. Some of the stratigraphic layers contain relatively thick calcium carbonate horizons. Tar was encountered in the San Pedro Formation in borings drilled between Dunsmuir and La Jolla Avenues. The geologic profiles show the symbol Qsp to indicate the San Pedro Formation.

5.2.5 Fernando Formation (Profile symbol: Qf)

Sedimentary bedrock of the Pliocene Fernando Formation unconformably underlies the San Pedro Formation at variable depths along the entire length of the alignment. However, based on current and prior boring data, the contact depth increases significantly west of Fairfax Avenue and was not encountered in the borings. The Fernando Formation where encountered in the prior and current borings along the tunnel alignment consists predominantly of massive, stiff to hard yellow-brown to olive-gray siltstone and claystone with few to rare thin sandstone interbeds. Locally, a thick interval of massive silty sandstone was encountered in core boring CEG-19, located on Wilshire Boulevard at Curson Avenue (CWDD/ESA/GRC, 1981). Concretionary deposits that have strength characteristics similar to that of boulders were locally encountered in borings in the Fernando Formation along the tunnel alignment. Concretionary zones are typically lensoidal and discontinuous.

Petroleum geologists assigned the early Pliocene-age rocks in the northern Los Angeles basin to the Repetto Formation and the late Pliocene rocks to the Pico Formation. This age division was based on major foraminiferal (single celled, primarily marine organisms) assemblages. However, prior geotechnical investigations along the alignment have followed the use of one formational name, Fernando Formation for the Pliocene section. Usage of the Fernando Formation name is consistent with the formation nomenclature shown by D. Lamar (1970) in his geologic map of the Elysian Park-Repetto Hills area, located northeast of the alignment area. The geologic profiles show the symbol Tf to indicate the Fernando Formation.

5.3 Geologic Structure

The geologic profiles along the alignment are shown on Plates 1-01 through 1-21. Geologic data used in preparation of the geologic profiles are from the following sources: geotechnical borings for the current investigation in 2011, borings drilled for the ACE study in 2009, rotary core borings drilled in 1980-1981 for Metro Rail (CWDD/ESA/GRC, 1981), and borings from earlier Metro Rail studies by Kaiser Engineers (1962). These geologic data sources were supplemented by numerous geotechnical borings drilled along or adjacent to the tunnel alignment over many years by the consulting firms of Woodward-Clyde Consultants, LeRoy Crandall and Associates, Law/Crandall, and MACTEC Engineering and Consulting, Inc. Pertinent sources of geotechnical data are listed in Section 14, References.

Geologic structure encompasses the contacts between the various geologic units, bedding within the geologic units, and faults. Details of the faults adjacent to the alignments are presented in Section 5.5. Geologic contacts of the units are shown on the Geologic Profiles. Measurements of stratification and bedding plane dip angles were made in the prior rotary core borings by CWDD/ESA/GRC in 1981 and noted where present in the current borings. Stratification, where noted on the prior boring logs, was primarily horizontal in the Older Alluvium and Lakewood Formation, from horizontal to about 15 degrees in the San Pedro Formation, and ranged from approximately 20 to 45 degrees in the Fernando Formation. The strike of the bedding was not determined since oriented core samples and borehole acoustic televiewer data were not collected. However, projection of geologic structure from the southeastern edge of the Elysian Hills suggests that the tunnel alignment is located on the southern flank of the west to northwest-trending Los Angeles Anticline. Based on this structural projection, it is inferred that the strike of the bedding is oriented in a general east to west direction and the bedding dips to the south.

5.4 Groundwater

The alignment passes through two of the four main hydrogeologic basins of the coastal plain of Los Angeles County. The alignment lies within the Central Basin from the eastern end to about the western city limits of Beverly Hills. The western portion of the alignment lies within the Santa Monica Basin. The Newport-Inglewood fault zone separates the two basins south of Beverly Hills (DWR, 1961).

Groundwater in the Central Basin occurs within several aquifers of the Lakewood and San Pedro Formations. The aquifers consist generally of permeable sands and gravels separated by semi-permeable to impermeable sandy clay to clay. The relatively shallow groundwater within the recent and/or Older Alluvium has been reported as semi-perched (DWR, 1961) or perched (CWDD/ESA/GRC, 1981). The Santa Monica Basin underlies the western portion of the alignment from the western portion of Beverly Hills to the Pacific Ocean. The Santa Monica, Charnock, and Overland faults subdivide the Santa Monica Basin into five sub-basins (DWR, 2004; MWD, 2007). These faults act as barriers to groundwater flow at depth (Poland, 1959, DWR, 1961). Groundwater occurrence in the Santa Monica Basin is generally confined with some areas that are unconfined or perched (MWD, 2007B).

Groundwater level depths measured in observation wells, overnight readings measured in soil borings, and depths measured during drilling of borings in ACE and PE phase explorations are presented in Boring Plan and Geologic Profiles Plates 1-01 through 1-21.

Groundwater levels measured along the alignment are described below for different segments from east to west. Exploratory borings drilled along Wilshire Boulevard between Western and Fairfax Avenues for the Metro Rail project from 1980 to 1981 encountered shallow groundwater, probably perched, between approximately 10 to 35 feet bgs as reported in CWDD/ESA/GRC (1981).

Groundwater level measurements in more recent ACE and PE monitoring wells ranged from approximately 15 feet to 45 feet bgs in the tunnel section reach between Western Avenue and the Wilshire/La Brea Station. Groundwater measurements from multi-level monitoring well/vapor probes along the alignment between Crenshaw Boulevard and Burnside Avenue collected in September 2007 indicate groundwater levels ranged between approximately 12 to 40 feet bgs (TRC, 2007). The groundwater levels along this portion of the alignment are similar to those encountered in the Metro Rail exploratory borings that were drilled in 1980 to 1981. The majority of the individual wells monitored in September 2007 exhibited different groundwater levels for each of the shallow and deep screened intervals suggesting perched or possibly, semi-confined groundwater.

In the tunnel section between the Wilshire/La Brea and Wilshire/Fairfax Stations, groundwater-level measurements in the ACE and PE phase monitoring wells ranged from approximately 10 feet to 90 feet bgs. In monitoring wells that were constructed with dual screen intervals for the ACE and PE studies between Masselin Avenue and the Wilshire/Fairfax Station, two different water levels corresponding to the two screened intervals were measured in all but one location. The difference generally ranged from about 12 to 25 feet in groundwater level elevation between the upper and lower screened interval in these dual screened monitoring wells along this tunnel section. This suggests probable perched groundwater as a reason for the difference in groundwater elevations.

Locally, groundwater as shallow as 5 to 10 feet bgs has been reported in prior borings drilled on Wilshire Boulevard between Curson and Orange Grove Avenues (LeRoy Crandall and Associates, 1983). A groundwater-level contour map of the Hollywood Quadrangle, showing the historically highest groundwater levels (CDMG, 1998), indicates groundwater depths ranged from historic highs of 10 to 20 feet bgs along this portion of the tunnel alignment. Groundwater measurements in shallow screened ACE and PE phase monitoring wells in this area ranged from 1 to 33 feet bgs. A review of historical groundwater contour maps indicate that a portion of the alignment is located near a historic artesian area delineated by Mendenhall (1905).

In the tunnel section west of the Wilshire/Fairfax Station to the Wilshire/La Cienega Station, groundwater-level measurements in the ACE and PE phase monitoring wells ranged from approximately 32 feet to 59 feet bgs. Groundwater-level measurements in the ACE and PE phase borings drilled at the Wilshire/La Cienega Station ranged from about 20 to 30 feet bgs. Groundwater-level measurements in borings may not represent static levels.

Groundwater-level measurements in the ACE and PE phase monitoring wells located in the tunnel section between the Wilshire/La Cienega and Wilshire/Rodeo Stations ranged from approximately

25 feet to 50 feet bgs. The depth to groundwater level, as measured in the ACE and PE monitoring wells, appears to generally increase (lower groundwater elevation) westward along this tunnel section.

Groundwater-level measurements in the ACE and PE phase borings drilled between the Wilshire/Rodeo and Century City Constellation Stations generally ranged from about 25 to 45 feet bgs. Two dual screened monitoring wells were installed at Beverly Hills High School; two different water levels in each of the wells corresponding to the two screened intervals were measured. The difference was about 20 to 35 feet in groundwater-level elevation between the upper and lower screened interval in these dual-screened monitoring wells, which suggests probable perched groundwater conditions. The boring for monitoring well M-119 installed at the Century City Constellation Station encountered groundwater seepage at a depth of 35 feet bgs when it was drilled, however it was dry when measured in May 2011. Variations in groundwater levels in this area are likely influenced by stratigraphic and lithologic differences related to depositional variations and faulting. Groundwater was rarely encountered west of the West Beverly Hills Lineament and south of the Santa Monica fault zone along the alignment.

Groundwater levels in geotechnical and fault investigation borings along Santa Monica Boulevard ranged from 20 to 50 feet bgs. Groundwater levels in the vicinity of the Santa Monica fault zone were generally around 20 feet bgs. Artesian groundwater conditions were encountered in Monitoring Well G-174A, located near the intersection of Santa Monica Boulevard and Fox Hills West in the vicinity of the Santa Monica fault zone. The groundwater depth was measured near the ground surface in this well. Borings for the fault investigation along Century Park West north of the Santa Monica fault zone encountered groundwater as shallow as 5 feet bgs, whereas groundwater was generally not encountered in borings south of the fault zone. Deep excavations for some office structures south of Santa Monica Boulevard in the Century City area encountered rare groundwater inflows. The occurrence of groundwater in this area is most likely influenced by stratigraphic differences related to depositional variations and faulting.

In the tunnel section beneath the Westwood Hills area, between Santa Monica and Wilshire Boulevards, depth to groundwater-level measurements in the ACE borings ranged from about 30 to 40 feet bgs. Groundwater-level measurements in borings may not represent static levels. In the Westwood area, the depth to groundwater-level in January, 2011 was measured at about 35 feet bgs in Monitoring Well G-179, located between Selby and Manning Avenues. Monitoring well G-186 was installed at the western portion of the Westwood Station during the ACE investigation. The depth to groundwater level in this well was measured at about 48 feet bgs in June 2011. Monitoring Well G-203 was installed at the Westwood/VA Hospital Station during the ACE investigation. The depth to groundwater level in this well was measured at about 71 feet bgs in June 2011.

Shallow groundwater levels are influenced by seasonal rainfall and infiltration in addition to possible nearby groundwater extraction. Consequently, groundwater-level measurements at a well made on one date do not capture longer term groundwater fluctuations.

5.5 Geologic/Seismic Hazards

5.5.1 Faults

The numerous faults in Southern California include active, potentially active, and inactive faults. The criteria for these major groups were developed by the California Geological Survey (previously the California Division of Mines and Geology) for the Alquist-Priolo Earthquake Fault Zoning Program (Hart, 1999). By definition, an active fault is one that has had surface displacement within Holocene time (about the last 11,000 years). A potentially active fault is a fault that has demonstrated surface displacement of Quaternary age deposits (last 1.6 million years). Inactive faults have not moved in the last 1.6 million years. Active and potentially active faults that are located within 5 miles of the alignment are discussed below with respect to their known recency of displacement and location relative to the alignment.

5.5.1.1 Active Faults

Santa Monica Fault

The 25-mile-long Santa Monica fault zone extends westward from the western edge of Beverly Hills across West Los Angeles and Santa Monica to Pacific Palisades where it trends offshore and parallels the Malibu coast to near Point Dume (Dolan and Sieh, 1992; Dolan et al., 1995; 2000a). The fault zone, which exhibits both reverse and left-lateral components of slip, extends eastward as the Hollywood Fault through a ¾-mile-wide left-step, or tear fault, which coincides with the northern part of the West Beverly Hills Lineament (WBHL) (Dolan and Sieh, 1992; Dolan et al., 1997; 2000a). The Santa Monica and Hollywood fault zones are part of a much longer system of oblique left-lateral/reverse faults forming the southern boundary of the Transverse Ranges that extend eastward for more than 150 miles through the northern part of the Los Angeles metropolitan region and to the west offshore (Dolan et al., 2000a).

The Santa Monica fault system is related to the Pliocene-Quaternary structural development of the Santa Monica Mountains. Prior to the late Miocene, the Santa Monica Fault was a normal fault that was reactivated as a reverse fault beginning in the Pliocene (Tsutsumi et al., 2001). In the Century City area, Tsutsumi et al. interpreted the Santa Monica fault zone to consist of three southern strands and one northern strand with only the northern strand being currently active. Other recent studies (Dolan et al., 2000a; Dolan and Pratt, 1997; Hummon et al., 1992, Ziony et al., 1985) indicate that the northern segment of the Santa Monica fault zone is active and offsets or deforms Holocene sediments.

A prominent, north-side-up topographic scarp that can be traced continuously from the eastern end of the fault zone in Century City to Pacific Palisades, where the fault zone extends offshore, marks the active strands of the Santa Monica fault zone through Century City, West Los Angeles, and Santa Monica. This topographic scarp provides the most definitive evidence for the location of the active strands of the Santa Monica fault zone.

Urbanization within west Los Angeles has limited the number of places the Santa Monica fault zone might be studied in detail to determine the locations of the active strands and, in turn, the fault's recent earthquake history. However, despite the dense development along the Santa Monica fault zone, the geomorphic signature of recent surface faulting, particularly the prominent scarp marking the active traces of the Santa Monica fault zone, is surprisingly well preserved (Dolan, et al., 2000a).

Dolan et al. (2000a) conducted the most detailed studies of the state of activity of the Santa Monica fault zone on the grounds of the VA property just west of the San Diego Freeway, about 1,000 feet south of the proposed Westwood/VA Hospital Station. Trenches revealed a complex zone of faulting that showed evidence for both contractional folding and reverse slip above a north-dipping thrust strand, as well as faulting on dozens of near-vertical, left-lateral strike-slip fault strands that merge downward with the main strand at a depth of 100 to 150 feet (Dolan and Pratt, 1997; Pratt et al., 1998). The total width of this complicated zone of faulting was more than 300 feet.

Dating based on carbon from offset layers indicated definitive evidence for surface rupture on some of these faults between 10,000 and 17,000 years ago, as well as probable evidence for surface rupture on another strike-slip strand between approximately 1,000 and 3,000 years ago, consistent with evidence for slip on the main strand in the most recent earthquake approximately 1,000 to 3,000 years before present.

A fault study has been conducted to evaluate the potential for active faults intersecting the Century City station options and tunnel alignments along Santa Monica and Constellation Boulevards. The investigation included 56 continuous core borings and 192 CPT soundings along 7 transects, and 5 geophysical seismic reflection lines along the same 7 transects, consolidated into the 5 seismic lines. A separate report provides a detailed description of the findings and backup data (Metro, 2011). A summary of the main findings is presented in Section 7.0.

The Santa Monica fault zone is clearly identified in the northern portions of two of the northwest-southeast trending fault investigation transects. The northern major fault traces are in Santa Monica Boulevard and are coincident and slightly south of the geomorphic scarp. In the vicinity of Avenue of the Stars, the major traces splay, crossing through Santa Monica Boulevard and subparallelling the geomorphic scarp.

Major northeast-southwest trending faults have been identified south of Santa Monica Boulevard. There is significant apparent vertical offset of formations and alluvial fan/estuarine units across these fault traces, although with an apparent opposite sense of movement from the current tectonic framework. They trend subparallel to the fault traces identified to the north; however, they do not have geomorphic expression. Where the active traces diverge to the northeast, these faults continue parallel and south of Santa Monica Boulevard. The faulted strata are mid- to late-Quaternary, probably on the order of several hundred thousand years old to at least 100,000 years old. Holocene sediments have not been identified in the borehole cores of the fault study, so it has not been possible to preclude that theses fault traces are Holocene active.

Hollywood Fault

The active Hollywood fault, trends approximately east-west along the base of the Santa Monica Mountains from the West Beverly Hills Lineament in the West Hollywood-Beverly Hills area (Dolan et al., 2000b and Dolan and Sieh, 1992) to the Los Feliz area of Los Angeles. Studies by several investigators (Dolan et al., 2000b; Dolan et al., 1997; Dolan and Sieh, 1992; Crook and Proctor, 1992) have indicated that the fault is active, based on geomorphic evidence, stratigraphic correlation between exploratory borings, and fault trenching studies. Additionally, the fault is considered active by the State Geologist.

The location of the Hollywood fault zone in the Hollywood area was identified during prior fault investigations (Earth Technology, 1993) for the Metro Red Line Project at La Brea Avenue and

Camino Palmero, north of Franklin Avenue. Geologic profiles developed from continuous core borings drilled for the prior fault investigation revealed a wide zone of stratigraphic offsets of alluvial sediments overlying granitic bedrock along the La Brea Avenue and Camino Palmero transects. Groundwater elevation changes on the order of 40 to 50 feet across the fault were also reported by Earth Technology (1993). Groundwater was encountered at depths ranging from about 45 to 55 feet bgs north of the main fault zone and at least 90 feet bgs south of the main fault zone (Earth Technology, 1993). This demonstrates that the fault zone is a barrier to the southward flow of groundwater.

Recent studies by several investigators (Dolan et al., 2000b; Dolan et al., 1997; Dolan and Sieh, 1992; Crook and Proctor, 1992) have indicated that the fault is active based on geomorphic evidence, stratigraphic correlation between exploratory borings, and fault trenching studies. Dolan et al. (1997) evaluated geomorphic elements apparent in the 1926 and 1934 editions of the U.S. Geological Survey topographic map of the Hollywood and Sawtelle Quadrangles. These older edition topographic maps have 5-foot contours allowing for greater resolution of possible topographic scarps and other geomorphic features. Locations of topographic scarps identified by Dolan et al (1997) in the topographic map were then field checked to see whether they may have been related to cultural modifications rather than geologic processes. Their interpretation was illustrated in a tectonic geomorphology map of landforms in the northern portion of the Hollywood and Sawtelle Quadrangles.

Newport-Inglewood Fault Zone

The active Inglewood fault of the Newport-Inglewood fault zone is approximately 2.9 miles south to southeast of the Project alignment. This fault zone is composed of a series of discontinuous northwest-trending en echelon faults extending from Ballona Gap southeastward to the area offshore of Newport Beach. This zone is reflected at the surface by a line of geomorphically young anticlinal hills and mesas formed by the folding and faulting of a thick sequence of Pleistocene-age sediments and Tertiary-age sedimentary rocks (Barrows, 1974). In 1933, the southern Los Angeles Basin section of the Newport-Inglewood fault zone ruptured to produce the M6.4 Long Beach earthquake (Hauksson and Gross, 1991). Fault-plane solutions for 39 small earthquakes (between 1977 and 1985) show mostly strike-slip faulting with some reverse faulting along the north segment (north of Dominguez Hills) and some normal faulting along the south segment (south of Dominguez Hills to Newport Beach) (Hauksson, 1987). Recent investigations by Law/Crandall (1993) in the Huntington Beach area indicate that the North Branch segment of the Newport-Inglewood fault zone offsets Holocene-age alluvial deposits in the vicinity of the Santa Ana River.

West Beverly Hills Lineament

The West Beverly Hills Lineament (WBHL) is a north-northwest-trending topographic feature that appears to cross Santa Monica Boulevard in the vicinity of South Moreno Drive. The WBHL marks a pronounced boundary between uplifted and highly dissected older sedimentary units to the west and a gently sloping, younger alluvial plain in Beverly Hills to the east. Identified by Dolan and Sieh (1992) and Dolan et al. (1997; 2000a) on the basis of this pronounced topographic dissimilarity, the lineament exhibits a semi-continuous series of east-facing topographic scarps. These scarps have been eroded and modified by the south-flowing drainage emanating from Benedict Canyon.

Various tectonic interpretations have been proposed for the WBHL. In the absence of previous fault subsurface exploration, the location and characteristics of the WBHL, including whether it is a fault zone, was not well defined. To the north of its intersection with the Santa Monica fault zone, the WBHL acts as a connection between the Santa Monica and Hollywood fault zones, transferring slip between these two oblique-slip fault systems (Dolan and Sieh, 1992; Dolan et al., 1997; 2000a). Dolan et al. (1997) speculated that it might represent an east-dipping normal fault associated with extension along the left step between these faults. To the south of its intersection with the Santa Monica fault zone, Dolan and Sieh (1992) and Dolan et al. (1997; 2000a) considered the WBHL to be the northern continuation of the active Newport-Inglewood fault zone located approximately 3 miles to the south-southeast.

The fault study regarding the Santa Monica fault (as discussed above) also evaluated the WBHL. A summary of the main findings is presented in Section 7.0.

Northwest-southeast faulting was identified in three of the fault transects. Fault traces were projected between the transects and were projected southward where evidence of faulting was observed from geotechnical borings. Taken together, the observations document the presence of a north-northwest-trending zone of late-Quaternary faulting and folding along the WBHL that extends through Santa Monica Boulevard.

The Newport-Inglewood fault zone is composed of a series of discontinuous, northwest-trending *en echelon* faults and pressure ridges extending from the Baldwin Hills southeastward to Newport Beach and continuing offshore to the south (Barrows, 1974). Based on its orientation and location, the WBHL is considered to be the northern extension of the Newport-Inglewood fault zone. By virtue of its assumed connection to the active Newport-Inglewood fault zone, the WBHL is now considered by the CGS to be an active fault (Bryant, 2005).

5.5.1.2 Blind Thrust Faults

Several deep, low-angle blind thrust faults underlie the Los Angeles Basin. These faults are not exposed at the ground surface and do not pose a ground rupture hazard. However, these faults are active features capable of generating future earthquakes. The blind thrust faults postulated to exist within 10 miles of the alignment are included in the following discussion.

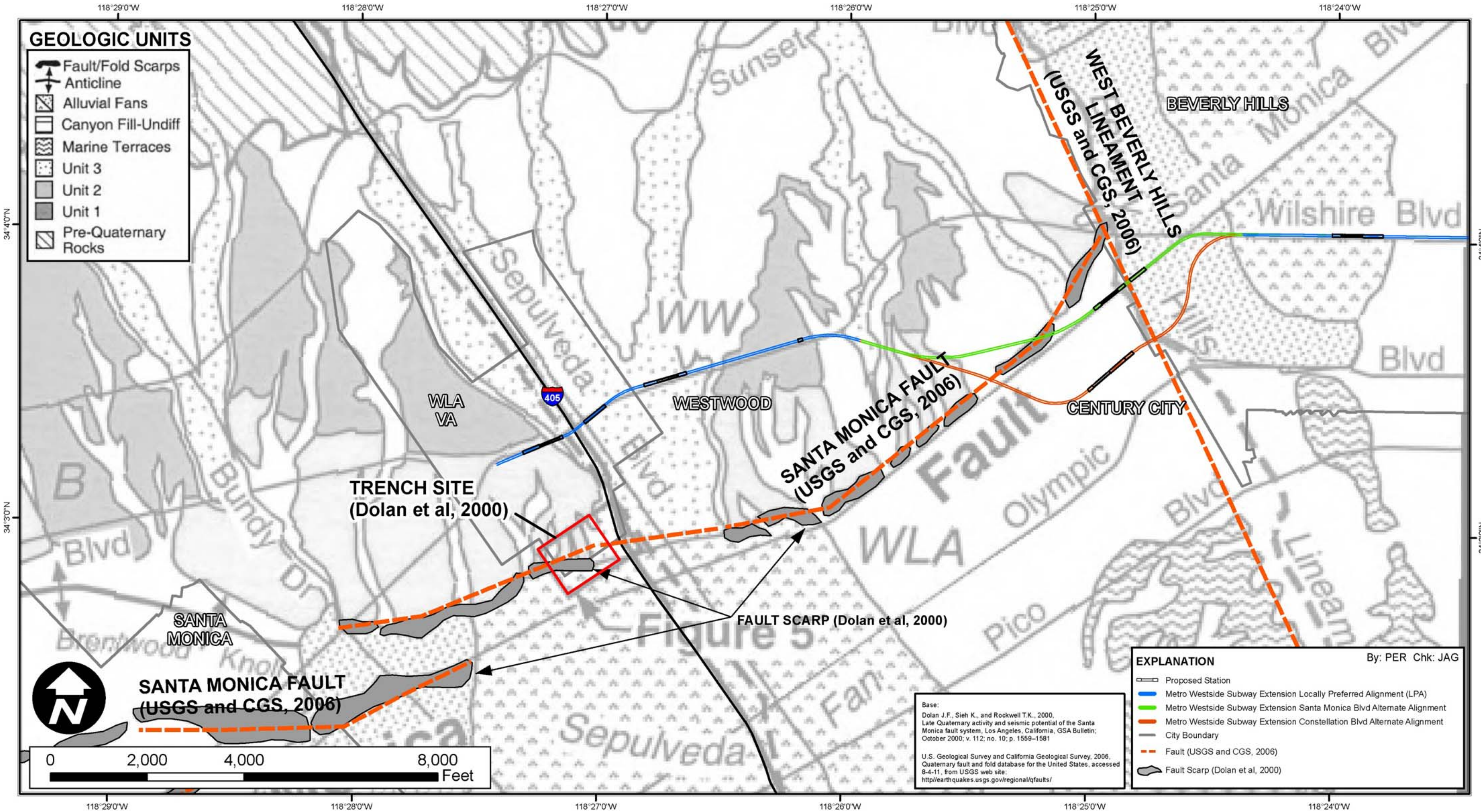
Elysian Park Thrust

The Elysian Thrust, originally defined by Hauksson (1990) as the Elysian Park Fold and Thrust Belt, was postulated to extend northwesterly from the Santa Ana Mountains to the Santa Monica Mountains, extending westerly and paralleling the Santa Monica-Hollywood and Malibu Coast faults. The Elysian Park Thrust is now believed to be smaller in size, only underlying the central Los Angeles Basin (Petersen et al., 1996). The Elysian Park Thrust, projected vertically to the ground surface, is approximately 4.5 miles east-southeast of the Project alignment at its closest point. As with other blind thrust faults in the Los Angeles area, the Elysian Park Thrust is not exposed at the surface and does not present a potential surface rupture hazard; however, the Elysian Park Thrust should be considered an active feature capable of generating future earthquakes. An average slip rate of 1.5 mm/yr and a maximum magnitude of 6.7 are estimated by Petersen et al. (1996) for the Elysian Park Thrust.

Puente Hills Thrust

The Puente Hills Blind-Thrust (PHT) fault system is defined based on seismic reflection profiles, petroleum well data and precisely located seismicity (Shaw et. al., 2002). This blind-thrust fault

Figure 5-3: Santa Monica Fault Zone



THIS PAGE INTENTIONALLY LEFT BLANK

system extends eastward from downtown Los Angeles to Brea in northern Orange County and overlies the Elysian Park Thrust. The PHT includes three north-dipping segments that are overlain by folds expressed at the surface as the Montebello Hills, the Santa Fe Springs Anticline, and the Coyote Hills. The PHT is believed to be the causative fault of the October 1, 1987, Whittier Narrows Earthquake (ML 5.9) [(Shaw et al., 2002)]. The vertical surface projection of PHT is approximately 6 miles east of the Project alignment at its closest point. Postulated earthquake scenarios for the PHT include single segment fault ruptures capable of producing an earthquake of magnitude 6.6 (Mw) and a multiple segment fault rupture capable of producing an earthquake of magnitude 7.1 (Mw). The PHT is not exposed at the ground surface and does not present a potential for surface fault rupture. However, based on deformation of late Quaternary-age sediments above this fault system and the occurrence of the Whittier Narrows earthquake, the PHT is considered an active fault capable of generating future earthquakes beneath the Los Angeles Basin.

5.5.1.3 Potentially Active Faults

The closest potentially active faults to the alignment are the Overland fault, the Charnock fault, and the MacArthur Park fault located approximately 2 miles south, 4 miles south, and 5 miles east-northeast of the Project alignment, respectively. Other nearby potentially active faults include the Coyote Pass fault and the Northridge Hills fault located about 12 miles east and 12 miles north-northwest of the Project alignment, respectively. The potentially active faults located within 10 miles of the alignment are discussed in the following section.

Overland Fault

The potentially active Overland fault is located approximately 2 miles south of the alignment. The Overland fault trends in a northwest direction between the Charnock fault and the Newport-Inglewood fault zone. The fault extends from the northwest flank of the Baldwin Hills to Santa Monica Boulevard in the vicinity of Overland Avenue. Based on water-level measurements, displacement along the fault is believed to be vertical, with an offset of about 30 feet (Poland, 1959). The west side of the fault has apparently moved downward, relative to the east side, forming a graben (up thrust block) between the Charnock and Overland faults. However, there is no evidence that this fault has offset late Pleistocene or Holocene-age alluvial deposits (County of Los Angeles Seismic Safety Element, 1990). Ziony and Jones (1989) indicate that the fault is potentially active (no displacement of Holocene-age alluvium). Additionally, the State Geologist considers the Overland fault to be potentially active (Jennings, 1994, 2010).

Charnock Fault

The potentially active Charnock fault is located approximately 4 miles south of the Project alignment. The Charnock fault trends in a northwest-southeast direction sub-parallel to the trend of the Newport-Inglewood fault zone and the Overland fault. Differential water levels across the fault occur in the early Pleistocene-age San Pedro Formation. However, there is no evidence that this fault has offset late Pleistocene- or Holocene-age alluvial deposits (County of Los Angeles Seismic Safety Element, 1990). Ziony and Jones (1989) indicate that the fault is potentially active (no displacement of Holocene-age alluvium). Additionally, the State Geologist considers the Overland fault to be potentially active (Jennings, 1994, 2010).

MacArthur Park Fault

The MacArthur Park fault is located approximately 5.5 miles east-northeast of the Project alignment. The fault, recently inferred west of downtown Los Angeles, has been located based on south-facing scarps, truncated drainages, and other geomorphic features (Dolan and Sieh, 1993). The fault is approximately 5 miles long, extending northwest from the Pershing Square area near downtown Los Angeles, through MacArthur Park to the Paramount Studios area in Hollywood. Current information suggests the fault is potentially active.

5.5.2 Seismicity

The seismicity of the region surrounding the alignment was determined from research of an electronic database of seismic data (Southern California Seismographic Network, 2010). This database includes earthquake data compiled by the California Institute of Technology from 1932 through 2010 and data from 1812 to 1931 compiled by Richter and the U.S. National Oceanic Atmospheric Administration (NOAA). The search for earthquakes that occurred within 60 kilometers of the east and west terminus of the tunnel indicates that up to 336 earthquakes of Richter magnitude 4.0 and greater occurred from 1932 through 2010; 0 earthquakes of estimated magnitude 6.0 or greater occurred between 1906 and 1931; and 0 earthquakes of estimated magnitude 7.0 or greater occurred between 1812 and 1905.

5.5.3 Historic Earthquakes

A partial list of these earthquakes, including the magnitude of the earthquake and the distance of the epicenter, is included in Table 5-1 and Table 5-2. Note that historic earthquakes with magnitudes greater than 5.5 are only shown in the tables. The list of the historic earthquakes is limited to the earthquakes within 60 kilometers of the east and west terminus of the tunnel alignment.

Table 5-1: List of Historic Earthquakes with Magnitude greater than 5.5 (Within last 150 years and within 60 Km of the west terminus of tunnel alignment)

Earthquakes (Oldest to Youngest)	Date of Earthquake	Magnitude	Distance to Epicenter (Kilometers)	Direction to Epicenter
Long Beach	March 11, 1933	6.4	56	SE
San Fernando	February 9, 1971	6.6	40	N
Whittier Narrows	October 1, 1987	5.9	35	ESE
Sierra Madre	June 28, 1991	5.8	38	NE
Northridge	January 17, 1994	6.7	20	NW

Table 5-2: List of Historic Earthquakes with Magnitude greater 5.5 (Within last 150 years and within 60 Km of the east terminus of tunnel alignment)

Earthquakes (Oldest to Youngest)	Date of Earthquake	Magnitude	Distance to Epicenter (Kilometers)	Direction to Epicenter
Long Beach	March 11, 1933	6.4	48	SE
San Fernando	February 9, 1971	6.6	40	N
Whittier Narrows	October 1, 1987	5.9	21	ESE
Sierra Madre	June 28, 1991	5.8	27	NE

Northridge	January 17, 1994	6.7	27	NW

5.5.4 Liquefaction

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. Significant damage to roads, utilities, pipelines, and buildings that occurred during the 1971 San Fernando and 1994 Northridge earthquakes was caused by liquefaction-induced ground displacement. Localities most susceptible to liquefaction-induced ground displacement are underlain by loose, water-saturated granular sediment within 50 feet of the ground surface. Liquefaction susceptibility generally decreases as the percentage of clay size particles in the soil increases. In areas within the alignments, sediments susceptible to liquefaction comprise the young (Holocene to late Holocene age) alluvial fan deposits and young (Holocene) alluvial plain sediments (CDMG, 1998a; 1998b). The older alluvial deposits are generally medium dense to dense and are considered by the CDMG (1998a, 1998b) to have a low liquefaction susceptibility.

The California Geological Survey (CGS) previously called the California Division of Mines and Geology (CDMG)has prepared seismic hazard maps for the Los Angeles Basin. The maps delineate liquefaction zones that have been defined by the CGS as areas where historic occurrence of liquefaction, or local geological, geotechnical, and groundwater conditions indicate a potential for permanent ground displacement such that mitigation (as defined in the Public Resources Code) would be required. The CGS uses criteria developed by the Seismic Hazard Mapping Act Advisory Committee in delineating liquefaction zones on the seismic hazard maps. Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

- Areas known to have experienced liquefaction during historical earthquakes
- All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated
- Areas where sufficient existing geotechnical data and analyses indicate that soils are potentially liquefiable
- Areas where existing geotechnical data are insufficient
- In areas of limited or no geotechnical data, susceptibility zones are evaluated using a combination of geologic considerations as follows:
  - Geologic age of the deposit (i.e., either late Holocene, Holocene, or latest Pleistocene),
  - Depth to groundwater, and
  - The M-7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than a specified acceleration

Following the CGS criteria, in areas containing Holocene-age deposits, the sediments are considered susceptible if the M7.5 weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high groundwater table is less than or equal to 30 feet bgs (CDMG, 1998a and 1998b).

Using these criteria, the CGS has rated the liquefaction susceptibility for the Holocene-age deposits (i.e., alluvial fans, stream deposits, and floodplains) in the alignment area as high, if saturated and, if not saturated, the susceptibility is rated as low (CGS, 1998a and 1998b). In contrast, the liquefaction susceptibility of older alluvial sediments (pre-Holocene alluvial fans and sediments comprising the elevated La Brea geomorphic surface) is rated as low irrespective of groundwater levels.

The zones of potentially liquefiable sediments delineated by the CGS (1999a and 1999b) along the alignment are the Holocene fan deposits from La Jolla Avenue to Beverly Boulevard in Beverly Hills and from Westwood Boulevard to about Bonsall Avenue, east of the I-405 Freeway. Liquefaction susceptibility zones have been delineated in the Hollywood Quadrangle beneath latest Holocene alluvial fans adjacent to the mountain front and large portions of the Holocene-age intrafan deposits.

The young alluvial deposits that have been geographically delineated by the CGS as susceptible to liquefaction are estimated to be approximately 10 to 35 feet thick. Preliminary tunnel profiles for the alignment show the tunnel crown elevations appear to be beneath the young alluvial deposits that are rated as highly susceptible to liquefaction.

For station locations with shallow groundwater and younger alluvial deposits, station walls may have to be designed for greater than usual lateral earth pressures to account for liquefaction potential. This condition is most likely to occur at the following stations:

- Wilshire/La Cienega
- Westwood/UCLA
- Westwood/VA Hospital

Settlement beneath the aforementioned planned stations due to liquefaction is considered remote due to the dense character of the Older Alluvium at station depths.

At each of the stations, the liquefaction potential was evaluated using blow count data from rotary-wash borings and cone penetration test data. The results of the liquefaction are discussed in more detail in Section 12 for the three stations listed above.

6.0 ENGINEERING PROPERTIES OF PRINCIPAL GEOLOGIC UNITS

Based on the results of the field explorations described in Section 3 and laboratory testing described in Section 4 for the ACE and PE phases, estimates were made of the engineering properties of principal geologic units. The principal geologic units anticipated to be encountered within the tunnel and station excavations are Older Alluvium/Lakewood Formation, San Pedro Formation, and Fernando Formation. A detailed description of the principal geologic units is provided in Section 5, Project Geology.

Field and laboratory data was compiled to estimate the minimum and maximum and a best estimate (median) value of the different engineering parmaters. The parameters were evaluated within fine grained and coarse grained portions of each geologic units separately. Considering the unique characteristics of tar impacted soils, engineering properties were also estimated for just tar impacted soils. The summary of the estimated engineering properties of the principal geologic units are presented in Table 6-1.

THIS PAGE INTENTIONALLY LEFT BLANK

.

Table 6-1: Engineering Properties of Principal Geologic Units

Geology	Younger Alluvium (Qal)				Older Alluvium (Qalo) + Lakewood (Qlw)				San Pedro (Qsp)						Fernando (Tf)	
Predominant Grain Size	Coarse-Grained		Fine-Grained		Coarse-Grained		Fine-Grained		Coarse-Grained (excluding tar-impacted soils)		Coarse-Grained (tar-impacted soils)		Fine-Grained (including tar-impacted soils)		Fine-Grained	
USCS Soil Classification	SP, SW, GP, GW, SM, SC, GM, GC, GP-GM, GW-GM SP-SM, SW-SM, SC-SM		CL, CH, ML, MH, CL-ML		SP, SW, GP, GW, SM, SC, GM, GC, GP-GM, GW-GM SP-SM, SW-SM, SC-SM		CL, CH, ML, MH, CL-ML		SP, SW, GP, GW, SM, SC, GM, GC, GP-GM, GW-GM SP-SM, SW-SM, SC-SM				CL, CH, ML, MH, CL-ML		ML, MH	
	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.
SPT Blow counts	5 to 54	20	4 to 47	12	8 to 98	43	7 to 88	31	12 to 50+	50+	16 to 50+	50+	10 to 50+	32	31 to 50+	50+
Moisture Content (%)	4 to 26	13	10 to 33	22	2 to 38	15	7 to 57	21	2 to 43	20	2 to 40	8	4 to 52	26	9 to 70	35
Dry Density (pcf)	98 to 122	112	87 to 120	101	87 to 133	111	66 to 130	105	77 to 131	103	74 to 121	109	74 to 116	98	55 to 113	85
Void Ratio	0.36 to 0.70	0.52	0.40 to 0.91	0.66	0.29 to 0.92	0.51	0.35 to 1.51	0.61	0.32 to 1.16	0.63	0.39 to 1.25	0.55	0.45 to 1.24	0.73	0.47 to 1.79	0.98
Fines Content (%)	11 to 48	34	51 to 84	68	3 to 51	29	50 to 99	70	1 to 50	22	2 to 35	13	51 to 99	77	68 to 99	95
Specific Gravity	2.68 to 2.81	2.76	-	2.65	2.51 to 2.86	2.68	2.45 to 2.98	2.68	2.52 to 2.83	2.66	2.44 to 2.68	2.6	2.51 to 2.83	2.70	2.45 to 2.81	2.56
Liquid Limit (%)	24 to 42	32**	29 to 75	44	NP to 45	26	NP to 82	40	NP to 50	30	NP	NP	NP to 84	45	NP to 66	51
Plasticity Index (%)	5 to 24	14**	11 to 45	23	NP to 24	9	NP to 53	21	NP to 35	14	NP	NP	NP to 57	23	NP to 34	16
Compression Index (C_c)	*	*	*	*	0.02 to 0.16	0.08	0.04 to 0.25	0.10	0.03 to 0.10	0.07	0.07 to 0.12	0.10	0.05 to 0.15	0.10	0.07 to 0.11	0.09
Recompression Index (C_r)	*	*	*	*	0.006 to 0.037	0.011	0.008 to 0.070	0.027	0.006 to 0.026	0.013	0.013 to 0.015	0.014	0.010 to 0.051	0.023	0.013 to 0.036	0.031

Notes:
NP: Non-plastic
*No data
** values representative of clayey sand soils. Other soil types have lower plasticity.

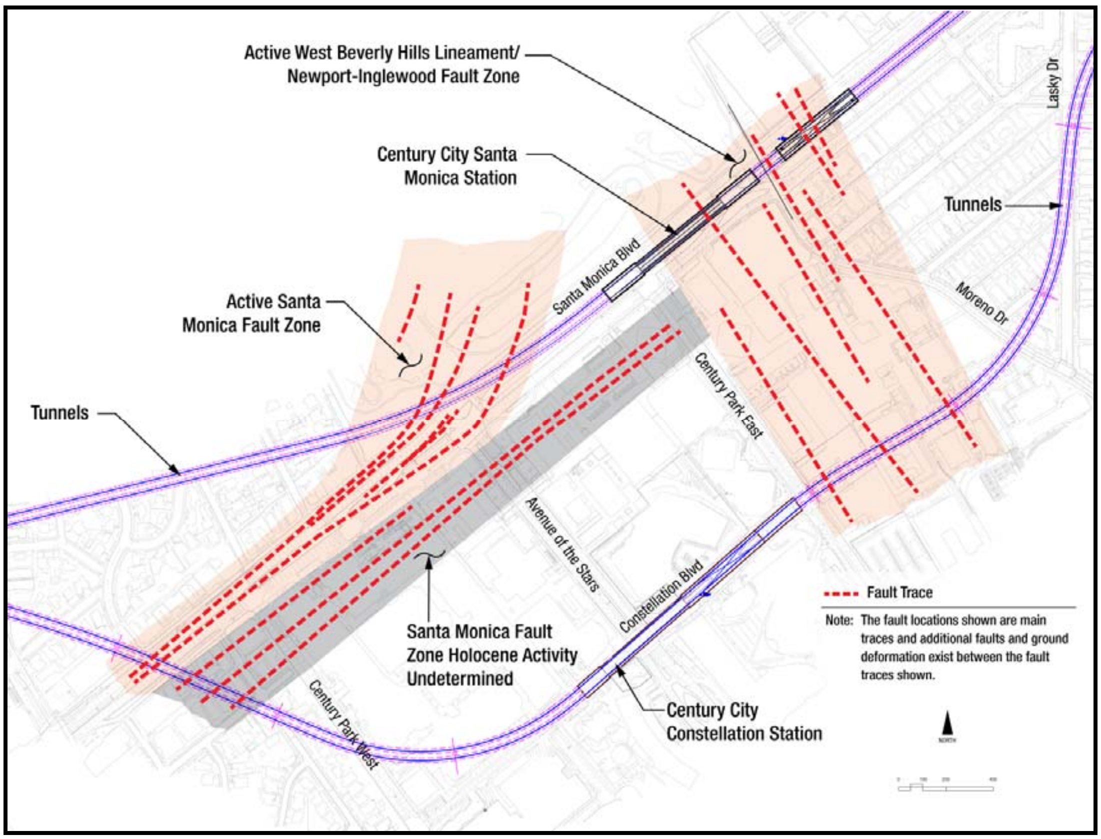
THIS PAGE INTENTIONALLY LEFT BLANK

7.0 FAULT INVESTIGATION SUMMARY

The Santa Monica fault zone has been previously inferred to trend along Santa Monica Boulevard from west of Century Park West to east of Avenue of the Stars, where its trace was thought to turn to the northeast. It has been postulated that the fault zone terminates at the geomorphic feature called the West Beverly Hills Lineament (WBHL), a north-south trending lineament crossing Santa Monica Boulevard east of South Moreno Drive thought to be a fault.

Analysis of borings, CPT data, and seismic reflection profiles along seven transects, in conjunction with mapped topographic landforms, have confirmed two active fault zones in the Century City area: the northeast-southwest trending Santa Monica fault zone and the northwest-southeast trending WBHL. Santa Monica Boulevard effectively lies within the Santa Monica fault zone from west of Century Park West to east of Avenue of the Stars, as shown in Figure 7-1. The originally proposed Century City Santa Monica Boulevard (west) Station at Avenue of the Stars would lie directly within this fault zone.

Figure 7-1: Santa Monica Fault Zone and West Beverly Hills Lineament



The WBHL is a wide fault zone with several well-defined strands situated along the eastern margin of Century City. It is the inferred northern extension of the active Newport-Inglewood fault zone. The WBHL terminates the active Santa Monica fault to the east. The location of the proposed Century City Santa Monica (east) Station would straddle the WBHL.

No evidence of faulting was found on the Century City Constellation Boulevard Station site. Based on the results of these fault investigations, there is clear evidence that the station locations on Santa Monica Boulevard (both east and west) would be located in active fault zones and are not viable options for station locations. The station on Constellation Boulevard would not be located within an active fault zone and is a viable option for a station location.

The details of the fault investigation are provided in the separate *Century City Fault Investigation Report* (Metro, 2011).

8.0 SUBSURFACE GAS INVESTIGATION SUMMARY

The tunnel alignment passes through areas that have been designated as "Methane Zones" by the Los Angeles Department of Building and Safety. Subsurface gas investigation in ACE and PE phase was performed for a 2.6 mile stretch of the tunnel alignment along Wilshire Boulevard between Fremont Place (Station 422+00) and San Vicente Boulevard (Station 560+00), and at Century City Constellation station and near the Westwood/VA Hospital station and GSA double crossover east of I-405.

The subsurface gas study for PE phase included installation of 19 nested groundwater with gas monitoring wells and vapor probes. Hydrogen sulfide (H_2S) and methane (CH_4) gas monitoring of the new wells/probes occurred as part of the PE phase during May through December 2011. In addition, 19 of the 25 monitoring wells installed in ACE phase relevant for the current alignment and 14 prior active wells sampled semiannually by TRC were also monitored during the PE phase. The field and laboratory data are presented in Table 3-8 through Table 3-9 and also shown on Plates 4-1 and 4-2.

8.1.1 Fremont Place (Station 422+00) to San Vicente Boulevard (Station 560+00)

24 gas monitoring wells (9 in ACE and 15 in PE phase) were installed in this stretch. Approximately 1.1 mile long portion of this stretch between Cochran Avenue (Station 493+00) and La Jolla Avenue (Station 550+60) displayed higher levels of gas pressure, methane, and hydrogen sulfide. Gas pressures in probes and wells reached 844 inches of water at M-7 and was 20 inches of water at M-13; methane levels reached 100% at M-13 and 90% at M-108; hydrogen sulfide levels reached 290 parts per million [ppm] at M-106 (200 feet east of La Brea Tar Pits) and 6,500 ppm at M-13 (Wilshire and Crescent Heights). A reading of 79 ppm hydrogen sulfide was recorded from M-108 located at Curson Avenue and Wilshire Boulevard near the southeast corner of La Brea Tar Pits area.

Elsewhere in the stretch (east of Station 493+00 and west of 550+60), no sample point in six installed wells displayed a pressure greater than 0.7 inches of water, contained greater than 2.3% methane (25% of the lower explosive limit), or indicated greater than 1 part per million [ppm]of hydrogen sulfide.

The portion of Wilshire Boulevard near the La Brea Tar Pits, also is characterized by having extensive tar sands, with tar seeps (i.e., to the surface) in the area. The tar sands and associated gases are located primarily in the San Pedro Formation and overlying soils (alluvium, or Lakewood Formation). The San Pedro Formation is shallow (i.e., 5 to 10 feet below ground surface) in this gassy area relative to the surrounding area which may lend to the gases being channeled to this area due to the natural structure.

The presence of tar sands between South Ridgeley Drive and Fairfax Avenue limited the ability to place wells at depth (i.e., below 45 feet) at locations such as M-113 because the tar sands are present down to approximately 110 feet bgs. In some cases a well screened in the San Pedro Formation will eventually be filled with oil (in some cases quite rapidly), so well screens were not placed directly in those zones.

8.1.2 Century City Constellation Station

One gas monitoring (M-119) was installed at this location. Methane concentration in M-119 at 70-75 foot depth was measured at 12%. The shallow depth well at M-119 (40-45 feet depth) had 2.7% methane, and the 25-foot deep vapor probe had 4.9% methane (fixed laboratory analysis), and the shallow probe had 0% methane.

8.1.3 Westwood/VA Hospital Station and GSA Double Cross over

Two gas monitoring wells (M-122 and M-124) were installed at this location. Methane concentration was less than 0.1%; hydrogen sulfide levels were about 1 ppm or less and the gas pressure was nearly zero, suggesting no subsurface gas hazards at this location.

8.1.4 Summary

Methane along the alignment is generally less than 5% (i.e., less than the lower explosive limit) in nearly all areas, with the exception of the portion of the alignment west of Cochran Avenue and east of La Jolla Avenue, which coincides with the Los Angeles Department of Building and Safety (LADBS) designated “High Potential Risk Zone” for methane. Gas pressures in probes and wells in this stretch reached up to 844 inches of water, methane levels reached 100% and hydrogen sulfide levels reached up to 6,500 ppm. The Century City Constellation and Westwood/VA Hospital station located within the LADBS designated “Methane Zone” and encountered low levels of methane, hydrogen sulfide and gas pressures as discussed earlier.

The soil cuttings retrieved from the drilling of geotechnical borings and installation of the gas monitoring wells were tested for waste characterization purposes in ACE and PE phases and were all found to be non-hazardous and were shipped to Soil Safe in Adelanto, California.

9.0 ENVIRONMENTAL SITE ASSESSMENT SUMMARY

A review of the field findings and analytical laboratory results shows that suspect constituents of concern were detected in the soil and/or the groundwater samples in 21 of the 31 borings advanced during this investigation. The constituents identified were related to releases of fuel compounds and/or chlorinated solvents or naturally occurring petroleum compounds.

The borings advanced during this assessment, and the soil and groundwater samples that were analyzed from the specific borings, are indicative of the conditions at a precise location. In several cases, the borings had to be moved farther from the suspect sources due to underground utilities and/or traffic control reasons. Therefore, further investigation (e.g., step-out borings near the original boring location) would be necessary to better delineate the possible extent of impacted areas along the Project alignment.

Considering the relatively lengthy history of retail/commercial (and some light industrial) development along a majority of the Project alignment, combined with the findings of this investigation, it is apparent that impacted soils and groundwater will be encountered along certain portions of the alignment during tunneling and excavation activities. A soil and groundwater management plan is recommended to address these issues.

THIS PAGE INTENTIONALLY LEFT BLANK

10.0 OIL WELL SURVEY SUMMARY

Oil well surveys were performed at four locations where abandoned wells were anticipated to interfere with the tunnel alignment. These four study areas and the respective well names in these areas are listed below.

10.1.1 Beverly Hills High School (football and lacrosse fields and tennis courts)

- "Rodeo" 107
- "Rodeo" 114
- "Wolfskill" 23

10.1.2 1950 Century Park East (Meridian's Bodies in Motion property)

- "Wolfskill" 23

10.1.3 Parking lot northeast of Constellation and Avenue of the Stars

- "Aladdin" 25E-1
- "Aladdin" 26
- "Aladdin" 28

10.1.4 Northwest quadrant of Wilshire and Fairfax (Johnnie's Coffee Shop)

- "Salt Lake" 10

"Wolfskill" 23 was shown on DOGGR maps to be in the parking garage 1950 Century Park East property adjacent to the lacrosse field of Beverly Hills high school (lacrosse field). Therefore, oil well surveys were conducted at both properties.

GeoVision performed geophysical investigations under AMEC's supervision to locate abandoned oil wells at Beverly Hills High School, "Wolfskill" 23, "Salt Lake" 10, and "Aladdin" 25-1, "Aladdin" 26, and "Aladdin" 28. In addition, DOGGR records were reviewed for oil wells possibly present at these locations. Based upon the results of the study, no definitive indications of any abandoned oil wells or associated infrastructure could be located in the study areas, except anamolies at "Wolfskill" 23, as discussed in the following sections. A summary of the oil well surveys at these four study areas are presented in the following sections.

10.1.5 Beverly Hills High School (football and lacrosse fields and tennis courts)

Oil well surveys at the football field did not show a definitive presence of any abandoned oil wells such as old oil wells "Rodeo" 114 and "Rodeo" 107 which plot in the high school property based upon records. DOGGR records plot the old oil well "Rodeo" 114 to be potentially in the field. However, these records are questionable and this may well not be located as plotted in the football field or it may have been abandoned with the casing pulled so that there is no metallic object. "Rodeo" 107 could not be located, possibly for the same reason. Additionally there was a fair amount of interference near the prospective "Rodeo" 107 location.

In the lacrosse field area, there was no evidence that "Wolfskill" 23 was located in that field; however, the near-surface metallic objects that were found during scanning are not related to oil wells. Four large magnetic anomalies (A1 through A4) were present in the data that may be related to steel-cased abandoned oil wells (or its infrastructure) or other buried metallic debris. Two of the anomalies (A1 and A2) may be related to a pipe segment or previous building infrastructure. Three (A1, A2 and A3) are located on or near the grass lacrosse field, which is surrounded by a metallic chain-link fence and a block retaining wall. The other anomaly (A4) is located southeast of the lacrosse field, in a small area adjacent to an asphalt road with utility vaults, chain-link fencing, reinforced concrete, a building and a retaining wall.

Anomalies A2, A3 and A4 (of the GeoVision report in Appendix E) may be related to abandoned oil wells, infrastructure, or other buried metallic debris but the closest, A2, is at least 80 ft south of the tunnel alignment. Accordingly, further investigation may be conducted as discussed in the summary.

No evidence of oil wells was observed in the tennis court areas.

10.1.6 1950 Century Park East (Meridian's Bodies in Motion property)

The geophysical survey at the at-grade parking garage at 1950 Century Park East (a health club) included part of the alley east of the structure, and part of the asphalt road west of the structure. No well-like anomalies were interpreted at the health club building parking garage from the geophysical data despite the fact that DOGGR maps place the abandoned "Wolfskill" 23 well within the footprint of the garage. Steel reinforcement in the concrete of the structure caused interference issues. Accordingly, further investigation may be conducted as discussed in the summary.

This will provide the location, nature, and characteristics of any anomaly which, if determined to be an abandoned oil well, will be safely treated according to DOGGR regulations.

10.1.7 Parking lot northeast of Constellation and Avenue of the Stars

For the Aladdin well search at the northeast corner of the Avenue of the Stars and Constellation Boulevard in the vacant lot, no significant well-like anomalies were located in the right-of-way of the Project alignment from the geophysical survey data. Several oil-well anomalies were interpreted to be located in the northern area of the empty lot, which is not at the locations indicated by some DOGGR records nor in the proposed right-of-way for the Project.

The location of the Aladdin well anomalies identified from the geophysical data vary significantly from the well locations shown on the DOGGR maps, indicating the importance of geophysical scanning and physically locating oil wells rather than relying solely on the mapping records

10.1.8 Northwest quadrant of Wilshire and Fairfax (Johnnie's Coffee Shop)

At the "Salt Lake" 10 well location near Johnnie's Coffee Shop (currently close), there was much interference from metal and buildings and the presence or absence of a well could not be established.

There are limited well construction records regarding well "Salt Lake" 10 when it was built in 1907, and there are no records of abandonment. Available records of the well indicated that it is idle (currently inactive but not decommissioned) and is considered an "orphan well," similar to hundreds of other inactive wells in the Los Angeles area.

Special precautions should be taken when drilling through this area knowing that there could be an open conduit from an oil and gas formation. Metro may consider placing a gas monitoring well near the mapped location of the oil well to determine whether there is excessive methane leakage resulting from an orphan well in that vicinity between Johnnie's Coffee Shop and Marinello's School of Beauty, off of the alley).from an "orphan" well in that vicinity [between Johnnie's Restaurant (currently closed) and the Marinello's School of Beauty, off of the alley)].

10.1.9 Summary

With the exception of the abandoned "Wolfskill" 23 well and possibly Anomaly A-1, there is no evidence of oil wells existing directly within the planned tunnel alignment. Since "Wolfskill" 23 is along the planned tunnel aligment as indicated by DOGGR maps, it is recommended that Horizontal Directional Drilling (HDD) and associated magnetometer surveys ber perforemd at this location. Similarly, in other locations, where the DOGGR records show abandoned wells within a distance of about 100 feet, in consideration of inaccuracy of these records, it would be prudent to further investigate such locations by exploring with HDD. Alternatively such suspect locations may be investigated from the tunnel face during tunneling. However, it should be realized that with closed face tunneling, there would be challenges for implementing this alternate method.

THIS PAGE INTENTIONALLY LEFT BLANK

11.0 GEOTECHNICAL INPUT FOR TUNNEL DESIGN

Section 5.0 discusses the geologic materials through which the tunnel will be excavated as shown on geologic profiles (see Plates 1-00 through 1-21). Along much of the alignment, the tunnel will be excavated below groundwater. In addition, some of the alignment will encounter high levels of methane and hydrogen sulfide, particularly between Cochran and La Jolla Avenues. In the Fairfax area, naturally occurring tar-impacted soils (tar sands and petroliferous silts and clays) will be encountered. Tar sands and petroliferous silts and clays are similar in that they are impacted by the presence of tar, but silts and clays contain far less of the hydrocarbon materials than do sands because the pores are much smaller in silts and clays. In Century City, the tunnel will be excavated through the Santa Monica fault zone and through the West Beverly Hills Lineament, as discussed in Section 5.0 and 7.0. In addition, east of Century Park East in Century City, the tunnel excavation alignment will be close to the existing "Wolfskill" 23 oil well, as discussed in Section 10.

Based on the geologic materials, fault crossing, subsurface gases, and groundwater, the tunnel alignment may be subdivided into three reaches, as described below.

11.1 Reaches

For the purposes of developing design/construction contracts, Metro may choose to subdivide tunnel alignment reaches corresponding to tunnel lengths in between two consecutive stations. However, from a geotechnical/geologic material characterization point of view, the following reaches may be considered for preliminary planning and design.

Majority of the tunnel alignment lies within the City of Los Angeles designated "methane zone." Based on the site-specific subsurface gas investigation conducted during the ACE and PE phases, an approximately 1.1-mile-long portion of the alignment between Cochran Avenue and La Jolla Avenue contains high levels of methane, hydrogen sulfide, and gas pressures. These findings support the current mapping of this portion of the alignment by the City of Los Angeles as a "high risk zone" for methane. As a result, a special tunnel lining and proper ventilation considerations will be required.

11.1.1 Western-Cochran Reach: Between Western Avenue and Cochran Avenue along Wilshire Boulevard (Sta. 371+00 to 486+50)

Along this reach, which is about 2.14 miles long, the tunnel will be excavated predominantly in the San Pedro and Fernando Formations. About 60 percent of the tunnel reach is expected to be excavated in the San Pedro Formation, about 15 percent will be excavated in Fernando Formation, and the remaining 25 percent will be excavated in mixed-face conditions.

Based on the soil types encountered within the planned tunnel diameter and 10 feet above and below the tunnel crown/invert (defined as the tunnel zone), it is expected that about 45 percent of the material within the tunnel excavation will be fine-grained and the remaining 55 percent will be coarse grained. Figure F-6.225 and F-7.227 in Appendix F in Volume 3, Laboratory Test Results shows composite plots of grain size and Atterberg Limits, respectively, for the soil types that will be encountered within the tunnel zone depths along the Western-Cochran reach. The fine-grained portions of the soil are classified as clays and silts with plasticity index values of 10 to 25 percent.

Based on the tunnel profiles considered during the PE phase, the crown of the tunnel within this reach will be located at depths of approximately 35 to 100 feet below the existing ground surface. Based on current groundwater conditions, as shown on Plates 1-00 through 1-04, the tunnel crown is expected to be under hydrostatic head of about 20 to 60 feet.

The engineering properties of different geologic materials expected to be encountered during excavation based on the PE phase tunnel profile in this reach are presented in Table 11-1.

11.1.2 Cochran-La Jolla Reach: Between Cochran Avenue and La Jolla Avenue along Wilshire Boulevard (Sta. 486+50 to 550+50)

Along this reach, which is about 1.22 miles long, the tunnel will be excavated predominantly in the San Pedro Formation and the Fernando Formation. About 65 percent of the tunnel reach is expected to be excavated in the San Pedro Formation, about 20 percent will be excavated in the Fernando Formation, and the remaining 15 percent will be excavated in mixed-face conditions.

The tunnel traverses through the La Brea Tar Pits in this reach and overlies a portion of the Salt Lake Oil Field. This portion of the tunnel is located within the City of Los Angeles' mapped "high potential risk zone" for methane and "tar pit area." The findings of the subsurface gas investigations conducted during the ACE and PE phases also support the current mapping of this portion of the tunnel by the City of Los Angeles as a "high risk zone" for methane. As a result, a special tunnel lining and proper ventilation considerations will be required. Tunnel excavation in this reach will encounter tar-impacted soils and high levels of methane and hydrogen sulfide. The tar content within the tar-impacted soils varies from 5 to 30 percent by weight, with an average value of 15 percent.

Analytical testing of soil and groundwater samples collected from monitoring wells indicates they are contaminated due to high concentrations of TPH/VOCs. Although the analytical results indicate that the tar-impacted soils are RCRA non-hazardous waste, due to their high concentrations of TPH, they will not be acceptable as a daily cover in landfill. The tar-impacted soils will have to be thermally treated prior to disposal at landfill sites. Additional testing on soil and groundwater should be performed during tunnel excavation to determine the concentrations of constituents and evaluate disposal methods. Larger quantities of soil will likely require transport to a facility that accepts hydrocarbon-impacted soils. Investigations into the use of tar sand materials, such as for paving materials, is on-going, and will be studied further during subsequent design phases.

Based on the soil types encountered within the planned tunnel diameter and 10 feet above and below the tunnel crown/invert, it is expected that about 45 percent of the material within the tunnel excavation will be fine-grained and the remaining 55 percent will be coarse-grained. Figure F-6.226 and F-7.228 in Appendix F in Volume 3, Laboratory Test Results shows composite plots of grain size and Atterberg Limits, respectively, for the soil types that will be encountered within the tunnel zone depths within the Cochran-La Jolla Reach. The fine-grained portions of the soil are classified as clays and silts with plasticity index values of 10 to 25 percent.

The crown of the tunnel within this reach will be located at depths of approximately 40 to 80 feet below the existing ground surface. Based on the current groundwater conditions, as shown on Plates 1-05 through 1-07, the tunnel crown is anticipated to be under hydrostatic head of about 10 to 70 feet.

The engineering properties of different geologic materials expected to be encountered during excavation based on the PE phase tunnel profile in this reach are presented in Table 11-2.

11.1.3 La Jolla-VA Reach: From La Jolla Avenue at Wilshire Boulevard through the End of the Project Alignment (Sta. 550+50 to 847+40)

Along this reach, which is about 5.62 miles long, the tunnel will be excavated in the San Pedro and Lakewood Formations or in Older Alluvium. About 50 percent of the tunnel reach is expected to be excavated in Older Alluvium, 25 percent in the San Pedro Formation, 10 percent each in the mixed-face of Lakewood/San Pedro and San Pedro/Fernando Formations, and the remaining 5 percent in the mixed-face of Younger Alluvium/Lakewood Formation.

This reach traverses through Century City, where the tunnel alignment will encounter the Santa Monica Fault zone and the Newport Inglewood fault zone/West Beverly Hills Lineament. The tunnel also needs to be designed for methane and hydrogen sulfide resulting from prior oil exploration activities within the Beverly Hills Oil Fields. The findings of the subsurface gas investigations conducted during the ACE and PE phases also support the current mapping of this portion of the tunnel in Century City by the City of Los Angeles as a “methane zone.”

Based on the soil types encountered within the planned tunnel diameter and 10 feet above and below the tunnel crown/invert, it is expected that about 55 percent of the material within the tunnel excavation will be fine-grained and the remaining 45 percent will be coarse-grained. Figure F-6.227 and F-7.229 in Appendix F in Volume 3, Laboratory Test Results shows composite plots of grain size and Atterberg Limits, respectively, for the soil types that will be encountered within the tunnel zone depths within the La Jolla-VA Reach. The fine-grained portions of the soil are classified as clays and silts with plasticity index values of 10 to 30 percent.

The crown of the tunnel within this reach will be located at depths of approximately 45 to 140 feet below the existing ground surface. Based on the current groundwater conditions, as shown on Plates 1-07 through 1-17, the tunnel crown is expected to be under hydrostatic head of 0 to 100 feet.

Artesian groundwater conditions are expected near Santa Monica Boulevard in Century City. It is likely that the artesian pressure conditions are a result of the Santa Monica fault zone which essentially acts as a groundwater barrier at the location of one or more confined aquifers such that the pressure head in the aquifer(s) is greater than the depth of the aquifer below the ground surface. In addition, east of Century Park East in Century City, the tunnel excavation alignment will be close to the existing “Wolfskill” 23 oil well, as discussed in Section 10.

The engineering properties of different geologic materials expected to be encountered during excavation based on the PE phase tunnel profile in this reach are presented in Table 11-3.

THIS PAGE INTENTIONALLY LEFT BLANK

Table 11-1: Engineering Properties of Principal Geologic Units (Western-Cochran reach)

Geology	Older Alluvium (Qalo) + Lakewood (Qlw)				San Pedro (Qsp)				Fernando (Tf)	
Predominant Grain Size	Coarse-Grained		Fine-Grained		Coarse-Grained		Fine-Grained		Fine-Grained	
USCS Soil Classification	SM, SC		CL, ML, CH, CL-ML		SC, SM, SP, SP-SM, SW SP-SM, SW-SM, SC-SM		CL, CH, ML, MH, CL-ML		ML	
	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.
SPT Blow Counts	10 to 36	28	8 to 32	22	20 to 100	68	16 to 68	36	31 to 99	51
Moisture Content (%)	12 to 26	19	21 to 38	25	8 to 32	20	16 to 43	27	18 to 70	39
Dry Density (pcf)	102 to 114	105	97 to 103	100	88 to 123	102	74 to 107	96	55 to 92	80
Void Ratio	0.53 to 0.63	0.58	0.63 to 0.73	0.68	0.35 to 0.91	0.64	0.56 to 1.24	0.76	0.78 to 1.79	1.13
Fines Content (%)	22 to 47	35	52 to 62	57	5 to 49	19	53 to 98	78	89 to 99	96
Specific Gravity	2.81*	2.81	2.45	2.45	2.52 to 2.77	2.64	2.45 to 2.81	2.56	2.45 to 2.81	2.57
Liquid Limit (%)***	27 to 37	32	43 to 60	52	NP to 50	29	NP to 66	51	37 to 66	54
Plasticity Index (%)***	19 to 25	22	20 to 45	33	NP to 35	15	NP to 56	23	7 to 25	17
Compression Index (Cc)	n/a**	n/a	n/a	n/a	0.023 to 0.053	0.034	0.065 to 0.073	0.069	0.037 to 0.071	0.061
Recompression Index (Cr)	n/a	n/a	n/a	n/a	0.004 to 0.016	0.009	0.010 to 0.011	0.011	0.010 to 0.020	0.017
Soil Pressure Coeff., At-rest, Ko	n/a	n/a	n/a	n/a	0.59 to 0.90	0.85	0.57 to 0.83	0.62	0.53 to 0.59	0.56
Soil Abrasion Test	n/a	n/a	n/a	n/a	14.5 to 38	28.7	n/a	n/a	1.5 to 6.5	2
Unconfined Compression, q_u (ksf)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	9 to 18	14
Expansion (%)	n/a	n/a	0.05	0.05	n/a	n/a	n/a	n/a	0.04 to 0.16	0.10
Collapse (%)	0.07	0.07	n/a	n/a	0 to 1.01	0.06	0.01 to 0.40	0.04	n/a	n/a
Corrosion:										
Minimum Resistivity (ohm-cm)	880-1,640	1260	560-1,720	1,184	420-2,150	1,309	480-1,520	818	156-480	315
pH	7.2-8.2	8	6-8	7	4-8	7	4-8	8	3-8	5
Chloride Content (ppm or mg/kg)	11-69	40	7-217	39	11-142	33	2-139	29	96-2,384	573
Sulfate Content (ppm or mg/kg)	165-377	271	14-263	106	39-5,333	1,055	43-6,599	921	1,637-7,926	4,653

* No range values given when there was only one test performed
** No test was performed
***Only results with plasticity were used to calculate the best estimate values

Table 11-2: Engineering Properties of Principal Geologic Units (Cochran-La Jolla Reach)

Geology	Older Alluvium (Qalo) + Lakewood (Qlw)				San Pedro (Qsp)				Fernando (Tf)			
Predominant Grain Size	Coarse-Grained		Fine-Grained		Coarse-Grained		Fine-Grained		Coarse-Grained		Fine-Grained	
USCS Soil Classification	SM, SC		CL, ML, CL-ML		GM, GP, SC, SM, SP, SP-SM, SW-SM		ML. MH		SILTSTONE (possibly concretion zone)		SILTSTONE	
	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.
SPT Blowcounts	16*	16	7 to 44	20	12 to 50+	50+	16 to 50+	43	n/a	n/a	35 to 50+	49
Moisture Content (%)	11.2 to 23.1	16.6	13.3 to 25.9	17.8	2 to 35	9	4 to 39	20	n/a	n/a	10 to 28	20
Dry Density (pcf)	107.6 to 111.2	109.4	89 to 110	98.8	91 to 120	107	81 to 115	100	n/a	n/a	75 to 92	86
Void Ratio	0.51 to 0.55	0.53	0.53 to 0.89	0.71	0.39 to 0.82	0.56	0.46 to 1.04	0.69	n/a	n/a	0.90 to 0.95	0.93
Fines Content (%)	13 to 38	19	62 to 71	68	2 to 41	16	12 to 90	61	n/a	n/a	67 to 98	79
Specific Gravity	n/a	n/a	n/a	n/a	2.44 to 2.69	2.64	2.7 to 2.8	2.70	n/a	n/a	2.63 to 2.73	2.68
Liquid Limit (%)***	NP	NP	49	49	42	42	44 to 64	52	n/a	n/a	47 to 55	50
Plasticity Index (%)***	NP	NP	NP to 28	27	21	21	16 to 31	21	n/a	n/a	5 to 18	9
Compression Index (Cc)	n/a*	n/a	n/a	n/a	0.68 to 0.16	0.013 to 0.015	n/a	n/a	n/a	n/a	n/a	n/a
Recompression Index (Cr)	n/a	n/a	n/a	n/a	0.096	0.014	n/a	n/a	n/a	n/a	n/a	n/a
Expansion/ Collapse Potential	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Soil Pressure Coeffieient, At-rest, Ko	1.12	1.12	n/a	n/a	0.59 to 0.72	0.66	n/a	n/a	n/a	n/a	n/a	n/a
Soil Abrasion	n/a	n/a	n/a	n/a	22 to 27	24.5	n/a	n/a	31	31	2.0 to 5.5	3.8
Unconfined Compression, q_u (ksf)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7 to 10	8
Tar Content (%)	3.7 to 16	9.1	4.6 to 13.1	8.8	7.1 to 20.4	13.6	4.0 to 18	7.3	n/a	n/a	6.4 to 29.5	18.5
Corrosion:												
Minimum Resistivity (ohm-cm)	n/a	n/a	520-1,560	867	392-480,000	47,357	720-2,240	1,333			244-4,400	1,066
pH	n/a	n/a	3-8	6	2-8	6	4-8	7			3-8	6
Chloride Content (ppm or mg/kg)	n/a	n/a	7-46	20	1-275	43	9-1,274	391			90-2,836	1,870
Sulfate Content (ppm or mg/kg)	n/a	n/a	74-87,990	15,700	12-8,074	848	173-3,590	1,241			530-7,151	4,180

* No range values given when there was only one test performed
** No test was performed
***Only results with plasticity were used to calculate the best estimate values

Table 11-3: Engineering Properties of Principal Geologic Units (La Jolla-VA Reach)

Geology	Younger Alluvium (Qal)				Older Alluvium + Lakewood Formations (Qalo + Qlw)				San Pedro Fromation (Qsp)			
Predominant Grain Size	Coarse-Grained		Fine-Grained		Coarse-Grained		Fine-Grained		Coarse-Grained		Fine-Grained	
USCS Soil Classification	GM, GP, SC, SM, SP, SP-SM		CH, CL, ML		GC, GW, GM, GP, SP-SM, SP-SC, SW-SM, SP, SW, SC, SM		CH, CL, MH, ML		GW-GM, SC, SM, SP, SP-SM, SW, SW-SM		CH, CL, CL-ML, MH, ML	
	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.	Range	Best Est.
SPT Blowcounts	5 to 50+	19	5 to 31	12	8 to 50+	50+	8 to 50+	34	12 to 50+	50+	10 to 50+	32
Moisture Content (%)	4.1 to 26	13.3	10.2 to 32	20.2	1.7 to 30.9	14.2	8.4 to 56.7	20.9	9.7 to 43.3	20	13 to 38	25.2
Dry Density (pcf)	99 to 120	113.6	87 to 114	101.2	87 to 130	111.1	66 to 130	104.3	77.7 to 120.3	99.7	87 to 114	100.6
Void Ratio	0.398 to 0.696	0.506	0.472 to 0.907	0.643	0.292 to 0.915	0.521	0.376 to 1.505	0.629	0.385 to 1.160	0.698	0.472 to 0.929	0.681
Fines Content (%)	11 to 48	26	51 to 84	68	5 to 50	27	50 to 99	71	6 to 50	31	51 to 99	73
Specific Gravity	2.68 to 2.81	2.76	2.616	2.616	2.51 to 2.86	2.68	2.53 to 2.98	2.71	2.53 to 2.83	2.68	2.51 to 2.83	2.70
Liquid Limit (%)***	24 to 42	30	31 to 50	42	21 to 48	30	22 to 82	39	30 to 49	37	29 to 78	45
Plasticity Index (%)***	5 to 24	12	13 to 32	22	4 to 35	11	6 to 48	21	11 to 27	19	7 to 45	23
Compression Index (Cc)	0.042	0.004	n/a	n/a	0.034 to 0.162	0.09	0.061 to 0.183	0.10	0.06 to 0.103	0.08	0.053 to 0.123	0.01 to 0.034
Recompression Index (Cr)	0.042	0.004	n/a	n/a	0.006 to 0.025	0.010	0.009 to 0.045	0.026	0.01 to 0.017	0.013	0.074	0.023
Expansion/ Collapse Potential	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Soil Pressure Coeffieient, At-rest, Ko	0.80 to 0.70	0.75	n/a	n/a	0.38 to 0.98	0.57	0.27 to 0.68	0.50	0.58 to 1.02	0.64	0.62 to 0.79	0.70
Soil Abrasion	n/a	n/a	n/a	n/a	4.5 to 27.5	11.5	1.6 to 38	4.00	5.5 to 23.5	7.7	n/a	n/a
Unconfined Compression, q_u (ksf)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Corrosion:												
Minimum Resistivity (ohm-cm)	3,680-22,400	10,427	960-2,480	1,570	300-6,400	2,848	600-3,920	1,495	600-3,440	1,600	480-2,360	1,090
pH	8	8	7-8	8	7-8	8	4-9	8	8	8	7-9	8
Chloride Content (ppm or mg/kg)	2-5	3	2-41	11	2-432	28	3-242	23	9-33	17	1-131	34
Sulfate Content (ppm or mg/kg)	6-45	24	7-108	42	10-104	47	8-559	59	36-1,002	453	11-1,215	364

* No range values given when there was only one test performed
** No test was performed
***Only results with plasticity were used to calculate the best estimate values

THIS PAGE INTENTIONALLY LEFT BLANK

12.0 GROUND MOTION STUDY

12.1 Ground Motion Parameters and Response Spectra

Response spectra for stations was computed in accordance with the Section 2.3.1 of Metro Rail Seismic Design Criteria. Two hazard levels were evaluated: Maximum Design Earthquake (MDE) and Operating Design Earthquake (ODE). The MDE and ODE risk levels are defined as the seismic ground motion with a 4% probability of exceedence in 100 years (corresponding to a return period of 2,475 years) and a 50% probability of exceedence in 100 years (corresponding to a return period of 150 years), respectively.

The response spectra for the above stated risk levels were estimated using the 2008 mapped values from the USGS Interactive PSHA Deaggregation website (USGS, 2011). The USGS deaggregation tool uses next generation attenuation (NGA) relationships of Boore-Atkinson (2008), Campbell-Bozorgnia (2008) and Chiou-Youngs (2008) for ground motion prediction equations. For the MDE level, ground motions were computed for probability of exceedance of 2% in 50 years (equivalent to 4% in 100 years). The estimated 5%-damped response spectra up to a period of 2 seconds for each station is presented in Section 13.

In summary, the peak ground acceleration (PGA) for stations varies from 0.26g to 0.30g for the ODE level and varies from 0.75g to 0.91g for MDE level. The PGAs for both hazard levels are presented in Table 12-1.

Table 12-1: Peak Ground Acceleration for ODE and MDE

	Peak Ground Acceleration (PGA)	
Station	**ODE**	**MDE**
Wilshire/La Brea	0.26g	0.85g
Wilshire/Fairfax	0.26g	0.85g
Wilshire/La Cienega	0.30g	0.86g
Wilshire/Rodeo	0.30g	0.91g
Century City Contellation	0.30g	0.75g
Century City Santa Monica	0.30g	0.88g
Westwood/UCLA	0.29g	0.88g
Westwood/VA Hospital	0.29g	0.88g

Ground motion parameters were estimated within tunnel zones using the available small strain shear wave velocity measurmenets from the cone penetration tests (CPTs). PGA was estimated using the USGS Deaggregation website for ODE and MDE levels. PGV was computed using the relationship between PGV-S_1 correlation presented in the FHWA-NHI-10-034 manual (2009). The degradation of shear wave velocity with strain level (for ODE and MDE) was obtained from Table 19.2-1 of FEMA P- 750 (2009). The shear wave velocity adjusted for strain level was then used in the USGS Deaggregation tool to compute the respective PGA and PGV in the manner stated above. The small strain shear wave velocity, PGA and PGV and those for ODE and MDE levels at tunnel elevation are presented in Plates 3-1 and 3.2.

12.2 Free-Field Displacement

Site response analyses were performed using one-dimensional equivalent linear program SHAKE91 (Idriss and Sun, 1992) to estimate free-field displacement of the soil column under the ODE and MDE hazard levels.

Seismic shear wave velocity information available from seismic CPTs were used in developing the one-dimensional soil profile and dynamic properties of soils for each of the stations. The thickness of the one-dimensional soil column in the model varied from 100 to 150 feet. Three appropriate recorded earthquake acceleration time histories were selected and spectrally matched to the rock-level response spectra in time-domain to obtain spectrum compatible time histories. The rock-level spectra was obtained using the 2008 USGS Deaggregation tool for a shear wave velocity of 560 meters per second. The shear strain time histories were obtained in each of the layers within the zone of interest for the station racking and an equivalent strain time histories was computed for soil column in this zone. The peak strain in the strain time history plot multiplied by the height of the staion box was taken as the estimated maximum free-free field displacement between the top and bottom of the station box. The free-field displacement values for ODE and MDE hazard levels computed in this manner for all the stations are presented in Table 12-2.

Table 12-2: Free-Field Displacements for ODE and MDE

Station	Free-Field Displacement (inches)	
	ODE	MDE
Wilshire/La Brea	0.25 inch in 50 feet	2.25 inch in 50 feet
Wilshire/Fairfax	0.4 inch in 50 feet	3.5 inch in 50 feet
Wilshire/La Cienega	0.3 inch in 50 feet	3 inch in 50 feet
Wilshire/Rodeo	0.4 inch in 55 feet	2.5 inch in 55 feet
Century City Contellation	0.5 inch in 75 feet	3.5 inch in 75 feet
Century City Santa Monica	0.3 inch in 50 feet	2 inch in 50 feet
Westwood/UCLA	0.3 inch in 50 feet	2.5 inch in 50 feet
Westwood/VA Hospital	0.25 inch in 50 feet	1.75 inch in 50 feet

It is noted that additional seismic CPTs will need to be performed in the Advanced Preliminary Engineering Phase (APE) to better characterize shear wave velocity profiles and to evaluate dynamic properties of the soils, particularly tar impacted soils. It is anticiapted that additional SHAKE runs will be performed in the APE phase to re-evalute the free-field displacement values presented in this report.

13.0 RECOMMENDATIONS FOR STATIONS

13.1 General

Seven stations are planned along the Project alignment. Five of these stations will be along Wilshire Boulevard, one station will be in Century City (either along Santa Monica Boulevard or Constellation Boulevard), and one station will be within the VA Hospital property. The stations will extend about 50 to 80 feet below the existing ground surface and require extensive shoring. The station excavations will be similar to the subterranean parking structures constructed beneath most of the high-rise buildings along the alignment. Therefore, much experience has been gathered over the years in constructing such subterranean structures that will be directly applicable to construction of the planned stations.

The entire excavation will be made before the mat foundation or the invert slab is placed and the rest of the permanent structure is subsequently built from the bottom up. Some form of temporary decking spanning the shoring elements will be placed at the street level to maintain surface traffic flow during station construction.

Station Excavation

The geologic formations that will be encountered within station excavation depths are shown on Plates 1-00 through 1-21. Within the planned depths of excavations for the stations, the following geologic units will be encountered in stratigraphically descending order: artificial fill, Younger Alluvium, Older Alluvium/Lakewood Formation, and San Pedro Formation. However, at the Wilshire/Rodeo, Westwood/UCLA, Westwood/VA Hospital, and Century City Santa Monica Boulevard Stations the excavations for stations will not encounter the San Pedro Formation. Siltstone bedrock of the Fernando Formation is not expected within excavations at any of the stations.

Cobbles and boulders were not observed in the borings. Based on the geologic understanding of the formations and their depositional characteristics, occasional cobbles or boulders may be encountered within excavations. If encountered in station excavations, these materials are not anticipated to pose any problems.

Excavations for the stations can be achieved with conventional heavy excavating equipment. Shoring could range from conventional soldier piles with lagging, secant piles to slurry wall construction. At the Wilshire/La Brea, Wilshire/Fairfax, Wilshire/La Cienega, and Westwood/UCLA Stations, where significant groundwater is anticipated, the use of slurry wall construction or tangent/secant piles for shoring could assist in reducing possible groundwater inflow.

Certain challenges will have to be addressed in conjunction with station excavation, such as the presence of major utility lines crossing the station footprint and the presence of existing tie back anchors from former basement constructions that protrude into the planned excavations at a number of station locations. Available records of building plans or tie-back installation records were provided to the PB Team in separate transmittals.

Groundwater

Groundwater was encountered at depths of 13 to greater than 70 feet bgs within the station footprints. Excavation of stations will require groundwater control ranging from the use of sump pumps to deep dewatering wells. The Wilshire/La Brea, Wilshire/Fairfax, Wilshire/La Cienega, and Westwood/UCLA Stations are expected to require dewatering using deep wells augmented with gravel-filled trenches and sumps. Water inflows into the excavation at the remaining stations are expected to be less, and dewatering wells might not be necessary at those stations, depending on the shallow groundwater conditions encountered at the time of excavation. Gravel-filled trenches and sumps still will be required as the excavation progresses and as perched water levels are encountered. Based on the data presented in this report, the dewatering requirements for each of the stations should be evaluated by the dewatering contractor.

Subsurface Gas Hazards and Tar Sands

The Wilshire/Fairfax Station is located within the City of Los Angeles' mapped "high potential (methane) risk zone" and "tar pit area." The Wilshire/La Brea and Century City Constellation Stations are located within the City of Los Angeles' "potential (methane) risk zone." Based on the ACE and PE phase investigations, high concentrations and gas pressures of methane and hydrogen sulfide were observed at the Wilshire/Fairfax Station, but not at Wilshire/La Brea or Century City Constellation Stations. However, since all of the stations are within designate "methane" zone, special provisions such as the use of impermeable membrane will need to be provided to prevent gas and/or water intrusion into the system. Several existing buildings in the vicinity of these stations were successfully constructed with subterranean depths comparable to the station depths.

Naturally occurring tar sands are present within geologic formations at the Wilshire/Fairfax Station. The Wilshire/La Brea Station is located 700 feet east of Cochran Avenue, and borings drilled at the station did not encounter tar-impacted soils.

Based on the borings drilled at the Wilshire/Fairfax Station, the tar content (by weight) varies from about 10 to 30 percent, with an average value of about 15 percent. Based on the analytical test results, tar sands were determined to be RCRA (Federal) non-hazardous waste and can be disposed after undergoing thermal treatment. Larger quantities of soil will likely require transport to a facility that accepts hydrocarbon-impacted soils. Investigations into the use of tar sand materials, such as for paving materials, is on-going, and will be studied further during subsequent design phases.

Fault Zones

The Santa Monica fault zone and the West Beverly Hills Lineament/Newport Inglewood fault zone will cross the Century City Santa Monica Station options (east and west, respectively). Therefore, both options would be located in active fault zones that are not considered viable for station locations. No evidence of faulting was found at the Century City Constellation Station site and therefore a station at this location is considered viable. The findings of the fault investigation are under review by the Metro Board of Directors; therefore this report provides recommendations for both Century City (Santa Monica east and Constellation) Station options.

Liquefaction Hazard

According to the California Geologic Survey Liquefaction Hazard maps (CDMG, 1998 and 1999 for Los Angeles and Beverly Hills, the Wilshire/La Cienega, Westwood/UCLA and Westwood/VA Hospital Stations are within the liquefaction zones. Therefore, site-specific liquefaction evaluation was performed for the three stations based on the Standard Penetration Test (SPT) blowcount data and Cone Penetration Test (CPT) data. The peak ground acceleration (PGA) used for ODE and MDE levels were 0.3g and 0.9g. The corresponding controlling earthquake magnitudes are 6.7 and 6.9, respectively.

A historic-high ground water level of 10, 20 and 30 feet below grade were used for Wilshire/La Cienega, Westwood/UCLA and Westwood/VA Hospital Stations, respectively, (California Division of Mines and Geology, 1998, revised 2001) in the liquefaction analysis.

The liquefaction potential was evaluated using the Youd and Idriss, 1997 (NCEER Technical Report 97-0022) consensus publication on liquefaction evaluation, and Youd et al., 2001 summary report from 1996 NCEER and 1998 NCEER/NSF workshop on evaluation of liquefaction resistance of soils. A summary of the liquefaction settlement for the three stations are presented in Sections 13-10, 13-14 and 13-15 and on Plates 5-1 through 5-3.

In Summary, the site-specific anlayses indicates there is no potential for liquefaction below the station foundations. A potential for liquefaction existing within the upper younger desposits at Wilshire/La Cienega and Westwood/UCLA Stations. Liquefaction-induced eath pressures on station walls will need to be considered in the design, if the soils are not remediated in-place. Ancillary structures can be supported on conventional spread footings within remediated soils or on deep pile foundations.

Soil and Groundwater Contamination

Based on the Phase II ESA study, suspect constituents of concern were detected in some soil and/or groundwater samples at five of the station locations: Wilshire/La Brea, Wilshire/Fairfax, Century City Constellation, Wilshire/La Cienega and Wilshire/Rodeo Stations. The constituents identified were related to releases of fuel compounds and/or chlorinated solvents or naturally occurring petroleum compounds. Therefore, excavated soils and groundwater from dewatering wells and sump pumps will have to be handled in accordance with applicable environmental regulations prior to disposal.

Foundation Support

Foundation soils at planned station depths are expected to be sufficiently firm to allow support of station structures on spread footings or a mat or quasi mat-type foundation system. Within the Wilshire/Fairfax Station footprint, where tar-impacted soils were encountered, special measures will be required to make subgrade soils suitable for support of spread footings or mat-type foundations. Such measures will include providing a waste slab at the bottom of the excavation to create a stable working platform for construction equipment.

Soil Corrosion Potential

Soil corrosion testing was performed by HDR-Schiff Associates on samples selected by AMEC during the ACE and PE phases. The corrosion test results are presented in Appendix F in Volume 3, Laboratory Test Results. The summary of the corrosion tests are presented in Tables F-1.1 through F-1.3 in Volume 3, Laboratory Test Results. The test results and soil corrosion mitigation measures for each station site are presented in reports prepared by HDR-Schiff Associates, as presented in Appendix F in Volume 3, Laboratory Test Results. The corrosion potential of the soils at each of the stations is discussed in the respective station recommendations section below.

According to Section 5.6.4 of the Metro Rail Design Criteria, any excavation support system in use for longer than 3 years should be designed as a permanent structure. Therefore, necessary corrosion protection should be provided for shoring if it is kept in use for longer than 3 years.

13.2 Lateral Pressures

Permanent Walls

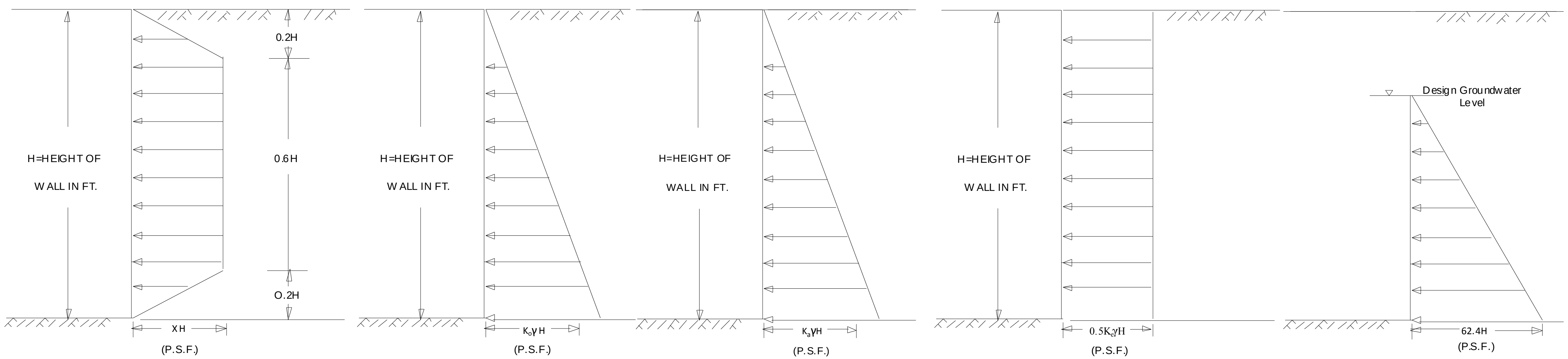
Section 5.6.4 of the Metro Rail Design Criteria indicates that buried permanent station walls should be designed for lateral at-rest earth pressures with a triangular distribution, as shown on Figure 13-1. Accordingly, the at-rest pressure coefficients applicable to each station are presented in the design summary sheets (Table 13-5 through Table 13-28).

Temporary Shoring

No specific specification is provided in the Metro Rail Design Criteria regarding lateral earth pressures for the design of temporary shoring. Typically, design of shoring for deep excavations is based on empirically derived trapezoidal lateral earth pressure distributions for shoring that is expected to undergo some deflection and some soil shear strength is mobilized, resulting in a near active pressure distribution. In fact, such trapezoidal pressure distributions were used for design of shoring for Metro stations for Segments 1 through 3 of the Metro Red Line and for the Gold Line Eastside extension.

For the Project, temporary shoring at the stations and crossover structures should be designed using the trapezoidal lateral earth pressure distribution, as shown in Figure 13-1. A pressure distribution of 30H may be used for shoring design for all stations except for the Wilshire/Fairfax Station where an earth pressure of 35H is recommended in recognition of unique characterisitics of the tar-impacted soils. Historically, for support of deep basement excavations along Wilshire Boulevard, significantly lower earth loading (20H to 24H)has been used successfully. These earth support systems have been typically tie-back soldier pile systems that tend to deflect sufficiently to allow mobilization of active earth pressure. Considering that excavations for Project stations will be supported with a more rigid internal bracing system that will be less prone to deflection, a greater earth pressure, as recommended here, would be prudent.

Figure 13-1: Earth Pressure Distribution



Shoring **Permanent Braced Walls** **Cantilever Walls** **Seismic Increment** **Hydrostatic**

Notes

1. X = 30 for all stations except, X = 35 for Wilshire/Fairfax Station

2. Total unit weight of soil (γ) for each station is provided in Table 13-5 through Table 13-28. For soils below groundwater, use buoyant unit weight (γ').

3. For both cantilevered and braced walls, the seismic increment is to be added to shoring distribution (for temporary) or cantilever wall distribution (for permanent)

4. The additional lateral earth pressure within liquefiable zones are provided on Plates 5-1 and 5-2 for the Wilshire/La Cienega and the Westwood/UCLA Stations, respectively

THIS PAGE INTENTIONALLY LEFT BLANK

Cantilevered Retaining Walls

It is expected that minor retaining walls will be required for at-grade structures, ramps, stairways, and other structures adjacent to the station. These retaining walls likely will be unrestrained and are considered as cantilever walls. Earth pressures for such walls should be based on the active pressure condition, and the design coefficients shown in Table 13-5 through Table 13-28 and pressure distribution as shown in Figure 13-1.

Hydrostatic Pressures

Permanent dewatering systems are not expected to be used for the Project stations. Therefore, portions of station walls below design groundwater level should be designed for hydrostatic pressures. In addition, if water-tight shoring systems, such as secant/tangent piles or a slurry wall construction method is used, hydrostatic pressures as recommended above should be added to the lateral earth pressures described above.

Current groundwater levels vary from about 12 feet to greater than 70 feet bgs. Groundwater levels will fluctuate over time, and since the subway will be in service for several decades, groundwater levels are expected to rise above current levels. Therefore, the historic high water levels presented in the design summary sheets and Table 13-1 should be used for design of station structures. Furthermore, station walls below grade should be waterproofed.

For the eight stations considered herein, the design water levels based on historic high readings (California Division of Mines and Geology, 1999) vary from 10 to 30 feet bgs. For comparison, the current and design groundwater levels at each of the station locations are presented in Table 13-1.

Table 13-1: Current and Historic High (Design) Groundwater Levels at Stations (in feet)

Station	Current Groundwater Level (below ground surface)	Historic High Groundwater Level (below ground surface)
Wilshire/La Brea	13.5 – 18	10
Wilshire/Fairfax	12.5 – 48	10
Wilshire/La Cienega	21.5 – 39.5	10
Wilshire/Rodeo	32 – 71	30
Century City Constellation	30 - 48	30
Century City Santa Monica	27 – 92.5	30
Westwood/UCLA	31.5 – 60	25
Westwood/VA Hospital	40 – 68	20

It is expected that minor retaining walls will not be located below the historic high water level. Minor retaining walls should be provided with wall drainage or weep holes to relieve water pressure.

Surcharge Pressures

Shoring, permanent walls below grade, and minor retaining walls should be designed to resist a uniform lateral pressure of 100 pounds per square foot due to HS20 traffic loading. Applicable surcharge pressures from adjacent buildings and foundations of minor structures should be estimated and added to the earth pressures stated above. Surcharge pressures from heavily loaded construction cranes and other traffic should be added to the above pressures.

The station roof also should be designed to resist the the weight of the overburden soil using the total unit weight of 125 pounds per cubic foot.

Seismic Earth Pressures

Minor retaining walls with a height of more than 12 feet and station walls and temporary shoring with more than 6 feet of unbalanced earth (where the difference in height of retained soil from one side of the structure to the other is greater than 6 feet) should be designed to support a seismic earth pressure. The seismic earth pressures should be computed using PGA for the ODE level. The seismic earth pressure coefficient (k_e) for each station is provided in the respective design summary sheets (Table 13-5 through Table 13-28). The seismic earth pressure computed in this manner will have a triangular pressure distribution. The equivalent uniform earth pressure may be computed as 50% of the triangular distribution, as shown in Figure 13-1 .

It is normal practice to add the seismic earth pressure (seismic increment) to the active pressures, such as for the design of temporary shoring. Since the station walls will be designed for an at-rest pressure condition or somewhere in between an active and at-rest condition, the seismic pressures computed should be added to the active pressures and checked against the at-rest pressures. The governing combination of active-plus-seismic or at-rest pressures with appropriate load factors should be used in the final design of shoring and permanent walls.

Furthermore, liquefaction-induced earth pressures shoud be considered in the design of permanent station walls unless the potentially liquefiable layers are remediated in-place. Liquefaction-induced earth pressure should be considered as equivalaent to that which would be produced by a fluid (triangular distribution) with a total unit weight of soil presented in the design summary sheets (Table 13-5 through Table 13-28). These additional pressures will apply only within the zone of liquefaction, as discussed further in the following sections.

13.3 Design Parameters

The following design parameters are provided on the design summary sheet prepared for each station:

- Bearing value, passive pressure coefficient (k_p), and coefficient of friction
- Unit modulus of subgrade reaction (K_s)for service, ODE, and MDE earthquake levels
- Current and design groundwater level
- Liquefaction potential
- Static (k_a) and seismic earth pressure coefficient (k_e) for station and minor cantilever walls and nearby cross passages
- Corrosion test results and mitigation measures
- Static and dynamic elastic modulus, poisson's ratio
- Shear wave velocity, peak ground acceleration, peak ground velocity for small strain, and ODE and MDE earthquake levels
- Free-field displacement between top and bottom of station box for ODE and MDE earthquake levels

More detailed geotechnical recommendations for each of the stations are provided in the following sections:

- Section 13.8 – Wilshire/La Brea Station
- Section 13.9 – Wilshire/Fairfax Station
- Section 13.10 – Wilshire/La Cienega Station
- Section 13.11 – Wilshire/Rodeo Station
- Section 13.12 – Century City Constellation Station
- Section 13.13 – Century City Santa Monica Station
- Section 13.14 – Westwood/UCLA
- Section 13.15 – Westwood/VA Hospital

13.4 Dewatering and Ground Settlement

Groundwater was encountered at depths of 12 to greater than 70 feet bgs, within the station footprints. Excavation of stations will require groundwater control to varying degrees ranging from use of gravel-filled trenches/sump pumps to deep dewatering wells at the discretion of the construction contractor. At least four stations, Wilshire/La Brea, Wilshire/Fairfax, Wilshire/La Cienega, and Westwood/UCLA, are currently expected to require dewatering using deep wells augmented by gravel-filled trenches and sumps.

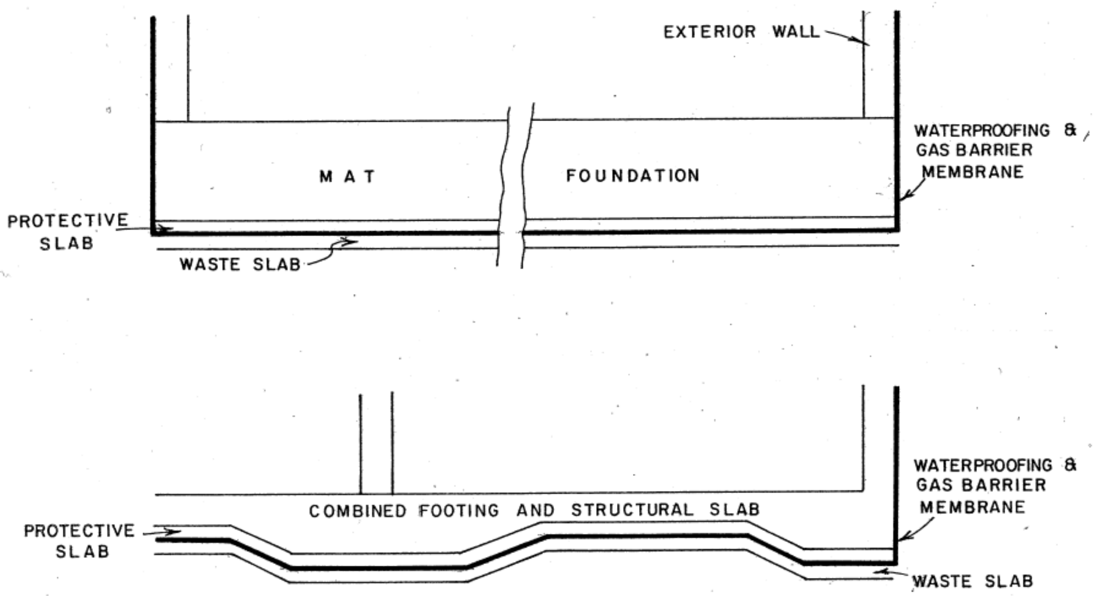
Given the soil stratigraphy and perched water conditions, a seepge flownet analysis to estimate water inflows would not be practical. However, based on prior experience on Wilshire Boulevard, water inflow rates of about 100 to 200 gallons per minute may be used for the preliminary design of dewatering wells. However, after a wet winter, the inflow rates could be higher; a further evaluation should be made closer to the time of excavation.

Significant settlement of adjacent properties due to dewatering is not anticipated because the soils have undergone multiple cycles of groundwater level flucations (high and low water levels) in the geologic past. Therefore, an increase in effective stress due to the dewatering for the station is not expected to result in significant settlement. Practical experience with construction along Wilshire Boulevard in the Project vicinity indicates that dewatering for 40- to 50-foot deep excavations has caused less than about 1 inch of settlement. However, since the station excavations extend as deep as 80 to 100 feet requiring extensive dewatering, settlement of settlement of properties adjacent to the stations cannot be precluded. It would be prudent to periodically monitor adjacent buildings during dewatering and station excavation

13.5 Mitigation Measures for Groundwater and Gassy Conditions

All of the stations will be constrcutred below current or design ground water level. It is anticipated that the stations will not be provided with subdrain system or permanent dewatering wells, therefore the station structure will have to be thoroughly waterproofed. In addition, stations are located within the City of Los Angeles Department of Building and Safety designated “methane zone”. Therefore, an impermeable membrane should be provided against water and/or gas intrusion into the system. The waterproofing/gas barrier material could consist of HDPE (High Density Polyethylene) or equivalent. For preliminary considerations, it is suggested that a water and gas barrier as presented below be used at all station locations. This type of system has been successfully used on all existing Metro Red and Purple line stations.

Figure 13-2: Waterproofing/Gas barrier



13.6 Construction Considerations

Based on the results of ACE and PE phase investigations and some of the hazards discussed earlier, the following construction considerations are typical for all station excavations and should be carefully evaluated. More station-specific considerations are provided in Sections 13.8 through 13.15.

- All station excavations will be made to varying degrees below groundwater, and soils encountered at the bottom of the excavation may be easily disturbed from construction equipment. Therefore, a layer of crushed rock or a waste slab (slurry slab) should be considered to stabilize the subgrade after excavation. Furthermore, a layer of BX1200 geogrid or equivalent could be used in conjunction with the gravel layers to provide additional protection against unstable subgrade conditions, particularly for heavy construction equipment.
- Existing tiebacks used for construction of adjacent buildings with subterranean levels may be projecting into the planned station excavation.
- A number of existing utilities such as storm drains, sewers, electrical conduits, and telecommunication lines are located underneath Wilshire Boulevard. All utilities will have to be carefully protected in place or relocated where possible.

- Ground settlement associated with dewatering should be properly evaluated. Existing utilities and buildings should be surveyed prior to the beginning of dewatering to periodically monitor the amount of ground settlement.
- Stations should be provided with a water-proofing and gas barrier (as needed).

13.7 Station Shoring Considerations Matrix

Based on the geologic materials, groundwater conditions, soil and groundwater contamination, existing buildings adjacent to the station excavations, and types of shoring method to enable excavation, a construction considerations matrix has been developed and is presented in Table 13-2. The table summarizes the factors affecting the decision-making to select type(s) of shoring systems for station and crossover excavation.

13.8 Wilshire/La Brea Station

13.8.1 General

The Wilshire/La Brea Station and the associated double crossover structure No. 10 is about 1,000 feet long and extends about 75 to 80 feet below Wilshire Boulevard from about South Orange Drive on the east to South Detroit Avenue on the west.

Existing buildings are located to the north and south of the station footprint at a lateral distance of about 10 to 20 feet from the station. The buildings have up to three subterranean levels extending to depths of about 25 to 30 feet below ground surface. The shoring systems for excavation support consisted of soldier piles and two levels of tieback anchors for deeper basements to enable construction of these buildings.

Information was presented in separate transmittals of available data from AMEC's files regarding depth of subterranean levels, the shoring system used for excavation support, and foundations of existing buildings for which AMEC had performed the geotechnical services during the original development of those buildings.

13.8.2 Field Explorations

A number of explorations were performed at and near the station location as part of the ACE and PE phases. In addition, explorations from prior investigations are located near the station. The applicable explorations, depths explored, and groundwater depths measured in these boreholes are presented in Table 13-3. The exploration locations are shown on Plate 1-04.

13.8.3 Soil and Groundwater Conditions

Subsurface conditions at the site consist of medium stiff to hard clays and silts interlayered with medium dense to very dense silty sands and sands and siltstone to depths of about 120.5 feet below ground surface. However, occasional zones of loose sands were encountered in the upper 20 feet. The soils beneath the station bottom consist of very stiff to hard clays and silts and dense to very dense sands of the San Pedro Formation. Siltstone bedrock of the Fernando Formation was encountered about 10 feet below the station bottom.

The Wilshire/La Brea Station is located 700 feet east of Cochran Avenue and borings drilled at the station did not encounter tar-impacted soils.

Groundwater levels were encountered as shallow as 13.5 feet below ground surface in groundwater monitoring wells and borings. Based on State of California published maps (California Division of Mines and Geology, 1999), the historic high groundwater level is a depth of about 10 feet below ground surface.

The design groundwater level for the station design should be taken as 10 feet below ground surface. Dewatering using deep wells and supplemented by gravel filled trenches and sumps are expected to be necessary prior to station excavations based on current groundwater measurements, but this should be reevaluated prior to construction by the dewatering contractor.

13.8.4 Soil Stratigraphy

Apart from the near-surface shallow (5- to 10-foot thick) fill and Younger Alluvium, the soil/bedrock stratigraphy at the station consists of about 30 to 50 feet of the Lakewood Formation overlying 35 to 45 feet of the San Pedro Formation underlain by the Fernando Formation. The station excavation will extend into the Lakewood and San Pedro Formations. Excavation in the Lakewood and San Pedro Formations can be performed using conventional earth-moving equipment. Siltstone bedrock of the Fernando Formation, which is located about 10 feet below the station bottom, will be encountered during installation of soldier piles. Hard drilling could be expected in siltstone bedrock due to the presence of occasional cemented zones/concretions.

13.8.5 Corrosion Potential

Corrosion testing for the on-site soils was performed by HDR-Schiff Associates Laboratory. The test results indicate that on-site soils are severely corrosive to ferrous metals, and aggressive to copper; sulfate attack on portland cement concrete is very severe. A corrosion mitigation report prepared by HDR-Schiff Associates and the laboratory test data are presented in Appendix F in Volume 3, Laboratory Test Results.

13.8.6 Liquefaction Potential

According to the California Geological Survey (CDMG, 1999), the site is not within an area identified as having a potential for liquefaction. Based on the dense/stiff nature of soils encountered in the borings drilled at the station location, the soils can be classified as pre-Holocene age material. Therefore, the potential for liquefaction is considered to be low.

13.8.7 Ground Motion Parameters

Based on the site-specific seismic CPT data, the small-strain shear wave velocity in the upper soils within station depths is estimated to be about 360 meters per second and the site can be classified as Site Class D (as defined by the California Building Code) for seismic design.

The Metro Rail Design Criteria defines two levels of earthquake ground motions for evaluation: the Maximum Design Earthquake (MDE) and the Operating Design Earthquake (ODE). The MDE and ODE risk levels are defined as the seismic ground motion with a 4% probability of exceedance in 100 years (corresponding to a return period of 2,475 years) and a 50% probability of exceedance in 100

Table 13-2: Station Shoring Considerations Matrix

Station	Geologic Units Expected In Excavations						Hazardous Gases	Contamination		Groundwater Control*		Excavation Support		
	Artificial Fill	Younger Alluvium	Older Alluvium	Lakewood	San Pedro	Tar-Impacted Soil	Methane and/or Hydrogen Sulfide	Soil	Groundwater	Dewatering Wells	Sump Pumps	Soldier Piles/Lagging	Secant Piles	Slurry Wall**
Wilshire/La Brea	X	X		X	X			X	X	X	X	X	X	X
Wilshire/Fairfax	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Wilshire/La Cienega	X	X	X		X				X	X	X	X	X	X
Wilshire/Rodeo	X	X	X						X		X	X	X	X
Century City Constellation	X		X	X	X		X	X	X		X	X	X	X
Century City Santa Monica	X	X	X								X	X	X	X
Westwood/UCLA	X	X	X	X						X	X	X	X	X
Westwood/VA Hospital		X	X								X	X	X	X

*Groundwater could be encountered in the future in larger quantities and higher elevations than currently observed; an additional assessment for the purpose of dewatering should be made by the dewatering contractor prior to excavation.
** Slurry wall method will be most effective at the Wilshire/La Brea, Wilshire/Fairfax, Wilshire/La Cienega and Westwood/UCLA Stations due to shallow groundwater conditions.

THIS PAGE INTENTIONALLY LEFT BLANK

Table 13-3: Subsurface Data for Wilshire/La Brea Station

Exploration Phase (Year)	Boring No.***	Boring Depth (feet)	Groundwater Depth (feet), Time after Drilling (or date/screen)
Prior (1984)	CWDD 18-2	95	Not Measured
Prior (1984)	CWDD 18-3	161	Not Measured
Prior (1984)	CWDD 18-4	95	Not Measured
Prior (1984)	CWDD 18-5	96	Not Measured
Prior (1984)	CWDD 18-6	80	Not Measured
Prior (1984)	CWDD 18-7	80	16, > 1 year
ACE (2009)	G-3	101	16, 25 minutes
ACE (2009)	G-4*	95	13.5 (shallow), 15.5 (deep)
ACE (2009)	M-3*	91	16.3, 5/14/11
ACE (2009)	M-4*	100	15.3, 5/14/11
ACE (2009)	M-5*	90	15.9, 5/13/11
PE (2011)	G-112	121	18, > 12 hours
PE (2011)	G-114	120	29, > 12 hours
PE (2011)	C-110	74.5	Not measured
PE (2011)	E-108	70.0	Not measured
PE (2011)	E-109	75.0	30**
PE (2011)	E-110	75.0	45**
PE (2011)	E-111	75.0	40**
PE (2011)	S-104	116.2	Not measured
PE (2011)	CB-101	85	57**

*monitoring wells installed in the borehole. See well diagrams in Appendix F for screen depths
**groundwater sample collected at this depth
*** C-series refers to cone penetration tests; CB-series refers to BAT® sampling cone penetration tests; CWDD-series refers to geotechnical borings by Converse Consultants; E-series refers to environmental borings; G-series refers to geotechnical borings; M-series refers to gas investigation borings; S-series refers to geotechnical sonic borings

years (corresponding to a return period of 150 years), respectively. A shear wave velocity of 560 meters per second was assumed for the San Pedro/Fernando Formations encountered below the station bottom in computing the ground motion parameters. The ground motion parameters are represented by recommended response spectra, computed probabilistically (using a Probabilistic Seismic Hazard Analysis, PSHA), for the two levels of motion; the results are shown in Table 13-4, as spectral ordinates in g's for the 5% damped response spectra:

Table 13-4: Response Spectra for Wilshire/La Brea Station

Earthquake Level	Latitude (degrees)	Longitude (degrees)	Formation	V_s (m/s)	Period (sec):	Spectral Accelerations (Sa)						
						0.01	0.10	0.20	0.30	0.50	1.00	2.00
ODE	34.0622	-118.3429	San Pedro/ Fernando	560	Sa (g):	0.26	0.52	0.63	0.56	0.41	0.22	0.10
MDE					Sa (g):	0.85	1.72	2.10	1.93	1.46	0.78	0.34

13.8.8 Recommendations

The following sections provide recommendations for the station design and other minor structures constructed outside the station.

13.8.8.1 Foundation Design

The station bottom is currently planned at a depth of up to about 80 feet below ground surface. The soils at the station depths are sufficiently firm to allow support of the station on spread footings or a mat or quasi mat-type foundation system. Settlement of the station supported on spread footings or a mat or quasi mat-type foundation system is expected to be less than ½ inch.

Minor structures such as ramps, stairways, and other structures ancillary to the stations can be supported on conventional spread footings bearing in properly compacted fill and/or undisturbed natural soils.

Design parameters for foundation design are presented in Table 13-5.

13.8.8.2 Excavation Support and Walls Below Grade

Considering the station is situated below existing streets and adjacent to existing buildings with subterranean levels, installation of tie-back anchors may not be feasible. Therefore, it is anticipated that station shoring will be internally braced. Nevertheless, tie-back anchors can be used in areas where the necessary space is available or permission can be obtained.

A conventional soldier pile/lagging system may be used, provided groundwater inflow into the excavation can be controlled. However, due to issues associated with contaminated groundwater, a relatively water-tight system, such as secant/tangent pile shoring or slurry wall construction, may be used for support of the station excavation to reduce the need to collect, possibly treat, and dispose of groundwater. Design parameters for shoring and permanent station walls are presented in Table 13-5. Recommended earth pressure distributions for design of shoring and station walls are shown in Figure 13-1

13.8.8.3 Groundwater Control

Since the station will extend about 60 to 70 feet below the current groundwater level, dewatering will be required for the station construction, particularly if the soldier pile/lagging option is used. Based on prior experience on Wilshire Boulevard, a water inflow rate of about 100 to 200 gallons per minute may be used for the preliminary design of dewatering wells. However, after a wet winter, the inflow rates could be higher; a further evaluation should be made closer to the time of excavation.

13.8.8.1 Construction Considerations

Analytical testing should be performed on samples of soil and groundwater from the dewatering system. Current results indicate that the soil and groundwater are contaminated and should be treated prior to disposal.

Due to shallow groundwater at the station, dewatering using deep wells will be required. This assessment is based on current groundwater measurements, but should be reevaluated prior to construction by the dewatering contractor. Even if a relatively impermeable shoring system is used, seepage into the excavation through the bottom will need to be anticipated.

Table 13-5: Geotechnical Design Parameters (Wilshire/La Brea Station)

Parameter	2009-2011 Geotechnical and Environmental Investigations						
		Estimated Range of Engineering Parameters[20]					
		Lakewood Formation (Qlw)		San Pedro Formation (Qsp)		Fernando Formation (Tf)	
Geologic Unit	Design Value	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Dry Unit Weight of Soil (pcf) [1]	102	97 -106 (100)	100 - 114 (107)	91 - 102 (97)	95 - 112 (103)	61 - 92 (81)	N/A
Total Unit Weight of Soil (pcf)[1]	124	121 - 133 (124)	120 - 128 (126)	119 - 129 (123)	119 - 132 (123)	96 - 118 (111)	N/A
Static Elastic Modulus (ksf)[2]	Varies	221-1,076 (460)	184-598 (340)	325-1,180 (560)	419-938 (580)	444-1,320 (630)	N/A
Unit Subgrade Modulus (k) (kcf)[3]		300 (small strain); 240 (ODE); 100 (MDE)					
Allowable Bearing Value (psf)	3,000[4], 8,000[5]	N/A					
Coefficient of Friction (μ)[6]	0.36	0.34 - 0.38 (0.36)					
Soil Pressure Coefficient, At-Rest Ko							
Bored Tunnel Section[7]	0.70	0.59 - 0.83 (0.70)					
Underground Station[8]	0.50	0.48 - 0.53 (0.50)					
Soil Pressure Coefficient, Active Ka[9]	0.33	0.32 - 0.40 (0.33)					
Soil Pressure Coefficient, Passive Kp[10]	2.5	1.85 - 2.5 (2.5)					
Soil Pressure Coefficient, Seismic Ke[11]	0.10	0.09 - 0.19 (0.10)					
Ground surface elevation (ft)[12]	Varies	196 - 200					
Groundwater Elevation (ft) [13]	190	186 - 190' (depth to historical high groundwater around 10' bgs)					
		178 - 186' (depth to current groundwater 13.5 - 18' bgs)					
Corrosivity Results[14]							
Minimum Resistivity (ohm-cm)	244	244 - 2,120					
pH	4	4 - 8					
Chloride Content (ppm or mg/kg)	888	2.4 - 888					
Sulfate Content (ppm or mg/kg)	6,509	14 - 6,509					
Poisson's Ratio[15]							
Unsaturated	0.33	0.32 - 0.34 (0.33)					
Saturated	0.35	0.33 - 0.37 (0.35)					

Table 13-5: Geotechnical Design Parameters (Wilshire/La Brea Station) (continued)

Parameter	2009-2011 Geotechnical and Environmental Investigations						
		Estimated Range of Engineering Parameters[20]					
		Lakewood Formation (Qlw)		San Pedro Formation (Qsp)		Fernando Formation (Tf)	
Geologic Unit	Design Value	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Liquefaction Potential (Yes or No)[13] Above Station bottom	No	See geotechnical report for further discussion					
Below Station bottom	No						
Dynamic Elastic Modulus (ksf)[16] Small Strain (Initial)	14,200	6,440 - 24,962 (14,200)					
ODE	9,545	4,330 -16,743 (9,545)					
MDE	1,455	659 - 2,553 (1,455)					
Shear Wave Velocity (fps)[16] Small Strain (Initial)	1,185	800 - 1,575 (1,185)					
ODE	975	656 - 1,290 (975)					
MDE	380	256 - 504 (380)					
Peak Ground Accel. (g)- Horiz.[17] ODE	0.26	0.26					
MDE	0.85	0.85					
Peak Ground Velocity (fps)- Horiz.[18] ODE	1.0	0.99					
MDE	3.5	3.53					
Free-Field Displacement for Station [19] ODE	0.25 inch in 50 feet	N/A					
MDE	2.25 inches in 50 feet						

N/A = Not Applicable
[1]Lab test data from PE phase investigation. Use submerged unit weight below design water level
[2]Based on 1% stress-strain relationship from Triaxial test results and relationship between elastic modulus and $N_{1,60}$ from Sabatini et al., (2002, P.148)
[3]Unit subgrade modulus for design of foundation for service, ODE, and MDE levels

[4]Spread footing supported on undisturbed natural and/or compacted fill (for minor structures). Increase the values by 30% for short-term seismic (ODE and MDE) and wind loads
[5]Mat foundation (or) large spread footings. Bearing value may be increased based on the foundation size, if commensurate settlement is acceptable. Increase the values by 30% for short-term seismic (ODE and MDE) and wind load conditions
[6]Coefficient of friction between mass concrete and subgrade soils
[7]Based on pressuremeter test results
[8]Based on site-specific shear strength data
[9,10]Active and passive earth pressure coefficients were based on laboratory shear strength data and AMEC's prior experience with similar soils along the alignment.
[11]Based on Mononobe-Okabe procedure and PGA for ODE
[12]Refer to Plate 1.04
[13]Estimated based on Seismic Hazard Zone Report for the Hollywood 7.5-minute Quadrangle, Los Angeles, California (1998)
[14]Design values are based on lowest resistivity, lowest pH, highest chloride and sulfate content test values
[15]Possion's Ratio was computed based on Duncan and Bursey (2007), CGPR#44, Virginia Tech
[16]Small Strain elastic modulus values were based on site-specific shear wave velocity of 1,185 foot per second and design Poission's Ratio of 0.35. ODE and MDE values were based on Table 19.2-1 of FEMA P- 750 (2009)
[17]PGA estimated in accordance with Chapter 2, Section 3 of LA Metro Design Code (2010)
[18]Based on PGV-S1 correlation (equations 13-1 and 13-2) of FHWA-NHI-10-034 (2009)
[19]Based on site-specific SHAKE analysis
[20]Average values are shown in parenthesis

13.9 Wilshire/Fairfax Station

13.9.1 General

The Wilshire/Fairfax Station is about 860 feet long and extends about 60 to 70 feet below Wilshire Boulevard from about 100 feet west of South Ogden Drive to 350 feet west of South Fairfax Avenue.

Existing buildings are located to the north and south of the station footprint at a lateral distance of about 10 to 20 feet from the station. The buildings have up to five subterranean levels extending to depths of up to about 65 feet below ground surface. The shoring systems for excavation support to enable construction of these buildings consisted of soldier piles and up to four levels of tieback anchors for deeper basements.

Information was presented in separate transmittals of available data from AMEC's files regarding depth of subterranean levels, the shoring system used for excavation support, and foundations of existing buildings for which AMEC had performed the geotechnical services during the original development of those buildings.

13.9.2 Field Explorations

A number of explorations were performed at and near the station location as part of the ACE and PE phases. In addition, explorations from prior investigations are located near the station. The applicable explorations, depths explored and groundwater depths measured in these boreholes are presented in Table 13-6. The exploration locations are shown on Plate 1-06.

13.9.3 Soil and Groundwater Conditions

Subsurface conditions at the site consist of medium stiff to stiff clays and silts interlayered with medium dense to dense silty sands and sands to a depth of about 20 to 25 feet below ground surface. Below this depth, tar-impacted soils (either tar sand or petroliferous silts or clays) and siltstone bedrock were encountered to depths of up to about 120 feet. Based on the blow counts, the tar-impacted soils classify as stiff to hard petroliferous silts and clays and dense to very dense tar sands. Siltstone bedrock of the Fernando Formation was encountered at depths of about 75 to 115 feet below ground surface.

The tar-impacted soils are primarily concentrated in the San Pedro and Fernando Formations and extend upward about 40 feet into the overlying Lakewood Formation and Older Alluvium. Based on the lab testing, tar content in the borings drilled at and near the station varies from about 5% to 30% (by weight) with an average of 15%. The greatest percentage of tar is present at depths of about 40 to 80 feet below ground surface.

Several gas monitoring wells were installed to measure the concentration of volatile organic compounds (VOCs) in the tar-impacted soils. Based on the monitoring well readings, the concentration of methane (CH_4) is up to about 100%. Hydrogen sulfide (H_2S) concentrations were measured to be up to about 6,500 ppm. Gas pressures were up to 844 inches of equivalent water height. A compilation of data collected in gas monitoring wells installed during the ACE and PE phases is presented in Tables 3-7 through 3-9 in Section 3 of this report.

Table 13-6: Subsurface Data for Wilshire/Fairfax Station

Exploration Phase (Year)	Boring No.**	Boring Depth (feet)	Groundwater Depth (feet), Time after Drilling (or date/screen)
Prior (1979)	4A (MA-79069)	102	13, 20 (heavy seepage)
Prior (1983)	1A (A-83353)	75	13, 5 days
Prior (1983)	1B (A-83353)	74	14, 3 days
Prior (1983)	6 (A-83353)	121	13, 5 days
Prior (1990)	8 (M L90123.ADEFO)	141	Not measured
Prior (1990)	3 (M 90192)	125	26, 25 minutes
ACE (2009)	G-5	101	16, 15 minutes
ACE (2009)	G-6*	81.5	12.5 (shallow), dry (deep)
ACE (2009)	G-7,7A	101, 150	Not measured
ACE (2009)	M-9	95	15.4
ACE (2009)	M-10	101	Not measured
ACE (2009)	M-11	101	Not measured
ACE (2009)	M-12	101	Not measured
PE (2011)	G-123	110	32, 15 minutes
PE (2011)	G-124	106	Not measured
PE (2011)	S-106*	122	17.5 (shallow), 48 (deep)
PE (2011)	CB-104	74	Not measured
PE (2011)	M-110	81	33.75 (shallow), 45.5 (deep)
PE (2011)	M-111*	81.5	22.8 (shallow), 45.5 (deep)
PE (2011)	M-112	70	Not measured
PE (2011)	M-113*	81.5	16.5 (shallow), 39.5 (deep)
PE (2011)	E-115	60.0	Not measured
PE (2011)	E-116	65.0	Not available
PE (2011)	E-117	55.0	Not encountered

*monitoring wells installed in the borehole. See well diagrams in Appendix F for screen depths
** C-series refers to cone penetration tests; CB-series refers to BAT® sampling cone penetration tests; E-series refers to environmental borings; G-series refers to geotechnical borings; M-series refers to gas investigation borings; S-series refers to geotechnical sonic borings; prior borings drilled by AMEC's predecessor companies and the Job No. is shown in parenthesis

Groundwater levels were encountered as shallow as 12.5 feet below ground surface in the groundwater monitoring wells and borings drilled within the station footprint. Based on State of California published maps (California Division of Mines and Geology, 1999), the historic high groundwater level is a depth of about 10 feet below ground surface.

The design groundwater level for the station design should be taken as 10 feet below ground surface. Station excavations will require dewatering prior to excavation.

13.9.4 Soil Stratigraphy

Apart from some localized fill, the soil/bedrock stratigraphy at the station primarily consists of about 15 to 40 feet of Older Alluvium/Lakewood Formation overlying about 55 to 100 feet of the San Pedro

Formation underlain by the Fernando Formation. The top of the Fernando Formation at the station location slopes down from the east to the west at depths of about 10 to 50 feet below the station bottom. The station excavation will extend into the Lakewood and San Pedro Formations and tar-impacted soils. Excavation in the Lakewood and San Pedro Formations can be performed using conventional earth-moving equipment. Siltstone bedrock of the Fernando Formation may be encountered during installation of soldier piles for shoring. Hard drilling could be expected in siltstone bedrock due to occasional cemented zones/concretions.

13.9.5 Soil Gas and Tar-impacted Soil

The site is immediately adjacent to the La Brea Tar Pits and overlies a portion of the Salt Lake Oil Field. The site is located within a City of Los Angeles mapped “high potential risk zone” for methane and “tar pit area.” The findings of the subsurface gas investigations conducted during the ACE and PE phases also support the current mapping of the station location by the City of Los Angeles as a “high risk zone” for methane.

Tar-impacted soils were encountered in borings to depths of about 15 to 130 feet below ground surface at the site. The tar content in the soils varies from about 5% to 30% with an average of 15%. Analytical testing of soil and groundwater samples collected from monitoring wells indicates they are contaminated due to high concentrations of TPH/VOCs. Although the analytical results indicate that the tar-impacted soils are RCRA non-hazardous waste, due to the high concentrations of TPH, they are not acceptable as a daily cover in landfill. The tar sand-impacted soils will have to be thermally treated prior to disposal at landfill sites. Additional testing on soil and groundwater should be performed during station excavation to determine the concentrations of constituents and evaluate disposal methods.

13.9.6 Corrosion Potential

Corrosion testing for the on-site soils was performed by HDR-Schiff Associates Laboratory. The test results indicate that on-site soils are severely corrosive to ferrous metals, and aggressive to copper; the potential for sulfate attack on portland cement concrete is considered very severe. A corrosion mitigation report prepared by HDR-Schiff Associates and the laboratory test data are presented in Appendix F in Volume 3, Laboratory Test Results.

13.9.7 Liquefaction Potential

According to the California Geological Survey (CDMG, 1999), the site is not within an area identified as having a potential for liquefaction. Based on the soils encountered in the borings drilled at the station location, the soils can be classified as pre-Holocene age material. Therefore, the potential for liquefaction is considered to be low.

13.9.8 Ground Motion Parameters

Based on the site-specific seismic CPT data, the small-strain shear wave velocity in the upper soils within station depths is estimated to be about 390 meters per second and the site can be classified as Site Class D (as defined by the California Building Code) for seismic design.

The Metro Rail Design Criteria defines two levels of earthquake ground motions for evaluation: the Maximum Design Earthquake (MDE) and the Operating Design Earthquake (ODE). The MDE and

ODE risk levels are defined as the seismic ground motion with a 4% probability of exceedance in 100 years (corresponding to a return period of 2,475 years) and a 50% probability of exceedance in 100 years (corresponding to a return period of 150 years), respectively. A shear wave velocity of 560 meters per second was assumed for San Pedro/Fernando Formations encountered below the station bottom in computing the ground motion parameters. The ground motion parameters are represented by recommended response spectra, computed probabilistically (using a Probabilistic Seismic Hazard Analysis, PSHA), for the two levels of motion; the results are shown in Table 13-7, as spectral ordinates in g's for the 5% damped response spectra:

Table 13-7: Response Spectra for Wilshire/Fairfax Station

Earthquake Level	Latitude (degrees)	Longitude (degrees)	Formation	V_s (m/s)	Period (sec):	Spectral Accelerations (Sa) 0.01	0.10	0.20	0.30	0.50	1.00	2.00
ODE	34.0630	-118.3614	San Pedro/ Fernando	560	Sa (g):	0.26	0.52	0.62	0.55	0.41	0.22	0.10
MDE					Sa (g):	0.85	1.72	2.10	1.92	1.46	0.78	0.35

13.9.9 Recommendations

The following sections provide recommendations for the station design and other minor structures constructed outside the station.

13.9.9.1 Foundation Design

The station bottom is currently planned at a depth of up to about 70 feet below ground surface. The soils at the station depths are sufficiently firm to allow support of the station on spread footings or a mat or quasi mat-type foundation system. Settlement of the station supported on spread footings or a mat or quasi mat-type foundation system is expected to be less than ½ inch.

Minor structures, such as ramps, stairways, and other structures ancillary to the stations, can be supported on conventional spread footings bearing in properly compacted fill and/or undisturbed natural soils.

Design parameters for foundation design are presented in Table 13-8.

13.9.9.2 Excavation Support and Walls Below Grade

Installation of shoring and excavation could expose contractors to methane and hydrogen sulfide. Although, this poses a high risk for the use of conventional shoring system, several parking garages have been successfully excavated and completed in the ground containing gases such as methane and hydrogen sulfide along Wilshire Boulevard, extending to depths of up to about 80 feet below ground surface. A conventional soldier pile/lagging with tieback anchors was used in a majority of these excavations; however, slurry walls were also used for some deep excavations. In addition, during the recent construction (in 2007) of a new museum building at the Los Angeles County Museum of Art, much less water than anticipated was pumped during dewatering. The low quantities of water were likely due to the shallower excavation depth and low permeability of the tar-impacted soils.

Metro

Table 13-8: Geotechnical Design Parameters (Wilshire/Fairfax Station)

Parameter	2009-2011 Geotechnical and Environmental Investigations						
		Estimated Range of Engineering Parameters[20]					
		Quaternary Older Alluvium (Qalo)		Lakewood Formation (Qlw)		San Pedro Formation (Qsp)	
Geologic Unit	Design Value	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Dry Unit Weight of Soil (pcf) [1]	103	96-107 (101)	109	87-112 (98)	108	79-110 (91)	95-121 (110)
Total Unit Weight of Soil (pcf)[1]	121	121-125 (123)	127	104-131 (118)	126	111-125 (116)	113-126 (118)
Static Elastic Modulus (ksf)[2]	Varies	120-752 (208)	394 - 473 (433)	185 - 273 (237)	NA	155-685 (375)	225-2,814 (783)
Unit Subgrade Modulus (k) (kcf)[3]	300 (small strain); 240 (ODE); 100 (MDE)						
Allowable Bearing Value (psf)	3,000[4], 8,000[5]	N/A					
Coefficient of Friction (μ)[6]	0.31	0.26-0.36 (0.31)					
Tar Content (% by weight)	9.6	3.7 - 18.5 (9.6)					
Soil Pressure Coefficient, At-Rest Ko							
Bored Tunnel Section[7]	0.92	0.72-1.12 (0.92)					
Underground Station[8]	0.55	0.50-0.63 (0.55)					
Soil Pressure Coefficient, Active Ka[9]	0.38	0.33-0.45 (0.38)					
Soil Pressure Coefficient, Passive Kp[10]	2.0	1.65 - 2.5 (2.5)					
Soil Pressure Coefficient, Seismic Ke[11]	0.10	0.10 - 0.12 (0.10)					
Ground surface elevation (ft)[12]	Varies	160 - 170					
Groundwater Elevation (ft) [13]	160	160' (depth to historical high groundwater around 10' bgs)					
		115 - 150' (depth to current groundwater 12.5 - 48' bgs)					
Corrosivity Results[14]							
Minimum Resistivity (ohm-cm)	520	520 - 26,400					
pH	3.3	3.3 - 8.2					
Chloride Content (ppm or mg/kg)	264	1.2 - 264					
Sulfate Content (ppm or mg/kg)	8,790	74 - 8,790					
Poisson's Ratio[15]							
Unsaturated	0.35	0.33 - 0.37 (0.35)					
Saturated	0.35	0.33 - 0.38 (0.35)					

Table 13-8: Geotechnical Design Parameters (Wilshire/Fairfax Station) (continued)

Parameter	2009-2011 Geotechnical and Environmental Investigations						
		Estimated Range of Engineering Parameters[20]					
		Quaternary Older Alluvium (Qalo)		Lakewood Formation (Qlw)		San Pedro Formation (Qsp)	
Geologic Unit	Design Value	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Liquefaction Potential (Yes or No)[13]							
Above Station bottom	No	See geotechnical report for further discussion					
Below Station bottom	No						
Dynamic Elastic Modulus (ksf)[16]							
Small Strain (Initial)	10,000	3,626-14,502 (10,000)					
ODE	6,770	2,438-9,752 (6,770)					
MDE	1,030	373-1,485 (1,030)					
Shear Wave Velocity (fps)[16]							
Small Strain (Initial)	1,000	600- 1,200 (1,000)					
ODE	820	492- 984 (820)					
MDE	320	192-384 (320)					
Peak Ground Accel. (g)- Horiz.[17]							
ODE	0.26	0.26					
MDE	0.85	0.85					
Peak Ground Velocity (fps)- Horiz.[18]							
ODE	1.01	1.01					
MDE	3.53	3.53					
Free-Field Displacement for Station[19]							
ODE	0.4 inch in 50 feet	N/A					
MDE	3.5 inches in 50 feet						

N/A = Not Applicable
[1]Lab test data from PE phase investigation. Use submerged unit weight below design water level
[2]Based on 1% stress-strain relationship from Triaxial test results and relationship between elastic modulus and $N_{1,60}$ from Sabatini et al., (2002, P.148)
[3]Unit subgrade modulus for design of foundation for service, ODE, and MDE levels

[4]Spread footing supported on undisturbed natural and/or compacted fill (for minor structures). Increase the values by 30% for short-term seismic (ODE and MDE) and wind loads
[5]Mat foundation (or) large spread footings. Bearing value may be increased based on the foundation size, if commensurate settlement is acceptable. Increase the values by 30% for short-term seismic (ODE and MDE) and wind load conditions
[6]Coefficient of friction between mass concrete and subgrade soils
[7]Based on pressuremeter test results
[8]Based on site-specific shear strength data
[9,10]Active and passive earth pressure coefficients were based on laboratory shear strength data and AMEC's prior experience with similar soils along the alignment.
[11]Based on Mononobe-Okabe procedure and PGA for ODE
[12]Refer to Plate 1.04
[13]Estimated based on Seismic Hazard Zone Report for the Hollywood 7.5-minute Quadrangle, Los Angeles, California (1998)
[14]Design values are based on lowest resistivity, lowest pH, highest chloride and sulfate content test values
[15]Possion's Ratio was computed based on Duncan and Bursey (2007), CGPR#44, Virginia Tech
[16]Small Strain elastic modulus values were based on site-specific shear wave velocity of 1,185 foot per second and design Poission's Ratio of 0.35. ODE and MDE values were based on Table 19.2-1 of FEMA P- 750 (2009)
[17]PGA estimated in accordance with Chapter 2, Section 3 of LA Metro Design Code (2010)
[18]Based on PGV-S1 correlation (equations 13-1 and 13-2) of FHWA-NHI-10-034 (2009)
[19]Based on site-specific SHAKE analysis
[20]Average values are shown in parenthesis

Considering the station is situated below existing streets and adjacent to existing buildings with subterranean levels, installation of tie-back anchors may not be feasible. Therefore, it is expected that station shoring will be internally braced. Nevertheless, tie-back anchors can be used in areas where the necessary space is available or permission can be obtained.

A conventional soldier pile/lagging system may be used, provided groundwater inflow into the excavation can be controlled. However, due to issues associated with contaminated groundwater, a relatively water-tight system, such as secant/tangent pile shoring or slurry wall construction, may be used for support of the station excavation to reduce the need to collect, possibly treat, and dispose of groundwater.

Design parameters for shoring and permanent walls are presented in Table 13-8. Recommended earth pressure distributions for design of shoring and station walls are shown in Figure 13-1.

13.9.9.3 Groundwater Control

Since the station will extend about 20 to 60 feet below the current groundwater level, dewatering will be required for station construction, particularly if a soldier pile/lagging option is used. Based on prior experience on Wilshire Boulevard, a water inflow rate of about 100 to 200 gallons per minute should be used for the preliminary design of dewatering wells. Water inflows could vary significantly, however, depending on groundwater conditions encountered at the time of excavation; the dewatering requirements should be evaluated by the dewatering contractor.

13.9.9.4 Construction Considerations

Due to shallow groundwater at the station, dewatering using deep wells may be required. This assessment is based on current groundwater measurements but should be reevaluated prior to construction by the dewatering contractor. However, even if a relatively impermeable shoring system is used, seepage into the excavation through the bottom will need to be anticipated.

Tar-impacted soils with a tar content of up to about 30% may be encountered during station excavation. Based on analytical testing, the tar-impacted soils are considered as RCRA non-hazardous. The excavated soils can be thermally treated before disposal or could be disposed of at Class I landfill (for example Kettleman Hills landfill) or could be used at a recycling facility for asphalt base or subbase.

Analytical testing should be performed on samples of soil and groundwater from the dewatering system. Current results indicate that the soil and groundwater are contaminated and should be treated prior to disposal.

Due the presence of tar in onsite soils, the bottom of the excavation may be soft and unstable under construction traffic, especially under a high ambient temperature expected during station construction. Therefore, a layer of crushed rock or a waste slab (slurry slab) may be placed after excavation to stabilize the subgrade. Furthermore, a layer of BX1200 geogrid or equivalent could be used in conjunction with the gravel layers to provide additional protection against unstable subgrade conditions, particularly under heavy construction equipment.

Station excavation and construction activities could expose workers to methane and hydrogen sulfide gases. Appropriate personal protective equipment (PPE) should be provided to all personnel in this environment.

Stations should be provided with a waterproofing and gas barrier.

13.10 Wilshire/La Cienega Station

13.10.1 General

The Wilshire/La Cienega Station and associated double crossover structure No. 10 is about 975 feet long and extends about 65 to 70 feet below Wilshire Boulevard from South Tower Drive on the east to South La Cienega Boulevard on the west.

Existing buildings are located to the north and south of the station footprint at a lateral distance of about 10 to 20 feet from the station. The buildings have up to three to four subterranean levels extending to depths of up to about 45 feet below ground surface. The shoring systems for excavation support to enable construction of these buildings consisted of soldier piles and up to two levels of tieback anchors for deeper basements.

Information was presented in separate transmittals of available data from AMEC's files regarding depth of subterranean levels, the shoring system used for excavation support, and foundations of existing buildings for which AMEC had performed the geotechnical services during the original development of those buildings.

13.10.2 Field Explorations

A number of explorations were performed at and near the station location as part of the ACE and PE phases. In addition, explorations from prior investigations are located near the station. The applicable explorations, the depths explored, and the groundwater depths measured in these boreholes are presented in Table 13-9. The exploration locations are shown on Plates 1-07 and 1-08.

13.10.3 Soil and Groundwater Conditions

Subsurface conditions at the site consist of medium stiff to hard clays and silts interlayered with medium dense to very dense silty sands and sands to depths of about 120 feet below ground surface. Soils beneath the station bottom consist of very stiff to hard clays and silts and dense to very dense sands of the San Pedro Formation.

Groundwater levels were encountered at a depth of about 21.5 feet in groundwater monitoring wells and borings, with seepage as shallow as 17.5 feet. Based on State of California published maps (California Division of Mines and Geology, 1999), the historic high groundwater level is at a depth of about 10 feet below ground surface.

The design groundwater level for the station design should be taken as 10 feet below ground surface. Dewatering using deep wells are expected to be necessary prior to station excavations based on current groundwater measurements, but this should be reevaluated prior to construction by the dewatering contractor.

Table 13-9: Subsurface Data for Wilshire/La Cienega Station

Exploration Phase (Year)	Boring No.***	Boring Depth (feet)	Groundwater Depth (feet), Time after Drilling (or date)
Prior (1969)	4 (MA-69086)	100.5	17.5, seepage
Prior (1969)	5 (MA-69086)	88	20, seepage
ACE (2009)	M-16*	100	39.6, 5/20/2011
ACE (2009)	M-17*	91	24.2, 5/18/2011
PE (2011)	G-127	112	41, >12 hours
PE (2011)	G-128	110	26, 12 hours
PE (2011)	G-129	120	30, 30 minutes
PE (2011)	G-130B	120	22, >12 hours
PE (2011)	G-131	121.5	21.5, >12 hours
PE (2011)	G-132	111.5	28, >12 hours
PE (2011)	S-107	122	Not measured
PE (2011)	C-112	120	Not measured
PE (2011)	E-120	70	63**
PE (2011)	E-121	65	63**
PE (2011)	E-122	65	43**

*monitoring wells installed in the borehole. See well diagrams in Appendix F for screen depths
** groundwater sample collected at this depth
*** C-series refers to cone penetration tests; E-series refers to environmental borings; G-series refers to geotechnical borings; M-series refers to gas investigation borings; S-series refers to geotechnical sonic borings; prior borings drilled by AMEC's predecessor companies and the Job No. is shown in parenthesis

13.10.4 Soil Stratigraphy

The soil/bedrock stratigraphy at the station consists of about 10 feet of fill and 10 to 30 feet of Younger/Older Alluvium underlain predominately by the San Pedro Formation. Older Alluvium about 10 to 15 feet thick will be encountered in the eastern portion of the station. About 40 to 50 feet of station excavation will be in the San Pedro Formation. Although excavation can be performed using conventional earth-moving equipment, some difficulty should be expected during installation of soldier piles for shoring in dense to very dense granular soils within the San Pedro Formation.

13.10.5 Corrosion Potential

Corrosion testing for on-site soils was performed by HDR-Schiff Associates Laboratory. The test results indicate that on-site soils are severely corrosive to ferrous metals and aggressive to copper; sulfate attack on portland cement concrete is considered to be moderate. A corrosion mitigation report prepared by HDR-Schiff Associates and the laboratory test data are presented in Appendix F in Volume 3, Laboratory Test Results.

13.10.6 Liquefaction Potential

According to the California Geological Survey (CDMG, 1999), the station site is within an area identified as having a potential for liquefaction. Therefore, a site-specific liquefaction evaluation was performed using blow count data from five borings and data from one CPT. The liquefaction evaluation was performed for the ODE level using a Magnitude of 6.5 and a PGA of 0.35g. The depths of the liquefiable layers and the liquefaction settlement within those layers are presented in Table 13-10 and also shown on Plate 5-1.

Table 13-10: Liquefaction Summary for Wilshire/La Cienega Station

Boring/CPT No.	Liquefiable Layers (depth below ground surface in feet)	Liquefaction Settlement (inches)
G-129	33 – 34	0.4
G-130	10 – 15 *	3.6
G-131	-	-
G-132	35 – 47.5	2.75
C-112	45.5 – 46.5	0.3

*layers above station roof

Based on these results, the potential for liquefaction underneath the station bottom is considered to be low. However, there is some potential for liquefaction in the upper soils. The CPT-based liquefaction evaluation indicates that the potential for settlement due to liquefaction is low compared to the SPT-based liquefaction settlement evaluation. Due to the frequency of the SPT sampling (at vertical spacings of about 5 feet), the thickness of the potentially liquefiable layers can be overestimated when using the SPT results, leading to a computation of greater liquefaction settlement. In contrast, the CPT provides a continuous stratigraphy of the subsurface conditions compared to the discrete SPT sampling in borings. Therefore, the CPT-based liquefaction settlement evaluation is considered to provide better-defined estimates of liquefaction-induced settlement than SPT-based liquefaction settlement evaluation. It is recommended that additional CPTs should be performed for this station at a spacing of 100 feet or less to further evaluate liquefaction potential and continuity of layers across the site.

If the liquefaction settlement in the upper soils is considered excessive for support of minor structures on spread footings, the soils can be remediated in-place using cement deep soil mixing or jet grouting. Alternatively, the minor structures could be supported on deep foundations such as drilled cast-in-place concrete piles bearing in non-liquefiable soils.

Due to the potentially liquefiable soils in the upper 45 feet, it is recommended that ancillary structures adjacent to the station be supported on separate foundations to reduce effects of differential settlements between the two structures. In addition, flexible connections should be used for utilities to accommodate differential settlements, particularly at points of entry to the station and at-grade ancillary structures.

13.10.7 Ground Motion Parameters

Based on the site-specific seismic CPT data, the small-strain shear wave velocity in the upper soils within station depths is estimated to be about 250 meters per second and the site can be classified as

Site Class D (as defined by the California Building Code) for seismic design of station and at-grade structures supported on soils remediated against liquefaction.

The Metro Rail Design Criteria defines two levels of earthquake ground motions for evaluation: the Maximum Design Earthquake (MDE) and the Operating Design Earthquake (ODE). The ground motion parameters for Maximum Design Earthquake (MDE) and Operating Design Earthquake (ODE) levels are presented below. The MDE and ODE risk levels are defined as the seismic ground motion with a 4% probability of exceedance in 100 years (corresponding to a return period of 2,475 years) and a 50% probability of exceedance in 100 years (corresponding to a return period of 150 years), respectively. A shear wave velocity of 300 meters per second was assumed for the alluvial soils encountered at the station location in computing the ground motion parameters. The ground motion parameters are represented by recommended response spectra, computed probabilistically (using a Probabilistic Seismic Hazard Analysis, PSHA), for the two levels of motion; the results are shown in Table 13-11, as spectral ordinates in g's for the 5% damped response spectra:

Table 13-11: Response Spectra for Wilshire/La Cienega Station

Earthquake Level	Latitude (degrees)	Longitude (degrees)	Formation	V_s (m/s)	Period (sec):	Spectral Accelerations (Sa) 0.01	0.10	0.20	0.30	0.50	1.00	2.00
ODE	34.0648	-118.3747	San Pedro	300	Sa (g):	0.30	0.53	0.68	0.66	0.55	0.33	0.16
MDE					Sa (g):	0.86	1.49	1.88	1.91	1.76	1.15	0.58

13.10.8 Recommendations

The following sections provide recommendations for the station design and other minor structures constructed outside the station.

13.10.8.1 Foundation Design

The station bottom is currently planned at a depth of about 70 feet below ground surface. The soils at the station depths are sufficiently firm to allow support of the station on spread footings or a mat or quasi mat-type foundation system. Settlement of the station supported on spread footings or a mat or quasi mat-type foundation system is anticipated to be less than ½ inch.

Due to the presence of potentially liquefiable layers at shallow depths, minor structures, such as ramps, stairways, and other structures ancillary to the stations, may be supported on conventional spread footings bearing in properly compacted fill and/or undisturbed natural soils only if the soils are remediated, as stated earlier. Alternatively, these structures will need to be supported on drilled cast-in-place concrete piles.

Design parameters for foundation design are presented in Table 13-12.

13.10.8.2 Excavation Support and Walls Below Grade

Considering the station is situated below existing streets and adjacent to existing buildings with subterranean levels, installation of tie-back anchors may not be feasible. Therefore, it is expected that station shoring will be internally braced. Nevertheless, tie-back anchors can be used in areas where the necessary space is available or permission can be obtained.

Table 13-12: Geotechnical Design Parameters (Wilshire/La Cienega Station)

Parameter	2009-2011 Geotechnical and Environmental Investigations						
		Estimated Range of Engineering Parameters[20]					
		Quaternary Younger Alluv. (Qal)		Quaternary Older Alluv. (Qalo)		San Pedro Formation (Qsp)	
Geologic Unit	Design Value	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Dry Unit Weight of Soil (pcf) [1]	101	90-101 (96)	104	107-108 (108)	92	78-114 (96)	92-120 (106)
Total Unit Weight of Soil (pcf)[1]	124	116-122 (119)	123	128-129 (129)	121	113-132 (123)	121-132 (126)
Static Elastic Modulus (ksf)[2]	Varies	110-205 (140)	398	123 - 458 (240)	478-1,013 (735)	83-562 (175)	209-1,165 (500)
Unit Subgrade Modulus (k) (kcf)[3]	300 (small strain); 240 (ODE); 100 (MDE)						
Allowable Bearing Value (psf)	3,000[4], 8,000[5]	N/A					
Coefficient of Friction (μ)[6]	0.30	0.22-0.43 (0.30)					
Soil Pressure Coefficient, At-Rest Ko							
Bored Tunnel Section[7]	0.67	0.58-0.79 (0.67)					
Underground Station[8]	0.55	0.43-0.66 (0.55)					
Soil Pressure Coefficient, Active Ka[9]	0.39	0.27-0.51 (0.39)					
Soil Pressure Coefficient, Passive Kp[10]	2.0	1.47 - 2.78 (2)					
Soil Pressure Coefficient, Seismic Ke[11]	0.10	0.0 - 0.20 (0.10)					
Ground surface elevation (ft)[12]	Varies	139 - 140					
Groundwater Elevation (ft) [13]		129-130 (depth to historical high groundwater around 10' bgs)					
	130	117.5 - 118.5 (depth to current groundwater 21.5 - 39.5' bgs)					
Corrosivity Results[14]							
Minimum Resistivity (ohm-cm)	480	480 - 1,760					
pH	7.4	7.4 - 8.1					
Chloride Content (ppm or mg/kg)	97	9 - 97					
Sulfate Content (ppm or mg/kg)	1,120	47 - 1,120					
Poisson's Ratio[15]							
Unsaturated	0.34	0.31 - 0.38 (0.34)					
Saturated	0.36	0.30 - 0.40 (0.36)					

Table 13-12: Geotechnical Design Parameters (Wilshire/La Cienega Station) (continued)

Parameter	2009-2011 Geotechnical and Environmental Investigations						
		Estimated Range of Engineering Parameters[20]					
		Quaternary Younger Alluv. (Qal)		Quaternary Older Alluv. (Qalo)		San Pedro Formation (Qsp)	
Geologic Unit	Design Value	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Liquefaction Potential (Yes or No)[13]							
Above Station bottom	Yes	See geotechnical report for further discussion					
Below Station bottom	No						
Dynamic Elastic Modulus (ksf)[16]							
Small Strain (Initial)	6,665	2,425-13,030 (6,665)					
ODE	4,200	1,528-8,208 (4,200)					
MDE	665	243-1,304 (665)					
Shear Wave Velocity (fps)[16]							
Small Strain (Initial)	815	491 - 1,138 (815)					
ODE	640	388-899 (640)					
MDE	260	157-364 (260)					
Peak Ground Accel. (g)- Horiz.[17]							
ODE	0.30	0.30					
MDE	0.86	0.86					
Peak Ground Velocity (fps)- Horiz.[18]							
ODE	1.47	1.47					
MDE	5.37	5.37					
Free-Field Displacement for Station [19]							
ODE	0.30 inch in 50 feet						
MDE	3.0 inches in 50 feet	N/A					

N/A = Not Applicable
[1]Lab test data from PE phase investigation. Use submerged unit weight below design water level
[2]Based on 1% stress-strain relationship from Triaxial test results and relationship between elastic modulus and $N_{1,60}$ from Sabatini et al., (2002, P.148)
[3]Unit subgrade modulus for design of foundation for service, ODE, and MDE levels

[4]Spread footing supported on undisturbed natural and/or compacted fill (for minor structures). Increase the values by 30% for short-term seismic (ODE and MDE) and wind loads
[5]Mat foundation (or) large spread footings. Bearing value may be increased based on the foundation size, if commensurate settlement is acceptable. Increase the values by 30% for short-term seismic (ODE and MDE) and wind load conditions
[6]Coefficient of friction between mass concrete and subgrade soils
[7]Based on pressuremeter test results
[8]Based on site-specific shear strength data
[9,10]Active and passive earth pressure coefficients were based on laboratory shear strength data and AMEC's prior experience with similar soils along the alignment.
[11]Based on Mononobe-Okabe procedure and PGA for ODE
[12]Refer to Plate 1.04
[13]Estimated based on Seismic Hazard Zone Report for the Hollywood 7.5-minute Quadrangle, Los Angeles, California (1998)
[14]Design values are based on lowest resistivity, lowest pH, highest chloride and sulfate content test values
[15]Possion's Ratio was computed based on Duncan and Bursey (2007), CGPR#44, Virginia Tech
[16]Small Strain elastic modulus values were based on site-specific shear wave velocity of 1,185 foot per second and design Poission's Ratio of 0.35. ODE and MDE values were based on Table 19.2-1 of FEMA P- 750 (2009)
[17]PGA estimated in accordance with Chapter 2, Section 3 of LA Metro Design Code (2010)
[18]Based on PGV-S1 correlation (equations 13-1 and 13-2) of FHWA-NHI-10-034 (2009)
[19]Based on site-specific SHAKE analysis
[20]Average values are shown in parenthesis

A conventional soldier pile/lagging system may be used, provided groundwater inflow into the excavation can be controlled. However, due to issues associated with contaminated groundwater, the use of a relatively water-tight system, such as secant/tangent pile shoring or slurry wall construction, may be more desirable for support of the station excavation to reduce the need to collect, possibly treat, and dispose of groundwater.

Design parameters for shoring and permanent station walls are presented in Table 13-12. Recommended earth pressure distributions for shoring and station walls are shown in Figure 13-1.

Based on the liquefaction results presented in Table 13-10, additional liquefaction-induced earth pressures between depths of about 35 to 45 feet below grade will occur on the station walls unless the potentially liquefiable layers are remediated in-place. Liquefaction-induced earth pressure should be considered as equivalent to that which would be produced by a fluid (triangular distribution) with a total unit weight as presented in Table 13-12 .

13.10.8.3 Groundwater Control

Since the station will extend about 30 to 50 feet below the current groundwater level, dewatering will be required for station construction, particularly if a soldier pile/lagging option is used. Based on prior experience on Wilshire Boulevard, a water inflow rate of about 100 to 200 gallons per minute may be used for the preliminary design of dewatering wells. Water inflows could vary significantly, however, depending on groundwater conditions encountered at the time of excavation; the dewatering requirements should be evaluated by the dewatering contractor.

13.10.8.4 Construction Considerations

Due to shallow groundwater at the station, dewatering using deep wells will be required. This assessment is based on current groundwater measurements but should be reevaluated prior to construction by the dewatering contractor. Even if a relatively impermeable shoring system is used, seepage into the excavation through the bottom will need to be anticipated.

Analytical testing should be performed on samples of groundwater extracted from the dewatering system. Current results indicate that groundwater is contaminated and should be treated prior to disposal.

13.11 Wilshire/Rodeo Station

13.11.1 General

The Wilshire/Rodeo Station is about 1,050 feet long and extends about 65 to 80 feet below Wilshire Boulevard from South Canon Drive on the east to South El Camino Drive on the west.

Existing buildings are located to the north and south of the station footprint. The buildings have up to five to six subterranean levels extending to depths of up to about 60 feet below ground surface. The shoring system for excavation supports consisted of soldier piles and likely up to six levels of tieback anchors for deeper basements to enable construction of these buildings.

Information was presented in separate transmittals of available data from AMEC's files regarding depth of subterranean levels, the shoring system used for excavation support, and foundations of existing buildings for which AMEC had performed the geotechnical services during the original development of those buildings.

13.11.2 Field Explorations

A number of explorations were performed at and near the station location as part of the ACE and PE phases. In addition, explorations from prior investigations are located near the station. The applicable explorations and the depths explored in these boreholes are listed in Table 13-13. The exploration locations are shown on Plates 1-09 and 1-10.

Table 13-13: Subsurface Data for Wilshire/Rodeo Station

Exploration Phase (Year)	Boring No.***	Boring Depth (feet)	Groundwater Depth (feet), Time after Drilling (or date)
Prior (1969)	5 (MA-69024)	78	41, Not available
Prior (1969)	6 (MA-69024)	75	42.5, Not available
Prior (1969)	7 (MA-69024)	60	43.5, Not available
ACE (2009)	G-11*	91.5	dry (shallow), 53.5 (deep)
ACE (2009)	G-12	81.5	28, 10 minutes
PE (2011)	G-143	91	38, 30 minutes
PE (2011)	G-144	121.5	53, 20 minutes
PE (2011)	G-145	121	71, >12 hours
PE (2011)	G-146	105	32, 2 weeks
PE (2011)	S-109	122	Not measured
PE (2011)	C-114	85	Not measured
PE (2011)	E-126	75	64**

*monitoring wells installed in the borehole. See well diagrams in Appendix F for screen depths.
** groundwater sample collected at this depth
*** C-series refers to cone penetration tests; E-series refers to environmental borings; G-series refers to geotechnical borings; S-series refers to geotechnical sonic borings; prior borings drilled by AMEC's predecessor companies and the Job No. is shown in parenthesis.

13.11.3 Soil and Groundwater Conditions

Subsurface conditions at the site consist of stiff to hard clays and silts and medium dense to very dense silty sands and sands to depths of about 121 feet below ground surface. The soils beneath the station bottom consist of very stiff to hard clays and silts and dense to very dense sands.

Groundwater levels were encountered at depths of about 32 to 71 feet in the borings with the shallowest water level at a depth of about 28 feet measured about 30 minutes after completion of boring and removal of drilling mud. Based on State of California published maps (California Division of Mines and Geology, 1999), the historic high groundwater level is a depth of about 30 feet below ground surface.

The design groundwater level for the station design should be taken as 30 feet below ground surface.

13.11.4 Soil Stratigraphy

The soil stratigraphy consists of about 10 to 30 feet of Younger Alluvium overlying more than 100 feet of Older Alluvium. The top of the San Pedro Formation is at about 15 to 35 feet below the station bottom. Excavation into alluvium can be performed using conventional earth-moving equipment. Some difficulty should be expected during installation of soldier pile for shoring in dense to very dense granular materials of the San Pedro Formation.

13.11.5 Corrosion Potential

Corrosion testing for on-site soils was performed by HDR-Schiff Associates Laboratory. The test results indicate that on-site soils are severely corrosive to ferrous metals and aggressive to copper; sulfate attack on portland cement concrete is considered to be moderate. A corrosion mitigation report prepared by HDR-Schiff Associates and the laboratory test data are presented in Appendix F in Volume 3, Laboratory Test Results.

13.11.6 Liquefaction Potential

According to the California Geological Survey (CDMG, 1999), the site is not within an area identified as having a potential for liquefaction. Based on the soils encountered in the borings drilled at the station location, the soils below the historic-high groundwater level can be classified as pre-Holocene age material. Therefore, the potential for liquefaction is considered to be low.

13.11.7 Ground Motion Parameters

Based on the site-specific seismic CPT data, the small-strain shear wave velocity in the upper soils within the station depths is estimated to be about 280 meters per second and the site can be classified as Site Class D (as defined by the California Building Code) for seismic design.

The Metro Rail Design Criteria defines two levels of earthquake ground motions for evaluation: the Maximum Design Earthquake (MDE) and the Operating Design Earthquake (ODE). The ground motion parameters for Maximum Design Earthquake (MDE) and Operating Design Earthquake (ODE) levels are presented below. The MDE and ODE risk levels are defined as the seismic ground motion with a 4% probability of exceedance in 100 years (corresponding to a return period of 2,475 years) and a 50% probability of exceedance in 100 years (corresponding to a return period of 150 years), respectively. A shear wave velocity of 300 meters per second was assumed for the alluvial soils encountered below the station bottom in computing the ground motion parameters. The ground motion parameters are represented by recommended response spectra, computed probabilistically (using a Probabilistic Seismic Hazard Analysis, PSHA), for the two levels of motion; the results are shown in Table 13-14, as spectral ordinates in g's for the 5% damped response spectra:

Table 13-14: Subsurface Data for Wilshire/Rodeo Station

Earthquake Level	Latitude (degrees)	Longitude (degrees)	Formation	V_s (m/s)	Period (sec):	Spectral Accelerations (Sa)						
						0.01	0.10	0.20	0.30	0.50	1.00	2.00
ODE	34.067	-118.399	Older Alluvium	300	Sa (g):	0.30	0.53	0.68	0.66	0.55	0.33	0.16
MDE					Sa (g):	0.91	1.55	1.94	2.00	1.87	1.26	0.63

13.11.8 Recommendations

The following sections provide recommendations for the station design and other minor structures constructed outside the station.

13.11.8.1 Foundation Design

The station bottom is currently planned at a depth of about 80 feet below ground surface. The soils at the station depths are sufficiently firm to allow support of the station on spread footings, or a mat or quasi mat-type foundation system. Settlement of the station supported on spread footings or a mat or quasi mat-type foundation system is anticipated to be less than ½ inch.

Minor structures, such as ramps, stairways, and other structures ancillary to the station, can be supported on conventional spread footings bearing in properly compacted fill and/or undisturbed natural soils.

Design parameters for foundation design are presented in Table 13-15.

13.11.8.2 Excavation Support and Walls Below Grade

Considering the station is situated below existing streets and adjacent to existing buildings with subterranean levels, installation of tie-back anchors may not be feasible. Therefore, it is expected that station shoring will be internally braced. Nevertheless, tie-back anchors can be used in areas where the necessary space is available or permission can be obtained.

Design parameters for shoring and permanent stations walls are presented in Table 13-15. Recommended earth pressure distributions for shoring and station walls are shown in Figure 13-1.

13.11.8.3 Groundwater Control

Since the station will extend about 10 to 50 feet below the current and historic high groundwater level, dewatering may be required for station construction. Excavation of stations will require groundwater control ranging from use of sump pumps to deep dewatering wells at the discretion of the construction contractor. At this station location, the need for dewatering wells is not expected if groundwater remains at current levels.

13.11.8.4 Construction Considerations

Analytical testing should be performed on groundwater collected from the dewatering systems. Current results indicate that groundwater is contaminated and should be treated prior to disposal.

Table 13-15: Geotechnical Design Parameters (Wilshire/Rodeo Station)

Parameter	2009-2011 Geotechnical and Environmental Investigations						
		Estimated Range of Engineering Parameters[20]					
		Quaternary Younger Alluv. (Qal)		Quaternary Older Alluv. (Qalo)		San Pedro Formation (Qsp)	
Geologic Unit	Design Value	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Dry Unit Weight of Soil (pcf) [1]	110	96-104 (101)	99-111 (105)	99-130 (109)	105-129 (116)	112	101-126 (115)
Total Unit Weight of Soil (pcf)[1]	125	115-124 (120)	120-1,32 (126)	122-141 (129)	121-141 (129)	116	122-137 (131)
Static Elastic Modulus (ksf)[2]	Varies	139-428 (220)	258-1,207 (525)	99-759 (193)	120-1,662 (668)	213	550-1,344 (710)
Unit Subgrade Modulus (k) (kcf)[3]	300 (small strain); 240 (ODE); 100 (MDE)						
Allowable Bearing Value (psf)	3000[4], 8000[5]	N/A					
Coefficient of Friction (μ)[6]	0.34	0.25-0.39 (0.34)					
Soil Pressure Coefficient, At-Rest Ko							
Bored Tunnel Section[7]	0.57	0.45-0.68 (0.57)					
Underground Station[8]	0.53	0.47-0.64 (0.53)					
Soil Pressure Coefficient, Active Ka[9]	0.36	0.31-0.47 (0.36)					
Soil Pressure Coefficient, Passive Kp[10]	2.0	1.59-2.44 (2)					
Soil Pressure Coefficient, Seismic Ke[11]	0.10	0.04-0.16 (0.1)					
Ground surface elevation (ft)[12]	Varies	220 - 231					
Groundwater Elevation (ft) [13]		190 - 201 (depth to historical high groundwater around 30' bgs)					
	195	160 - 168 (depth to current groundwater 32 - 71' bgs)					
Corrosivity Results[14]							
Minimum Resistivity (ohm-cm)	900	900 - 2,840					
pH	4	4 - 8.3					
Chloride Content (ppm or mg/kg)	20	2 - 20					
Sulfate Content (ppm or mg/kg)	122	12 - 122					
Poisson's Ratio[15]							
Unsaturated	0.33	0.31 - 0.37 (0.33)					
Saturated	0.35	0.32 - 0.39 (0.35)					

Table 13-15: Geotechnical Design Parameters (Wilshire/Rodeo Station) (continued)

Parameter	2009-2011 Geotechnical and Environmental Investigations						
		Estimated Range of Engineering Parameters[20]					
		Quaternary Younger Alluv. (Qal)		Quaternary Older Alluv. (Qalo)		San Pedro Formation (Qsp)	
Geologic Unit	Design Value	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Liquefaction Potential (Yes or No)[13]							
Above Station bottom	No	See geotechnical report for further discussion					
Below Station bottom	No						
Dynamic Elastic Modulus (ksf)[16]							
Small Strain (Initial)	8,560	5,265-12,665 (8,560)					
ODE	5,330	3,280-7,545(5,330)					
MDE	880	537-1,300 (880)					
Shear Wave Velocity (fps)[16]							
Small Strain (Initial)	920	723-1,122 (920)					
ODE	730	571-886 (730)					
MDE	295	231-359 (295)					
Peak Ground Accel. (g)- Horiz.[17]							
ODE	0.30	0.30					
MDE	0.91	0.91					
Peak Ground Velocity (fps)- Horiz.[18]							
ODE	1.49	1.49					
MDE	5.7	5.7					
Free-Field Displacement for Station [19]							
ODE	0.4 inch in 55 feet	N/A					
MDE	2.5 inches in 55 feet						

N/A = Not Applicable
[1]Lab test data from PE phase investigation. Use submerged unit weight below design water level
[2]Based on 1% stress-strain relationship from Triaxial test results and relationship between elastic modulus and $N_{1,60}$ from Sabatini et al., (2002, P.148)
[3]Unit subgrade modulus for design of foundation for service, ODE, and MDE levels

[4]Spread footing supported on undisturbed natural and/or compacted fill (for minor structures). Increase the values by 30% for short-term seismic (ODE and MDE) and wind loads
[5]Mat foundation (or) large spread footings. Bearing value may be increased based on the foundation size, if commensurate settlement is acceptable. Increase the values by 30% for short-term seismic (ODE and MDE) and wind load conditions
[6]Coefficient of friction between mass concrete and subgrade soils
[7]Based on pressuremeter test results
[8]Based on site-specific shear strength data
[9,10]Active and passive earth pressure coefficients were based on laboratory shear strength data and AMEC's prior experience with similar soils along the alignment.
[11]Based on Mononobe-Okabe procedure and PGA for ODE
[12]Refer to Plate 1.04
[13]Estimated based on Seismic Hazard Zone Report for the Hollywood 7.5-minute Quadrangle, Los Angeles, California (1998)
[14]Design values are based on lowest resistivity, lowest pH, highest chloride and sulfate content test values
[15]Possion's Ratio was computed based on Duncan and Bursey (2007), CGPR#44, Virginia Tech
[16]Small Strain elastic modulus values were based on site-specific shear wave velocity of 1,185 foot per second and design Poission's Ratio of 0.35. ODE and MDE values were based on Table 19.2-1 of FEMA P- 750 (2009)
[17]PGA estimated in accordance with Chapter 2, Section 3 of LA Metro Design Code (2010)
[18]Based on PGV-S1 correlation (equations 13-1 and 13-2) of FHWA-NHI-10-034 (2009)
[19]Based on site-specific SHAKE analysis
[20]Average values are shown in parenthesis

13.12 Century City Constellation Station

13.12.1 General

The Century City Constellation Station and the associated double crossover structure No. 10 is about 1,300 feet long and extends about 80 to 90 feet below Constellation Boulevard from Century Park East to 300 feet west of Avenue of the Stars.

Existing buildings are located to the north and south of the station footprint at a lateral distance of about 100 feet from the station. The buildings have subterranean levels extending to depths of up to about 100 feet below ground surface. The shoring system for excavation support consisted of soldier piles and up to 14 levels of tieback anchors for deeper basements to enable construction of these buildings.

Information was presented in separate transmittals of available data from AMEC's files regarding depth of subterranean levels, the shoring system used for excavation support, and foundations of existing buildings for which AMEC had performed the geotechnical services during the original development of those buildings.

13.12.2 Field Explorations

A number of explorations were performed at the station location as part of the ACE and PE phases. In addition, explorations from prior investigations are located near the station. The applicable explorations, depths explored, and groundwater depths measured in these boreholes are presented in Table 13-16. The exploration locations are shown on Plates 1-12 and 1-13.

13.12.3 Soil and Groundwater Conditions

Subsurface conditions at the site consist of about 5 to 30 feet of existing fill comprised of lean clay, silty clay, and silty sand. No debris was observed within the fill. Beneath the fill, natural soils consisting of dense to very dense silty sands and sands and stiff to hard clays and silts were encountered to depths of about 170 feet below ground surface. The soils beneath the station bottom consist of very stiff to hard clays and silts and very dense silty sands and sands of the San Pedro Formation.

Groundwater levels were encountered at depths of about 30 to 50 feet in nearby groundwater monitoring wells and borings. Based on State of California published maps (California Division of Mines and Geology, 1999), the historic high groundwater level is at a depth of about 30 feet below ground surface.

The design groundwater level for the station design should be taken as 30 feet below ground surface.

13.12.4 Soil Stratigraphy

Apart from existing fill that extends to about 5 to 30 feet below ground surface, the soil stratigraphy at the station consists of about 30 to 55 feet of the Lakewood Formation overlying the San Pedro Formation. The station excavation will extend into the Lakewood and San Pedro Formations. Excavation in the Lakewood and San Pedro Formations can be performed using conventional earth-

Table 13-16: Subsurface Data for Century City Constellation Station

Exploration Phase (Year)	Boring No.***	Boring Depth (feet)	Groundwater Depth (feet), Time after Drilling (or date)
Prior (1959)	22 (M 59446)	80	35
Prior (1966)	6 (MA-66362)	100	41 (seepage)
Prior (1968)	1 (MA-68111)	74	Not measured
Prior (1969)	1 (MA-69036)	175	Not measured
Prior (1969)	4 (MA-69036)	170	Not measured
Prior (1969)	5 (MA-69036)	170	28 (seepage), 84 (10 minutes)
Prior (1969)	9 (MA-69036)	120	No water, 30 minutes
Prior (1962)	2 (M 62353)	150	49 (seepage)
Prior (1979)	6 (M ADE-79167)	75.5	Not measured
Prior (1984)	3 (M ADE 84277)	101	Not measured
Prior (1984)	5 (M ADE 84277)	80	Not measured
Prior (1990)	3 (M L90354.ADEO)	75	58.5, 15 hrs after drilling
PE (2011)	G-168	112	Not measured
PE (2011)	G-169	121	48, 30 minutes
PE (2011)	M-119*	76	Not measured
PE (2011)	M-120*	Not drilled	N/A
PE (2011)	M-121*	Not drilled	N/A
PE (2011)	C-121	62	Not measured
PE (2011)	E-132	85	Not measured
PE (2011)	E-133	85	27**
PE (2011)	E-134	90	85**

*monitoring wells installed in the borehole. See well diagrams in Appendix F for screen depths
** groundwater sample collected at this depth
*** C-series refers to cone penetration tests; E-series refers to environmental borings; G-series refers to geotechnical borings; M-series refers to gas investigation borings; prior borings drilled by AMEC's predecessor companies and the Job No. is shown in parenthesis

moving equipment.. Hard drilling should also be expected during installation of soldier piles in dense to very dense granular deposits within the San Pedro Formation.

13.12.5 Soil Gas

The site is immediately adjacent to and overlies the Beverly Hills Oil Field. The site is located within a City of Los Angeles mapped "methane zone." The measured concentrations of methane, hydrogen sulfide and gas pressures were almost negligible suggesting no subsurface gas hazards at this station.

13.12.6 Corrosion Potential

Corrosion testing for on-site soils was performed by HDR-Schiff Associates Laboratory. The test results indicate that on-site soils are severely corrosive to ferrous metals and aggressive to copper; potential for sulfate attack on portland cement concrete is considered to be negligible. A corrosion mitigation report prepared by HDR-Schiff Associates along with the laboratory test data are presented in Appendix F in Volume 3, Laboratory Test Results.

13.12.7 Liquefaction Potential

According to the California Geological Survey (CDMG, 1999), the site is not within an area identified as having a potential for liquefaction. Based on the soils encountered in the borings drilled at the station location, the soils below the historic high groundwater level can be classified as pre-Holocene age material. Therefore, the potential for liquefaction is considered to be low.

13.12.8 Ground Motion Parameters

Based on the site-specific seismic CPT data, the small-strain shear wave velocity in the upper soils within station depths is estimated to be about 225 meters per second and the site can be classified as Site Class D (as defined by the California Building Code) for seismic design.

The Metro Rail Design Criteria defines two levels of earthquake ground motions for evaluation: the Maximum Design Earthquake (MDE) and the Operating Design Earthquake (ODE). The ground motion parameters for Maximum Design Earthquake (MDE) and Operating Design Earthquake (ODE) levels are presented below. The MDE and ODE risk levels are defined as the seismic ground motion with a 4% probability of exceedance in 100 years (corresponding to a return period of 2,475 years) and a 50% probability of exceedance in 100 years (corresponding to a return period of 150 years), respectively. A shear wave velocity of 300 meters per second was assumed for the Lakewood and San Pedro Formations encountered below the station bottom in computing the ground motion parameters. The ground motion parameters are represented by recommended response spectra, computed probabilistically (using a Probabilistic Seismic Hazard Analysis, PSHA), for the two levels of motion; the results are shown in Table 13-17, as spectral ordinates in g's for the 5% damped response spectra:

Table 13-17: Response Spectra for Century City Constellation Station

Earthquake Level	Latitude (degrees)	Longitude (degrees)	Formation	V_s (m/s)	Period (sec):	Spectral Accelerations (Sa) 0.01	0.1	0.2	0.3	0.5	1	2
ODE	34.0587	-118.4159	San Pedro	225	Sa (g):	0.30	0.50	0.64	0.65	0.57	0.38	0.20
MDE					Sa (g):	0.75	1.20	1.55	1.63	1.58	1.20	0.71

The ground motion values presented above are based on the 2008 USGS fault model. However, based on the recent discovery of strands of the Santa Monica fault zone and extension of the Newport-Inglewood fault zone in Century City, it is expected that ground motions will likely change. The locations of the new faults, slip rates, maximum expected earthquake magnitudes, and recurrence intervals of the earthquakes on these faults should be evaluated. Therefore, the ground motion values will need to be re-evaluated for this station as part of the APE phase.

13.12.9 Recommendations

The following sections provide recommendations for the station design and other minor structures constructed outside the station.

13.12.9.1 Foundation Design

The station bottom is currently planned at a depth of about 80 to 90 feet below ground surface. The soils at the station depths are sufficiently firm to allow support of the station on spread footings or a mat or quasi mat-type foundation system. Settlement of the station supported on spread footings or a mat or quasi mat-type foundation system is anticipated to be less than ½ inch.

Existing fill, up to about 30 feet thick, was encountered in the borings. Based on the densities and SPT blow count data obtained in the borings, it appears that the fill is moderately well compacted. At this time, it could not be determined if the existing fill is certified and if it is properly compacted fill placed under the supervision of a qualified geotechnical engineer. Therefore, support of minor structures, such as ramps, stairways, and other structures ancillary to the stations, on conventional spread footings bearing within the properly compacted fill is acceptable only if these fill soils are determined to be certified fill upon further review. Otherwise, existing fill soils will have to be removed underneath the minor structures and recompacted as properly compacted fill. Alternatively, minor structures may be supported on drilled cast-in-place concrete piles.

Design parameters for foundation design are presented in Table 13-18.

13.12.9.2 Excavation Support and Walls Below Grade

Considering the station is situated below existing streets and adjacent to existing buildings with subterranean levels, installation of tie-back anchors may not be feasible. Therefore, it is expected that station shoring will be internally braced. Nevertheless, tie-back anchors can be used in areas where the necessary space is available or permission can be obtained.

Design parameters for shoring and permanent station walls are presented in Table 13-18. Recommended earth pressure distributions for shoring and station walls are shown in Figure 13-1.

13.12.9.3 Groundwater Control

Since the station will extend about 40 to 60 feet below the current groundwater level, dewatering may be required for station construction. Based on prior experience along Wilshire Boulevard, deep basement excavation dewatering has been accomplished by pumping from a limited number of deep wells strategically located within the site and augmented by gravel-filled trenches and sumps throughout the excavation area.

Excavation of stations will require groundwater control ranging from use of sump pumps to deep dewatering wells at the discretion of the construction contractor. At this station location, the need for dewatering wells is not expected if groundwater remains at current levels.

13.12.9.4 Construction Considerations

Analytical testing should be performed on samples of excavated soil and groundwater from the dewatering system. Current results indicate that the soil and groundwater are contaminated and should be treated prior to disposal.

Stations should be provided with a waterproofing and gas barrier.

Table 13-18: Geotechnical Design Parameters (Century City Constellation Station)

Parameter	2009-2011 Geotechnical and Environmental Investigations									
	Design Value		Estimated Range of Engineering Parameters[20]							
			Fill (Af)		Quaternary Older Alluv. (Qalo)		Lakewood Formation (Qlw)		San Pedro Formation (Qsp)	
Geologic Unit	Fill	Native	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Dry Unit Weight of Soil (pcf)[1]	109	107	93 - 109 (100)	118	N/A	113	87 - 113 (101)	101 - 120 (109)	112 - 116 (114)	86 - 119 (99)
Total Unit Weight of Soil (pcf)[1]	130	125	117 - 128 (124)	136	N/A	127	115 - 134 (124)	120 - 136 (125)	131 - 133 (132)	111 -131 (119)
Static Elastic Modulus (ksf)[2]	325	Varies	116 - 269 (183)	465	N/A	864	196 - 558 (245)	731-1453 (1,148)	274 - 285 (279)	1,065-1,265 (1,159)
Unit Subgrade Modulus (k) (kcf)[3]	300 (small strain); 240 (ODE); 100 (MDE)									
Allowable Bearing Value (psf)	N/A	3,000[4], 8,000[5]	N/A		N/A					
Coefficient of Friction (μ)[6]	0.32	0.36	0.24 - 0.40 (0.32)		0.26 - 0.43 (0.36)					
Soil Pressure Coefficient, At-Rest Ko										
Bored Tunnel Section[7]	N/A	0.63	N/A		0.36 - 0.84 (0.63)					
Underground Station[8]	0.55	0.50	0.46 - 0.66 (0.55)		0.43 - 0.63 (0.50)					
Soil Pressure Coefficient, Active Ka[9]	0.38	0.33	0.29 - 0.49 (0.38)		0.27 - 0.45 (0.33)					
Soil Pressure Coefficient, Passive Kp[10]	2.00	2.50	1.53 - 2.55 (2.00)		1.65 - 2.77 (2.5)					
Soil Pressure Coefficient, Seismic Ke[11]	-	0.10	0.10							
Ground surface elevation (ft)[12]	Varies		284 - 292							
Groundwater Elevation (ft)[13]	262		254 - 262 (depth to historical high groundwater around 30' bgs)							
			244 - 250 (depth to current groundwater around 30 - 48' bgs)							

Table 13-18: Geotechnical Design Parameters (Century City Constellation Station) (continued)

Parameter	2009-2011 Geotechnical and Environmental Investigations									
	Design Value		Estimated Range of Engineering Parameters[20]							
			Fill (Af)		Quaternary Older Alluv. (Qalo)		Lakewood Formation (Qlw)		San Pedro Formation (Qsp)	
Geologic Unit	Fill	Native	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Corrosivity Results[14]										
Minimum Resistivity (ohm-cm)	640		640 - 3,040							
pH	7.3		7.3 - 8.2							
Chloride Content (ppm or mg/kg)	99		4 - 99							
Sulfate Content (ppm or mg/kg)	968		25 - 968							
Poisson's Ratio[15]										
Unsaturated	0.29	0.31	0.25 - 0.29 (0.29)		0.26 - 0.35 (0.31)					
Saturated	0.35	0.33	0.31 - 0.40 (0.35)		0.30 - 0.38 (0.33)					
Liquefaction Potential (Yes or No)[13]	No		See geotechnical report for further discussion							
Dynamic Elastic Modulus (ksf)[16]										
Small Strain (Initial)	5,360		3,623 - 7,271 (5,360)							
ODE	3,350		2,260 - 4,544 (3,350)							
MDE	730		497 - 999 (730)							
Shear Wave Velocity (fps)[16]										
Small Strain (Initial)	730		600 - 850 (730)							
ODE	575		474 - 672 (575)							
MDE	270		222 - 315 (270)							
Peak Ground Accel. (g)- Horiz.[17]										
ODE	0.30		0.30							
MDE	0.75		0.75							

Table 13-18: Geotechnical Design Parameters (Century City Constellation Station) (continued)

Parameter	2009-2011 Geotechnical and Environmental Investigations									
	Design Value		Estimated Range of Engineering Parameters[20]							
			Fill (Af)		Quaternary Older Alluv. (Qalo)		Lakewood Formation (Qlw)		San Pedro Formation (Qsp)	
Geologic Unit	Fill	Native	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Peak Ground Velocity (fps)- Horiz.[18]										
ODE	1.72		1.72							
MDE	5.48		5.48							
Free-Field Displacement for Station[19]										
ODE	0.5 inch in 75 feet									
MDE	3.5 inches in 75 feet		N/A							

N/A = Not Applicable

[1]Lab test data from PE phase investigation. Use submerged unit weight below design water level

[2]Based on 1% stress-strain relationship from Triaxial test results and relationship between elastic modulus and $N_{1,60}$ from Sabatini et al., (2002, P.148)

[3]Unit subgrade modulus for design of foundation for service, ODE, and MDE levels

[4]Spread footing supported on undisturbed natural and/or compacted fill (for minor structures). Increase the values by 30% for short-term seismic (ODE and MDE) and wind loads

[5]Mat foundation (or) large spread footings. Bearing value may be increased based on the foundation size, if commensurate settlement is acceptable. Increase the values by 30% for short-term seismic (ODE and MDE) and wind load conditions

[6]Coefficient of friction between mass concrete and subgrade soils

[7]Based on pressuremeter test results

[8]Based on site-specific shear strength data

[9,10]Active and passive earth pressure coefficients were based on laboratory shear strength data and AMEC's prior experience with similar soils along the alignment.

[11]Based on Mononobe-Okabe procedure and PGA for ODE

[12]Refer to Plate 1.04

[13]Estimated based on Seismic Hazard Zone Report for the Hollywood 7.5-minute Quadrangle, Los Angeles, California (1998)

[14]Design values are based on lowest resistivity, lowest pH, highest chloride and sulfate content test values

[15]Possion's Ratio was computed based on Duncan and Bursey (2007), CGPR#44, Virginia Tech

[16]Small Strain elastic modulus values were based on site-specific shear wave velocity of 1,185 foot per second and design Poission's Ratio of 0.35. ODE and MDE values were based on Table 19.2-1 of FEMA P- 750 (2009)

[17]PGA estimated in accordance with Chapter 2, Section 3 of LA Metro Design Code (2010)

[18]Based on PGV-S1 correlation (equations 13-1 and 13-2) of FHWA-NHI-10-034 (2009)

[19]Based on site-specific SHAKE analysis

[20]Average values are shown in parenthesis

13.13 Century City Santa Monica Station

13.13.1 General

The Century City Santa Monica Station and the associated double crossover structure No. 10 is about 1,300 feet long and extends about 70 to 90 feet below Santa Monica Boulevard from 500 feet east of Moreno Drive to about 200 feet west of Century Park West.

Existing buildings are located to the north and south of the station footprint at a lateral distance of about 50 to 100 feet from the station. The buildings have four to five subterranean levels extending to depths of up to about 40 feet below ground surface. The shoring systems for excavation support of existing buildings consisted of soldier piles and likely up to three to four levels of tieback anchors for deeper basements to enable construction of these buildings.

Information was presented in separate transmittals of available data from AMEC's files regarding depth of subterranean levels, the shoring system used for excavation support, and foundations of existing buildings for which AMEC had performed the geotechnical services during the original development of those buildings.

13.13.2 Field Explorations

A number of explorations were performed at and near the station location as part of the ACE and PE phases. In addition, explorations from prior investigations are located near the station. The applicable explorations, depths explored, and groundwater depths measured in these boreholes are presented in Table 13-19. The exploration locations are shown on Plate 1-19.

Table 13-19: Subsurface Data for Century City Santa Monica Station

Exploration Phase (Year)	Boring No.**	Boring Depth (feet)	Groundwater Depth (feet), Time after Drilling (or date)
Prior (1966)	4 (MA-66248)	120	85, 21 hours
Prior (1966)	11 (MA-66248)	100	90, seepage
Prior (1969)	1 (MA-69046)	80	72, 10 minutes
Prior (1969)	4 (MA-69046)	100	76, completion of drilling
ACE (2009)	M-18*	100	60, seepage
PE (2011)	G-154	86.5	50, 12 hours
PE (2011)	G-155	Not drilled	N/A
PE (2011)	T2-B10	79	groundwater not observed
PE (2011)	G-156*	121	27 (shallow), 45.5 (deep)
PE (2011)	T2E-B3	200	49, seepage
PE (2011)	T2E-B5	200	92.5, 15 hours
PE (2011)	T2E-B8	105	34.6, during drilling

*monitoring wells installed in the borehole. See well diagrams in Appendix F for screen depths
** G-series refers to geotechnical borings; M-series refers to gas investigation borings; T-series refers to transect borings for fault investigation; prior borings drilled by AMEC's predecessor companies and the Job No. is shown in parenthesis

13.13.3 Soil and Groundwater Conditions

Subsurface conditions at the site consist of about 5 feet of existing fill comprised of sandy silt and silty sand. No debris was observed within the fill. Beneath the fill, natural soils consisting of dense to very dense silty sands and sands and stiff to hard clays and silts were encountered to depths of about 200 feet below ground surface. The soils beneath the station bottom consist of very stiff to hard clays and silts and very dense silty sands and sands.

Groundwater levels were encountered at depths of about 27 to 92.5 feet in the borings and monitoring wells. Based on State of California published maps (California Division of Mines and Geology, 1999), the historic high groundwater level is a depth of about 30 feet below ground surface.

The design groundwater level for the station design should be taken as 30 feet below ground surface.

13.13.4 Soil Stratigraphy

The soil stratigraphy at the site consists of shallow existing fill and Younger Alluvium (about 5 feet thick) underlain by Older Alluvium. Excavation in Older Alluvium can be performed using conventional earth-moving equipment. Some difficulty should be expected during station excavation and during installation of soldier piles for shoring due to the presence of coarse gravel layers.

13.13.5 Geologic and Seismic Hazards

AMEC performed fault studies in Century City to evaluate the location of active faults in the vicinity of the Century City Santa Monica Station east and west options. The investigation was conducted for the Santa Monica fault zone and the West Beverly Hills Lineament/Newport Inglewood fault zone in Century City and the adjacent western portion of Beverly Hills. The findings of the fault studies indicate that both station options lie within active fault zones and are not considered as viable options for station locations. However, since the findings of the fault studies have not been reviewed by the Metro Board of Directors and a decision for not selecting this station location is still pending, recommendations for this station are included in this report.

13.13.6 Corrosion Potential

Corrosion testing for on-site soils was performed by HDR-Schiff Associates Laboratory. The test results indicate that on-site soils are severely corrosive to ferrous metals and aggressive to copper; the potential for sulfate attack on portland cement concrete is considered to be negligible. A corrosion mitigation report prepared by HDR-Schiff Associates and the laboratory test data are presented in Appendix F in Volume 3, Laboratory Test Results.

13.13.7 Liquefaction Potential

According to the California Geological Survey (CDMG, 1999), the site is not within an area identified as having a potential for liquefaction. Based on the soils encountered in the borings drilled at the station location, the soils below the historic high groundwater level can be classified as pre-Holocene age material. Therefore, the potential for liquefaction is considered to be low.

13.13.8 Ground Motion Parameters

Based on the seismic shear wave measurements from prior projects and shear wave velocity and blow count correlation, the small-strain shear wave velocity in the upper soils within station depths is estimated to be about 305 meters per second and the site can be classified as Site Class D (as defined by the California Building Code) for seismic design.

The Metro Rail Design Criteria defines two levels of earthquake ground motions for evaluation: the Maximum Design Earthquake (MDE) and the Operating Design Earthquake (ODE). The ground motion parameters for Maximum Design Earthquake (MDE) and Operating Design Earthquake (ODE) levels are presented below. The MDE and ODE risk levels are defined as the seismic ground motion with a 4% probability of exceedance in 100 years (corresponding to a return period of 2,475 years) and a 50% probability of exceedance in 100 years (corresponding to a return period of 150 years), respectively. A shear wave velocity of 305 meters per second was assumed for the Older Alluvium encountered below the station bottom in computing the ground motion parameters. The ground motion parameters are represented by recommended response spectra, computed probabilistically (using a Probabilistic Seismic Hazard Analysis, PSHA), for the two levels of motion; the results are shown in Table 13-20, as spectral ordinates in g's for the 5% damped response spectra:

Table 13-20: Response Spectra for Century City Santa Monica Station

Earthquake Level	Latitude (degrees)	Longitude (degrees)	Formation	V_s (m/s)	Period (sec):	Spectral Accelerations (Sa)						
						0.01	0.1	0.2	0.3	0.5	1	2
ODE	34.0635	-118.4151	Older Alluvium	305	Sa (g):	0.30	0.52	0.66	0.64	0.53	0.32	0.16
MDE					Sa (g):	0.88	1.48	1.86	1.93	1.82	1.23	0.62

The ground motion values presented above are based on the 2008 USGS fault model. However, based on the recent discovery of strands of the Santa Monica fault zone and an extension of the Newport-Inglewood fault zone in Century City, it is expected that the ground motions will likely change. The locations of the new faults, slip rates, maximum expected earthquake magnitudes, and recurrence intervals of the earthquakes on these faults should be evaluated. Therefore, the ground motion values will need to be re-evaluated during the APE phase for this station.

13.13.9 Recommendations

The following sections provide recommendations for the station design and other minor structures constructed outside the station. The hazard from potential fault plane displacement of active faults and their effects on the station design were not considered in providing the recommendations in the following sections.

13.13.9.1 Foundation Design

The station bottom is currently planned at a depth of about 70 to 85 feet below ground surface. The soils at the station depths are sufficiently firm to allow support of the station on spread footings or a mat or quasi mat-type foundation system. Settlement of the station supported on spread footings or a mat or quasi mat-type foundation system is expected to be less than ½ inch.

Design parameters for foundation design are presented in Table 13-21.

13.13.9.2 Excavation Support and Walls Below Grade

Considering the station is situated below existing streets and adjacent to existing buildings with subterranean levels, installation of tie-back anchors may not be feasible. Therefore, it is expected that station shoring will be internally braced. Nevertheless, tie-back anchors can be used in areas where the necessary space is available or permission can be obtained.

Design parameters for shoring and permanent station walls are presented in Table 13-21. Recommended earth pressure distributions for shoring and station walls are shown in Figure 13-1.

13.13.9.3 Groundwater Control

Since the station will extend about 55 feet below the current groundwater level, dewatering may be required for station construction. Excavation of stations will require groundwater control ranging from use of sump pumps to deep dewatering wells at the discretion of the construction contractor. At this station location, the need for dewatering wells is not expected if groundwater remains at current levels.

The existing 20-foot by 16-foot Benedict Canyon storm drain that runs along Marino Drive extends through the center of the station and the No. 10 double crossover. It is expected that the majority of the north-south canyon drainage will be conveyed through this storm drain box above the station ceiling elevation.

13.13.9.4 Construction Considerations

The existing 20-foot by 16-foot Benedict Canyon storm crosses the station and will be located above the station box. Considering the size of this storm drain, it can be either protected in place or realigned, if possible.

Artesian groundwater conditions should be expected near Santa Monica Boulevard in Century City and west of the station location. It is likely that the artesian pressure conditions are a result of the Santa Monica fault zone which essentially acts as groundwater barriers. Unanticipated high water inflows may be encountered during station excavation within certain perched water bearing zones.

13.14 Westwood/UCLA Station

13.14.1 General

The Westwood/UCLA Station is about 900 feet long and extends about 70 to 75 feet below Wilshire Boulevard from Westwood Boulevard on the east to about 150 feet east of Veteran Avenue.

Existing buildings are located to the north and south of the station footprint at a lateral distance of about 20 to 80 feet from the station. An existing UCLA parking lot is located to the north of the station. The existing buildings have up to five subterranean levels extending to depths of about 40 feet below ground surface. The shoring systems for excavation support consisted of soldier piles and up to four levels of tieback anchors for deeper basements to enable construction of these buildings.

Table 13-21: Geotechnical Design Parameters (Century City Santa Monica Station)

Parameter	2009-2011 Geotechnical and Environmental Investigations		
		Estimated Range of Engineering Parameters[20]	
		Quaternary Older Alluvium (Qalo)	
Geologic Unit	Design Value	Fine-Grained	Coarse-Grained
Dry Unit Weight of Soil (pcf) [1]	111	87 - 121 (105)	99 - 129 (116)
Total Unit Weight of Soil (pcf)[1]	128	115 - 135 (125)	120 - 142 (130)
Static Elastic Modulus (ksf)[2]	Varies	150 - 1,962 (375)	334 - 1,305 (795)
Unit Subgrade Modulus (k) (kcf)[3]	300 (small strain); 240 (ODE); 100 (MDE)		
Allowable Bearing Value (psf)	3,000[4], 8,000[5]	N/A	
Coefficient of Friction (μ)[6]	0.30	0.28 - 0.36 (0.30)	
Soil Pressure Coefficient, At-Rest Ko			
Bored Tunnel Section[7]	0.62	0.62	
Underground Station[8]	0.58	0.50 - 0.60 (0.58)	
Soil Pressure Coefficient, Active Ka[9]	0.41	0.33 - 0.43 (0.41)	
Soil Pressure Coefficient, Passive Kp[10]	2.0	1.75 - 2.26 (2.0)	
Soil Pressure Coefficient, Seismic Ke[11]	0.10	0.10	
Ground surface elevation (ft)[12]	Varies	269 - 279	
Groundwater Elevation (ft) [13]	249	239 - 249 (depth to historical high groundwater around 25' bgs)	
		224 - 225 (depth to current groundwater 27 - 92.5' bgs)	
Corrosivity Results[14]			
Minimum Resistivity (ohm-cm)	800	800 - 2,200	
pH	7.1	7.1 - 7.8	
Chloride Content (ppm or mg/kg)	29	5 - 29	
Sulfate Content (ppm or mg/kg)	120	16 - 120	
Poisson's Ratio[15]			
Unsaturated	0.34	0.26 - 0.35 (0.34)	
Saturated	0.37	0.33 - 0.38 (0.37)	

Table 13-21: Geotechnical Design Parameters (Century City Santa Monica Station) (continued)

Parameter	2009-2011 Geotechnical and Environmental Investigations		
		Estimated Range of Engineering Parameters[20]	
		Quaternary Older Alluvium (Qalo)	
Geologic Unit	Design Value	Fine-Grained	Coarse-Grained
Liquefaction Potential (Yes or No)[13]			
Above Station bottom	No	See geotechnical report for further discussion	
Below Station bottom	No		
Dynamic Elastic Modulus (ksf)[16]			
Small Strain (Initial)	10,210	6,535 - 14,706 (10,210)	
ODE	6,370	4,080 - 9,179 (6,370)	
MDE	1,047	669 - 1,507 (1,050)	
Shear Wave Velocity (fps)[16]			
Small Strain (Initial)	1,000	800 - 1,200 (1,000)	
ODE	790	632 - 948 (790)	
MDE	320	256 - 384 (320)	
Peak Ground Accel. (g)- Horiz.[17]			
ODE	0.30	0.30	
MDE	0.88	0.88	
Peak Ground Velocity (fps)- Horiz.[18]			
ODE	1.45	1.45	
MDE	5.58	5.58	
Free-Field Displacement for Station [19]			
ODE	0.3 inch in 50 feet	N/A	
MDE	2 inches in 50 feet		

N/A = Not Applicable
[1]Lab test data from PE phase investigation. Use submerged unit weight below design water level
[2]Based on 1% stress-strain relationship from Triaxial test results and relationship between elastic modulus and $N_{1,60}$ from Sabatini et al., (2002, P.148)
[3]Unit subgrade modulus for design of foundation for service, ODE, and MDE levels

[4]Spread footing supported on undisturbed natural and/or compacted fill (for minor structures). Increase the values by 30% for short-term seismic (ODE and MDE) and wind loads
[5]Mat foundation (or) large spread footings. Bearing value may be increased based on the foundation size, if commensurate settlement is acceptable. Increase the values by 30% for short-term seismic (ODE and MDE) and wind load conditions
[6]Coefficient of friction between mass concrete and subgrade soils
[7]Based on pressuremeter test results
[8]Based on site-specific shear strength data
[9,10]Active and passive earth pressure coefficients were based on laboratory shear strength data and AMEC's prior experience with similar soils along the alignment.
[11]Based on Mononobe-Okabe procedure and PGA for ODE
[12]Refer to Plate 1.04
[13]Estimated based on Seismic Hazard Zone Report for the Hollywood 7.5-minute Quadrangle, Los Angeles, California (1998)
[14]Design values are based on lowest resistivity, lowest pH, highest chloride and sulfate content test values
[15]Possion's Ratio was computed based on Duncan and Bursey (2007), CGPR#44, Virginia Tech
[16]Small Strain elastic modulus values were based on site-specific shear wave velocity of 1,185 foot per second and design Poission's Ratio of 0.35. ODE and MDE values were based on Table 19.2-1 of FEMA P- 750 (2009)
[17]PGA estimated in accordance with Chapter 2, Section 3 of LA Metro Design Code (2010)
[18]Based on PGV-S1 correlation (equations 13-1 and 13-2) of FHWA-NHI-10-034 (2009)
[19]Based on site-specific SHAKE analysis
[20]Average values are shown in parenthesis

Information was presented in separate transmittals of available data from AMEC's files regarding depth of subterranean levels, the shoring system used for excavation support, and foundations of existing buildings for which AMEC had performed the geotechnical services during the original development of those buildings.

13.14.2 Field Explorations

A number of explorations were performed at and near the station location as part of the ACE and PE phases. In addition, explorations from prior investigations are located near the station. The applicable explorations, depths explored, and groundwater depths measured in these boreholes are presented in Table 13-22. The exploration locations are shown on Plates 1-15 and 1-16.

Table 13-22: Subsurface Data for Westwood/UCLA Station

Exploration Phase (Year)	Boring No.***	Boring Depth (feet)	Groundwater Depth (feet), Time after Drilling (or date/screen)
Prior (1979)	1 (M ADE-79027)	101.5	44.5, 50 minutes
Prior (1979)	4* (M ADE-79027)	81	31.5, 1 month
Prior (1979)	8 (M ADE-79027)	101	34.5, 5 days
Prior (1989)	5 (M L89154.AB)	60	0, water overflowing
Prior (1989)	6 (M L89154.AB)	80	19.5, 30 minutes
PE (2011)	G-186*	121	48 (shallow)
PE (2011)	G-188	101	60, 12 hours
PE (2011)	G-189	121	38.5, 12 hours
PE (2011)	G-190	121	31.5, 12 hours
PE (2011)	G-191	121	43, 30 minutes
PE (2011)	S-114	120	Not measured
PE (2011)	C-124	93	Not measured
PE (2011)	E-126	75	64**

*monitoring wells installed in the borehole. See well diagrams in Appendix F for screen depths
** groundwater sample collected at this depth
*** C-series refers to cone penetration tests; E-series refers to environmental borings; G-series refers to geotechnical borings; S-series refers to geotechnical sonic borings; prior borings drilled by AMEC's predecessor companies and the Job No. is shown in parenthesis

13.14.3 Soil and Groundwater Conditions

Subsurface conditions at the site consist of shallow fill (5 feet thick) underlain by medium stiff to hard clays and silts interlayered with medium dense to very dense silty sands, sands and gravels to depths of about 121 feet below ground surface. However, some loose silty sands and sands were encountered in the upper 30 feet. The soils beneath the station bottom consist of very stiff to hard clays and silts and dense to very dense sands.

Groundwater levels were encountered at depths of about 31.5 to 60 feet in borings. In addition, a boring drilled in 1989 by LeRoy Crandall & Associates for the Armand Hammer Museum at Wilshire/Glendon had water overflowing from the borehole after completion of drilling. It was concluded that the water was draining from a confined aquifer located at a depth of about 50 feet. During excavation for the basement, significant quantities of water were encountered from the sandier zones. However, dewatering was performed using trenches and sump pumps rather than deep wells.

Based on the groundwater levels observed in the current monitoring wells and borings, it appears that the groundwater level is indicative of a perched condition within the sandier zones. A monitoring well installed in boring G-186 between depths of 25 and 35 feet did not encounter water; however, a deeper well installed between depths of 48 and 68 feet encountered water at about 48 feet below ground surface. AMEC also performed a pump test in pump well P-103 installed in sonic core boring S-114. Based on the pump rates, inflow rates of less than 3 gallons per minute were observed during pumping.

Based on State of California published maps (California Division of Mines and Geology, 1999), the historic high groundwater level is at a depth of about 25 feet below ground surface.

The design groundwater level for the station design should be taken as 25 feet below ground surface.

13.14.4 Soil Stratigraphy

Apart from a thin layer of fill, soil stratigraphy at the site consists of 10 to 45 feet of Younger Alluvium over 80 to 95 feet of Older Alluvium overlying the San Pedro Formation. Excavation will extend into Younger and Older Alluvium and can be performed using conventional earth-moving equipment. Some difficulty should be expected during station excavation and during installation of soldier piles for shoring due to the presence of coarse gravel layers.

13.14.5 Corrosion Potential

Corrosion testing for on-site soils was performed by HDR-Schiff Associates Laboratory. The test results indicate that the on-site soils are severely corrosive to ferrous metals and aggressive to copper; the potential for sulfate attack on portland cement concrete is negligible. A corrosion mitigation report prepared by HDR-Schiff Associates and the laboratory test data are presented in Appendix F in Volume 3, Laboratory Test Results.

13.14.6 Liquefaction Potential

According to the California Geological Survey (CDMG, 1999), the site lies within an area identified as having a potential for liquefaction. Therefore, a site-specific liquefaction evaluation was performed using blow count data from four borings and data from one CPT. The liquefaction evaluation was performed for the ODE level using a Magnitude of 6.7 and a PGA of 0.35g. The depths of the liquefaction layers and the liquefaction settlement within those layers for the ODE level are presented in Table 13-23 and also shown on Plate 5-2.

Based on these results, the potential for liquefaction underneath the station bottom is considered to be low. Although liquefaction was not observed in three of the borings, G-186 and C-124, which were performed near the west end of the station, indicate a potential for liquefaction at the depths indicated. In addition, the liquefiable layers appear to be somewhat continuous over the distance between G-186 and C-124. Therefore, liquefaction settlement and liquefaction-induced earth pressure on the station walls should be considered between depths of about 35 and 50 feet below grade.

Table 13-23: Liquefaction Summary for Westwood/UCLA Station

Boring/CPT No.	Liquefiable Layers (depth below ground surface in feet)	Liquefaction Settlement (inches)
G-186	35.5 – 38.5, 45 – 47.5	1, 0.7
G-189	-	-
G-190	-	-
G-191	-	-
C-124	34.5 – 36.5, 44 – 45, 46.5 – 50	0.6, 0.25, 0.7

Due to the frequency of the SPT sampling (at vertical spacings of about 5 feet), the thickness of the potentially liquefiable layers can be overestimated when using the SPT results, leading to a computation of greater liquefaction settlement. In contrast, the CPT provides a continuous stratigraphy of the subsurface conditions compared to the discrete SPT sampling in borings. Therefore, the CPT-based liquefaction settlement evaluation is considered to provide better-defined estimates of liquefaction-induced settlement than SPT-based liquefaction settlement evaluation. It is recommended that additional CPTs should be performed for this station at a spacing of 100 feet or less to further evaluate liquefaction potential and continuity of layers across the site. If the liquefaction settlement in the upper soils is considered excessive for support of minor structures on spread footings, the soils can be remediated in-place using cement deep soil mixing or jet grouting. Alternatively, the minor structures could be supported on deep foundations such as drilled cast-in-place concrete piles bearing in non-liquefiable soils.

Due to the potentially liquefiable soils in the upper 50 feet, it is recommended that ancillary structures adjacent to the station be supported on separate foundations to reduce effects of differential settlement between the two structures. In addition, flexible connections should be used for utilities to accommodate differential settlements, particularly at points of entry to the station and at-grade ancillary structures.

13.14.7 Ground Motion Parameters

Based on the site-specific seismic CPT data, the small-strain shear wave velocity in the upper soils within the station depths is estimated to be about 300 meters per second and the site can be classified as Site Class D (as defined by the California Building Code) for seismic design.

The Metro Rail Design Criteria defines two levels of earthquake ground motions for evaluation: the Maximum Design Earthquake (MDE) and the Operating Design Earthquake (ODE). The ground motion parameters for Maximum Design Earthquake (MDE) and Operating Design Earthquake (ODE) levels are presented below. The MDE and ODE risk levels are defined as the seismic ground motion with a 4% probability of exceedance in 100 years (corresponding to a return period of 2,475 years) and a 50% probability of exceedance in 100 years (corresponding to a return period of 150 years), respectively. A shear wave velocity of 300 meters per second was assumed for the alluvial soils encountered at the station location in estimating the ground motion parameters. The ground motion parameters are represented by recommended response spectra, computed probabilistically (using a Probabilistic Seismic Hazard Analysis, PSHA), for the two levels of motion; the results are shown in Table 13-24, as spectral ordinates in g's for the 5% damped response spectra:

Table 13-24: Response Spectra for Westwood/UCLA Station

Earthquake Level	Latitude (degrees)	Longitude (degrees)	Formation	V_s (m/s)	Period (sec):	Spectral Accelerations (Sa) 0.01	0.10	0.20	0.30	0.50	1.00	2.00
ODE	34.0583	-118.4460	Lakewood	300	Sa (g):	0.29	0.52	0.66	0.64	0.53	0.32	0.16
MDE					Sa (g):	0.88	1.50	1.86	1.92	1.78	1.19	0.60

13.14.8 Recommendations

The following sections provide recommendations for the station design and other minor structures constructed outside the station.

13.14.8.1 Foundation Design

The station bottom is currently planned at a depth of about 75 feet below ground surface. The soils at the station depths are sufficiently firm to allow support of the station on spread footings or a mat or quasi mat-type foundation system. Settlement of the station supported on spread footings or a mat or quasi mat-type foundation system is expected to be less than ½ inch.

Due to the presence of potentially liquefiable layers at shallow depths, minor structures, such as ramps, stairways, and other structures ancillary to the station, may be supported on conventional spread footings bearing in properly compacted fill and/or undisturbed natural soils only if the soils are remediated, as discussed earlier. Alternatively, these structures will have to be supported on drilled piles.

Design parameters for foundation design are presented in Table 13-25.

13.14.8.2 Excavation Support and Walls Below Grade

Considering the station is situated below existing streets and adjacent to existing buildings with subterranean levels, installation of tie-back anchors may not be feasible. Therefore, it is expected that station shoring will be internally braced. Nevertheless, tie-back anchors can be used in areas where the necessary space is available or permission can be obtained.

Design parameters for shoring and permanent station walls are presented in Table 13-25.

Based on the liquefaction results presented in Table 13-23, additional liquefaction-induced earth pressures between depths of about 35 to 50 feet below grade will be induced on the station walls unless the potentially liquefiable layers are remediated in-place. Liquefaction-induced earth pressure should be considered as equivalent to that which would be produced by a fluid (triangular distribution)with a total unit weight as presented in Table 13-25.

13.14.8.3 Groundwater Control

Since the station will extend about 15 to 45 feet below the current groundwater level, dewatering will be required for station construction. Based on prior experience along Wilshire Boulevard, deep basement excavation dewatering has been accomplished by pumping from a limited number of deep wells strategically located within the site and augmented by gravel-filled trenches and sumps throughout the excavation area. This technique was found to be satisfactory during the subterranean

Table 13-25: Geotechnical Design Parameters (Westwood/ UCLA Station)

Parameter	Design Value	2009-2011 Geotechnical and Environmental Investigations					
		Estimated Range of Engineering Parameters[20]					
		Quaternary Younger Alluvium (Qal)		Quaternary Older Alluvium (Qalo)		San Pedro Formation (Qsp)	
Geologic Unit		Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Dry Unit Weight of Soil (pcf) [1]	107	89-98 (93)	109-120 (117)	92-117 (103)	98-128 (113)	N/A	N/A
Total Unit Weight of Soil (pcf)[1]	125	109-123 (117)	126-136 (130)	117-135 (125)	114-143 (128)	N/A	N/A
Static Elastic Modulus (ksf)[2]	Varies	76-296 (170)	81-629 (320)	133-377 (250)	153-613 (470)	N/A	N/A
Unit Subgrade Modulus (k) (kcf)[3]	300 (small strain); 240 (ODE); 100 (MDE)						
Allowable Bearing Value (psf)	3,000[4], 8,000[5]	N/A					
Coefficient of Friction (μ)[6]	0.35	0.29-0.40 (0.35)					
Soil Pressure Coefficient, At-Rest Ko							
Bored Tunnel Section[7]	0.63	0.46-0.78 (0.63)					
Underground Station[8]	0.52	0.45-0.59 (0.52)					
Soil Pressure Coefficient, Active Ka[9]	0.35	0.29-0.42 (0.35)					
Soil Pressure Coefficient, Passive Kp[10]	2.5	1.78-2.54 (2.5)					
Soil Pressure Coefficient, Seismic Ke[11]	0.1	0.01 - 0.19 (0.1)					
Ground surface elevation (ft)[12]	Varies	302 - 308					
Groundwater Elevation (ft) [13]	283	277-283 (depth to historical high groundwater around 25' bgs)					
		258 - 276.5 (depth to current groundwater 31.5 - 60' bgs)					
Corrosivity Results[14]							
Minimum Resistivity (ohm-cm)	880	880 - 22,400					
pH	7.2	7.2 - 8.0					
Chloride Content (ppm or mg/kg)	22	2 - 22					
Sulfate Content (ppm or mg/kg)	103	6 - 103					
Poisson's Ratio[15]							
Unsaturated	0.33	0.32 - 0.35 (0.33)					
Saturated	0.34	0.31 - 0.37 (0.34)					

Table 13-25: Geotechnical Design Parameters (Westwood/ UCLA Station) (continued)

Parameter	2009-2011 Geotechnical and Environmental Investigations						
		Estimated Range of Engineering Parameters[20]					
		Quaternary Younger Alluvium (Qal)		Quaternary Older Alluvium (Qalo)		San Pedro Formation (Qsp)	
Geologic Unit	Design Value	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Liquefaction Potential (Yes or No)[13]							
Above Station bottom	Yes	See geotechnical report for further discussion					
Below Station bottom	No						
Dynamic Elastic Modulus (ksf)[16]							
Small Strain (Initial)	10,335	3,178 - 32,585 (10,335)					
ODE	6,615	2,034 - 20,843 (6615)					
MDE	1,055	324 - 3,339 (1055)					
Shear Wave Velocity (fps)[16]							
Small Strain (Initial)	1,010	560 - 1,793 (1010)					
ODE	805	448 - 1,434 (805)					
MDE	320	179 - 574 (320)					
Peak Ground Accel. (g)- Horiz.[17]							
ODE	0.29	0.29					
MDE	0.88	0.88					
Peak Ground Velocity (fps)- Horiz.[18]							
ODE	1.45	1.45					
MDE	5.40	5.40					
Free-Field Displacement for Station[19]							
ODE	0.3 inch in 50 feet	N/A					
MDE	2.5 inches in 50 feet						

N/A = Not Applicable
[1]Lab test data from PE phase investigation. Use submerged unit weight below design water level
[2]Based on 1% stress-strain relationship from Triaxial test results and relationship between elastic modulus and $N_{1,60}$ from Sabatini et al., (2002, P.148)
[3]Unit subgrade modulus for design of foundation for service, ODE, and MDE levels
[4]Spread footing supported on undisturbed natural and/or compacted fill (for minor structures). Increase the values by 30% for short-term seismic (ODE and MDE) and wind loads

[5]Mat foundation (or) large spread footings. Bearing value may be increased based on the foundation size, if commensurate settlement is acceptable. Increase the values by 30% for short-term seismic (ODE and MDE) and wind load conditions
[6]Coefficient of friction between mass concrete and subgrade soils
[7]Based on pressuremeter test results
[8]Based on site-specific shear strength data
[9,10]Active and passive earth pressure coefficients were based on laboratory shear strength data and AMEC's prior experience with similar soils along the alignment.
[11]Based on Mononobe-Okabe procedure and PGA for ODE
[12]Refer to Plate 1.04
[13]Estimated based on Seismic Hazard Zone Report for the Hollywood 7.5-minute Quadrangle, Los Angeles, California (1998)
[14]Design values are based on lowest resistivity, lowest pH, highest chloride and sulfate content test values
[15]Possion's Ratio was computed based on Duncan and Bursey (2007), CGPR#44, Virginia Tech
[16]Small Strain elastic modulus values were based on site-specific shear wave velocity of 1,185 foot per second and design Poission's Ratio of 0.35. ODE and MDE values were based on Table 19.2-1 of FEMA P- 750 (2009)
[17]PGA estimated in accordance with Chapter 2, Section 3 of LA Metro Design Code (2010)
[18]Based on PGV-S1 correlation (equations 13-1 and 13-2) of FHWA-NHI-10-034 (2009)
[19]Based on site-specific SHAKE analysis
[20]Average values are shown in parenthesis

excavation for the Armand Hammer Museum at Wilshire Boulevard and Glendon Avenue. Although significant quantities of water were encountered from the sandier zones, dewatering was only performed using trenches and sump pumps rather than deep wells.

However, considering that the water is under artesian condition in the deeper aquifer and that the station excavation will extend near the top of the aquifer and the shoring will be installed through the aquifer, it is expected that dewatering using deep wells will be needed for groundwater control. The dewatering requirements should be further evaluated by the dewatering contractor.

13.15 Westwood/VA Hospital Station

13.15.1 General

The Westwood/VA Hospital Station and the associated double crossover structure No. 645R is about 950 feet long and extends about 65 to 80 feet below ground surface. The majority of the station will be constructed in the north portion of the VA Hospital parking lot, immediately south of Wilshire Boulevard and east of Bonsalle Avenue. The station spans from about 50 feet east of the southbound Wilshire Boulevard on-ramp to the San Diego Freeway to about 100 feet west of Bonsalle Avenue. Since this station is the western terminus of the project alignment, a tail track about 600 feet west of the station and a vent shaft about 75 feet deep will be constructed at the western end.

The Westwood/VA Hospital Station will not be adjacent to any existing buildings or structures except for the existing Bonsalle Avenue Bridge undercrossing structure of Wilshire Boulevard, which is about 75 feet north of the station. Furthermore, the station is not underneath Wilshire Boulevard, which is a major thoroughfare with numerous buried utilities. The ground surface slopes from the east and west toward Bonsalle Avenue. Landscape and vegetation cover the western portion of the station and the tail track area.

13.15.2 Field Explorations

A number of explorations were performed at the station location as part of the ACE and PE phases. In addition, explorations from prior investigations are located near the station. The applicable explorations, the depths explored, and groundwater depths measured in these boreholes are presented in Table 13-26. The exploration locations are shown on Plates 1-16 and 1-17.

13.15.3 Soil and Groundwater Conditions

Subsurface conditions at the site consist of medium stiff to hard clays and silts in the upper 40 to 50 feet underlain by medium dense to very dense silty sands and sands to depths of about 121 feet below ground surface. However, some loose silty sands and sands were encountered at isolated depths in the upper 30 feet. The soils beneath the station bottom consist of dense to very dense sands with occasional very stiff to hard silts and clays.

Groundwater levels were encountered at a depth of about 68 feet in a groundwater monitoring well installed in Boring G-203. A shallower well installed in the boring between depths of about 0 and 40 feet did not encounter groundwater. The shallowest water level measured in the borings was at a depth of about 40 feet below ground surface.

Table 13-26: Subsurface Data for Westwood/VA Hospital Station

Exploration Phase (Year)	Boring No.**	Boring Depth (feet)	Groundwater Depth (feet), Time after Drilling (or date)
ACE (2009)	G-24	81.5	69, 10 minutes
PE (2011)	G-201	Not drilled	N/A
PE (2011)	G-203*	121.5	Dry (shallow), 68 (deeper)
PE (2011)	G-204	121.5	40, 12 hours
PE (2011)	G-205	121	60, 30 minutes
PE (2011)	S-115	122	Not measured
PE (2011)	C-127	70	Not measured
PE (2011)	M-124 (Not drilled)	N/A	N/A
PE (2011)	C-128A	64	Not measured
Caltrans/I-405	R-07-0007	101.5	Not measured
Caltrans/I-405	CPT-07-0018	44	Not measured

* monitoring wells installed in the borehole
** C- and CPT-series refer to cone penetration tests; G-series refers to geotechnical borings; M-series refers to gas investigation borings; S-series refers to geotechnical sonic borings; prior borings drilled by AMEC's predecessor companies and the Job No. is shown in the parenthesis; Caltrans/I-405 explorations are by Earth Mechanics, Inc.

Based on State of California published maps (California Division of Mines and Geology, 1999), the historic high groundwater level is a depth of about 20 to 25 feet below ground surface.

The design groundwater level for the station design should be taken as 20 feet below ground surface.

13.15.4 Soil Stratigraphy

Soils stratigraphy at the site consists of a thin layer of Younger Alluvium overlying deep older alluvial deposits. Excavation in Older Alluvium can be performed using conventional earth-moving equipment.

13.15.5 Corrosion Potential

Corrosion testing for on-site soils was performed by HDR-Schiff Associates Laboratory. The test results indicate that on-site soils are severely corrosive to ferrous metals and aggressive to copper; the potential for sulfate attack on portland cement concrete is considered to be moderate. A corrosion mitigation report prepared by HDR-Schiff Associates and the laboratory test data are presented in Appendix F in Volume 3, Laboratory Test Results.

13.15.6 Liquefaction Potential

According to the California Geological Survey (CDMG, 1999), the site lies within an area identified as having a potential for liquefaction. Therefore, a site-specific liquefaction evaluation was performed using blow count data from three borings and data from one CPT. The liquefaction evaluation was performed for the ODE level using a Magnitude of 6.7 and a PGA of 0.35g.

Based on the SPT and CPT-based calculations stated above, the potential for liquefaction and liquefaction-induced settlement is considered to be low. Both station and at-grade structures can be supported on spread or mat foundations.

13.15.7 Ground Motion Parameters

Based on the site-specific seismic CPT data, the small-strain shear wave velocity in the upper soils within station depths is estimated to be about 390 meters per second and the site can be classified as Site Class D (as defined by the California Building Code) for seismic design.

The Metro Rail Design Criteria defines two levels of earthquake ground motions for evaluation: the Maximum Design Earthquake (MDE) and the Operating Design Earthquake (ODE). The ground motion parameters for Maximum Design Earthquake (MDE) and Operating Design Earthquake (ODE) levels are presented below. The MDE and ODE risk levels are defined as the seismic ground motion with a 4% probability of exceedance in 100 years (corresponding to a return period of 2,475 years) and a 50% probability of exceedance in 100 years (corresponding to a return period of 150 years), respectively. A shear wave velocity of 300 meters per second was assumed for the alluvial soils encountered at the station location in computing the ground motion. The ground motion parameters are represented by recommended response spectra, computed probabilistically (using a Probabilistic Seismic Hazard Analysis, PSHA), for the two levels of motion; the results are shown in Table 13-27, as spectral ordinates in g's for the 5% damped response spectra:

Table 13-27: Response Spectra for Westwood/VA Hospital Station

Earthquake Level	Latitude (degrees)	Longitude (degrees)	Formation	V_s (m/s)	Period (sec):	Spectral Accelerations (Sa) 0.01	0.10	0.20	0.30	0.50	1.00	2.00
ODE	34.0546	-118.4537	Older Alluvium	390	Sa (g):	0.29	0.51	0.65	0.63	0.52	0.32	0.16
MDE					Sa (g):	0.88	1.48	1.85	1.90	1.76	1.19	0.59

13.15.8 Recommendations

The following sections provide recommendations for the station design and other minor structures constructed outside the station.

13.15.8.1 Foundation Design

The station bottom is currently planned at a depth of about 70 feet below ground surface. The soils at the station depths are sufficiently firm to allow support of the station on spread footings or a mat or quasi mat-type foundation system. Settlement of the station supported on spread footings or a mat or quasi mat-type foundation system is anticipated to be less than ½ inch.

Minor structures, such as ramps, stairways, and other structures ancillary to the station, may be supported on conventional spread footings bearing in properly compacted fill and/or undisturbed natural soils.

Design parameters for foundation design are presented in Table 13-28.

Metro

Table 13-28: Geotechnical Design Parameters (Westwood/VA Hospital Station)

Parameter	Design Value	2009-2011 Geotechnical and Environmental Investigations: Estimated Range of Engineering Parameters[20]					
Geologic Unit		Quaternary Younger Alluvium (Qal)		Quaternary Older Alluvium (Qalo)		San Pedro Formation (Qsp)	
		Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Dry Unit Weight of Soil (pcf) [1]	111	N/A	N/A	92-119 (108)	101 - 133 (115)	N/A	N/A
Total Unit Weight of Soil (pcf)[1]	128	N/A	N/A	116-134 (127)	113 - 146 (129)	N/A	N/A
Static Elastic Modulus (ksf)[2]	Varies	163	N/A	114-543 (217)	406-1,307 (666)	N/A	N/A
Unit Subgrade Modulus (k) (kcf)[3]	300 (small strain); 240 (ODE); 100 (MDE)						
Allowable Bearing Value (psf)	3,000[4], 8,000[5]	N/A					
Coefficient of Friction (μ)[6]	0.36	0.31 - 0.40 (0.36)					
Soil Pressure Coefficient, At-Rest Ko							
Bored Tunnel Section[7]	0.58	0.50 - 0.70 (0.58)					
Underground Station[8]	0.50	0.43-0.66 (0.50)					
Soil Pressure Coefficient, Active Ka[9]	0.33	0.29 - 0.40 (0.33)					
Soil Pressure Coefficient, Passive Kp[10]	2.50	1.92 - 2.55 (2.50)					
Soil Pressure Coefficient, Seismic Ke[11]	0.10	0.06 - 0.17 (0.10)					
Ground surface elevation (ft)[12]	Varies	320 - 327					
Groundwater Elevation (ft) [13]	307	300 - 307 (depth to historical high groundwater around 20' bgs)					
		258 - 282 (depth to current groundwater 40 - 68' bgs)					
Corrosivity Results[14]							
Minimum Resistivity (ohm-cm)	760	760 - 5,600					
pH	6.9	6.9 - 8.0					
Chloride Content (ppm or mg/kg)	242	2 - 242					
Sulfate Content (ppm or mg/kg)	559	7 - 559					
Poisson's Ratio[15]							
Unsaturated	0.37	0.30 - 0.43 (0.37)					
Saturated	0.33	0.31 - 0.36 (0.33)					

Table 13-28: Geotechnical Design Parameters (Westwood/VA Hospital Station) (continued)

Parameter	2009-2011 Geotechnical and Environmental Investigations						
	Design Value	Estimated Range of Engineering Parameters[20]					
		Quaternary Younger Alluvium (Qal)		Quaternary Older Alluvium (Qalo)		San Pedro Formation (Qsp)	
Geologic Unit		Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained
Liquefaction Potential (Yes or No)[13]							
Above Station bottom	Yes	See geotechnical report for further discussion					
Below Station bottom	No						
Dynamic Elastic Modulus (ksf)[16]							
Small Strain (Initial)	5,320	4,266 – 6,504 (5,319)					
ODE	3,385	2,722 – 4,147 (3,386)					
MDE	545	435 – 664 (545)					
Shear Wave Velocity (fps)[16]							
Small Strain (Initial)	725	651 – 804 (727)					
ODE	580	520 – 642 (580)					
MDE	233	208 – 257 (233)					
Peak Ground Accel. (g)- Horiz.[17]							
ODE	0.29	0.29					
MDE	0.73	0.73					
Peak Ground Velocity (fps)- Horiz.[18]							
ODE	168	1.68					
MDE	5.25	5.25					
Free-Field Displacement for Station [19]							
ODE	0.25 inch in 50 feet	N/A					
MDE	1.75 inches in 50 feet						

N/A = Not Applicable
[1]Lab test data from PE phase investigation. Use submerged unit weight below design water level
[2]Based on 1% stress-strain relationship from Triaxial test results and relationship between elastic modulus and $N_{1,60}$ from Sabatini et al., (2002, P.148)
[3]Unit subgrade modulus for design of foundation for service, ODE, and MDE levels
[4]Spread footing supported on undisturbed natural and/or compacted fill (for minor structures). Increase the values by 30% for short-term seismic (ODE and MDE) and wind loads

[5]Mat foundation (or) large spread footings. Bearing value may be increased based on the foundation size, if commensurate settlement is acceptable. Increase the values by 30% for short-term seismic (ODE and MDE) and wind load conditions
[6]Coefficient of friction between mass concrete and subgrade soils
[7]Based on pressuremeter test results
[8]Based on site-specific shear strength data
[9,10]Active and passive earth pressure coefficients were based on laboratory shear strength data and AMEC's prior experience with similar soils along the alignment.
[11]Based on Mononobe-Okabe procedure and PGA for ODE
[12]Refer to Plate 1.04
[13]Estimated based on Seismic Hazard Zone Report for the Hollywood 7.5-minute Quadrangle, Los Angeles, California (1998)
[14]Design values are based on lowest resistivity, lowest pH, highest chloride and sulfate content test values
[15]Possion's Ratio was computed based on Duncan and Bursey (2007), CGPR#44, Virginia Tech
[16]Small Strain elastic modulus values were based on site-specific shear wave velocity of 1,185 foot per second and design Poission's Ratio of 0.35. ODE and MDE values were based on Table 19.2-1 of FEMA P- 750 (2009)
[17]PGA estimated in accordance with Chapter 2, Section 3 of LA Metro Design Code (2010)
[18]Based on PGV-S1 correlation (equations 13-1 and 13-2) of FHWA-NHI-10-034 (2009)
[19]Based on site-specific SHAKE analysis
[20]Average values are shown in parenthesis

13.15.8.2 Excavation Support and Walls Below Grade

Considering that the station is located within an existing parking lot, conventional soldier piles with lagging and tie back anchors may be used for excavation support.

Design parameters for shoring and permanent wall design are presented in Table 13-28.

13.15.8.3 Groundwater Control

Since the station will extend about 5 to 30 feet below the current groundwater levels, dewatering may be required for station construction. Based on prior experience along the Wilshire Boulevard corridor, deep basement excavation dewatering has been accomplished by pumping from a limited number of deep wells strategically located within the site and augmented by gravel-filled trenches and sumps throughout the excavation area.

Excavation of stations will require groundwater control ranging from the use of sump pumps to deep dewatering wells at the discretion of the construction contractor. At this station location, the need for dewatering wells is not expected if groundwater remains at current levels.

THIS PAGE INTENTIONALLY LEFT BLANK

14.0 REFERENCES

AMEC, 2011, "Century City Area Fault Investigation Report, Westside Subway Extension, Los Angles, California," report dated October 14, 2011.

Barrows, A. G., 1974, "A Review of the Geology and Earthquake History of the Newport-Inglewood Structural Zone, Southern California," California Division of Mines and Geology Special Report 114.

Bryant, W. A., (compiler), 2005, "Digital Database of Quaternary and Younger Faults from the Fault Activity Map of California, Version 2.0," California Geological Survey Web Page, http://www.conrv.ca.gov/CGS/information/publications/QuaternaryFaults_ver2.htm> 8-13-07

California Department of Water Resources, 2004, "California's Groundwater Bulletin 118-Los Angeles County Coastal Plain West Coast Basin," Updated 2/27/04, Website: http://www.dpla.water.ca.gov/publications/groundwater/bulletin118/basins/pdfs-desc/4-11.03.pdf

California Department of Water Resources, 1961, "Planned Utilization of the Groundwater Basins of the Coastal Plain of Los Angeles County, App. A, Groundwater Geology," Bulletin 104.

California Division of Oil and Gas Sacramento (USA), 1974, "California Oil and Gas Fields, Volume II, South, Central Coastal and Offshore California," California," January 1, 1974, Publication Number TR-1

California Division of Mines and Geology, 1999a, "State of California Seismic Hazard Zones, Beverly Hills Quadrangle, Official Map," released March 25, 1999.

California Division of Mines and Geology, 1999b, "State of California Seismic Hazard Zones, Hollywood Quadrange Official Map

California Division of Mines and Geology, 1998a, "Seismic Hazard Evaluation of the Beverly Hills 7.5 Minute Quadrangle, Los Angeles County, California," Seismic Hazard Zone Report 023, updated figure 3.5 in 2005.

California Division of Mines and Geology, 1998b, "Seismic Hazard Evaluation of the Hollywood 7.5-Minute Quadrangle, Los Angeles County, California," CDMG Open-File Report 98-17

California Geological Survey, 2003, "CGS Bulletin 118," http://www.groundwater.water.ca.gov/bulletin118/index.cfm

Catchings, R. D., Gandhok, G., Goldman, M. R., and Okaya, D., 2001, "Seismic Image and Fault Relations of the Santa Monica Thrust Fault, West Los Angeles, California," *U. S. Geological Survey, Open-File Report 01-111.*

City of Los Angeles GIS Mapping, 2004, "Methane and Methane Buffer Zones," http://www.meredithassociates.com/pdf/Methane_Zone_Map.pdf

Converse Consultants Earth Science Associated Geo/Resources Consultants, 1984, “Geotechnical Report, Metro Rail Project Design Unit A220, Los Angeles, California,” March 1984, Project Number 503

Converse Ward Davis Dixon, Earth Science Associates, Geo-Resource Consultants, (CWDD/ESA/GRC), 1981, “Geotechnical Investigation Report, Volume I; Volume II -- Appendices 1 and 2," for Southern California Rapid Transit Metro Rail Project

Converse Ward Davis Dixon Earth Science Associates Geo/Resource Consultants, 1981, “Geotechnical Investigation Report,” Volume 1, Appendices, Southern California Rapid Transit District Metro Rail Project

Converse Ward Davis Dixon Earth Science Associates Geo/Resource Consultants, 1981, “Geotechnical Investigation Report,” Volume 2, Appendices, Southern California Rapid Transit District Metro Rail Project, pp.II-142 -211

Converse Consultants West, 1992, “Preliminary Geotechnical Report Proposed Metro Rail Mid- City Segment, Wilshire Blvd.-Western Station to Pico-San Vicente Station, Los Angeles Rail Rapid Transit Project, Los Angeles, California” September 14, 1992, Project Number 91-31-208-01

County of Los Angeles, 2007, “Department of Water Resources, Los Angeles County, California,” www.sd.water.ca.gov

Crook, R., Jr., Proctor, R. J., and Lindvall, E.E., 1983, “Seismicity of the Santa Monica and Hollywood Faults Determined by Trenching,” Technical Report to the U.S. Geological Survey, Contract No. 14-08-001-20523, p. 26.

Crook, R., Jr., and Proctor, R. J., 1992 “The Santa Monica and Hollywood Faults and the Southern Boundary of the Transverse Ranges Province” in *Engineering Geology Practice in Southern California.*

Department of Natural Resources State of California, 1954, “Geology of Southern California Bulletin 170, Division of Mines,” 1954

Department of Public Works, 2007, “Navigate Los Angeles, California” http://navigatela.lacity.org/index.cfm

Department of Water Resources, 1961, “Planned Utilization of the Ground Water Basins of the Coastal Plain of Los Angeles County, Appendix A. Ground Water Geology” June, 1961

Dolan, J. F. and Sieh K., 1992, “Tectonic Geomorphology of the Northern Los Angeles Basin: Seismic Hazards and Kinematics of Young Fault Movement,” in Ehlig, P.L., and Steiner, E.A., eds., Engineering Geology Field Trips: Orange County, Santa Monica Mountains, and Malibu, Guidebook and Volume: Berkley, California, Association of Engineering Geologists, p. B-20-26.

Dolan, J. F. and Sieh, K., 1992, “Paleoseismology and Geomorphology of the Northern Los Angeles Basin: Evidence for Holocene Activity on the Santa Monica Fault and Identification of New

Strike-Slip Faults through Downtown Los Angeles," EOS, Transactions of the American Geophysical Union, Vol. 73, p. 589.

Dolan, J. F. and Sieh K., 1993, "Tectonic Geomorphology of the Northern Los Angeles Basin: Seismic Hazards and Kinematics of Young Fault Movement," in Ehlig, P.L., and Steiner, E.A., eds., Engineering Geology Field Trips: Orange County, Santa Monica Mountains, and Malibu, Guidebook and Volume: Berkley, California, Association of Engineering Geologists, p. B-20-26.

Dolan, J. F., Sieh, K., Rockwell, T. K. Yeats, R.S., Shaw J., Suppe, J., Huftile, G., and Gath, E., 1995, "Prospects for Larger or More Frequent Earthquakes in the Los Angeles Metropolitan Region, California," *Science,* Vol. 267, pp. 199-205.

Dolan, J. F., Sieh, K. E., Rockwell, T. K., Guptil, P., and Miller, G., 1997, "Active Tectonics, Paleoseismology, and Seismic Hazards of the Hollywood Fault, Northern Los Angeles Basin, California," *Geological Society of America Bulletin,* Vol. 109, No. 12

Dolan, J. F. and Pratt, T.L., 1997, "High-Resolution Seismic Reflection Profiling of the Santa Monica Fault Zone, West Los Angeles, California," Geophysical Research Letters, Vol. 24, No. 16, pp. 2051-2054.

Dolan, J. F., Sieh, K., and Rockwell, T.K., 2000a, "Late Quaternary Activity and Seismic Potential of the Santa Monica Fault System, Los Angeles, California," Geological Society of America Bulletin, Vol. 12, No. 10.

Dolan, J. F., Stevens, D., and Rockwell, T. K., 2000b, "Paleoseismologic Evidence for an Early to Mid-Holocene Age of the Most Recent Surface Fault Rupture on the Hollywood Fault, Los Angeles, California" Bulletin of the Seismological Society of America, April 2000.

Duncan, J. M., and Bursey, A., 2007, Soil and Rock Modulus Correlations for Geotechnical Engineering, Center for Geotechnical Practice and Research, Virginia Tech.

Earth Technology Corporation, 1993, "Investigations of the Hollywood Fault Zone, Segment 3, Metro Red Line, Los Angeles, California," July 1993, Project Number 92-2038

Engineering-Science, 1986, Design-Research-Planning, "Appendices to Core Study, Subsurface Conditions Report, an Evaluation of Methane Gas Potential along Candidate Alignments of the Los Angeles Metro Rail Project," May 1986

Engineering-Science, 1986, "Case Study, Subsurface Conditions Report, an Evaluation of Methane Gas Potential along Candidate Alignments of the LA Metro Rail Project," May 1986

Engineering-Science, 1992, "1992 Compilation of Monitoring Data on Gas Probes Along Proposed Metro Rail Alignment Project," Volume 1 of 2, September 1992, PE 298/211.0921/YO

Engineering-Science, 1992, "1992 Compilation of Monitoring Data on Gas Probes Along Proposed Metro Rail Alignment Project," Volume 2 of 2, September 1992, PE 298/211.0921/YO

Enviro-Rail, 1994, “Alignment for Reassessment for Metro Red Line Segment 3 Mid City (R83) and Western Extension (G87),” Contract ENO 27, Metro Red Line Western Extension (G87), March 1996.

Enviro-Rail, 1996, “Phase III- Western Extension Reassessment Study,” Contract ENO 27, Metro Red Line Western Extension (G87), March 1996

Federal Highway Administration, 2009, Technical Manual for Design and Construction of Road Tunnels – Civil Elements, Publication FHWA-NHI-10-034.

FEMA, 2009, NEHRP Recommended Seismic Provisions for New Buildings and Other Structures, FEMA P-750.

Hart, E.W., 1973, revised 1999, “Fault-Rupture Hazard Zones in California,” California Division of Mines and Geology, Special Publication 42.

Hauksson, E., 1987, “Seismotectonics of the Newport-Inglewood Fault Zone in the Los Angeles Basin, Southern California,” *Bulletin of the Seismological Society of America,* Vol. 77, pp. 539-561.

Hauksson, E., 1990, “Earthquakes, Faulting, and Stress in the Los Angeles Basin," *Journal of Geophysical Research*, Volume 95, No. B10, pp. 15,365-15,394.

Hill, R. L., Sprotte, E. C., Chapman, R. H., Chase, G. W., Bennett, J. H., Real, C. R., Borchardt, G., and Weber, F. H., Jr., 1979, “Earthquake Hazards Associated with Faults in the Greater Los Angeles Metropolitan Area, Los Angeles County, California, Including Faults in the Santa Monica–Raymond, Verdugo–Eagle Rock and Benedict Canyon Fault Zones,” *California Division of Mines and Geology, Open File Report 79-16LA.*

Hummon, C., Schnieder C. L., Yeats, R. S., Dolan, J. F., Sieh, K. E., and Huftile, G. J., 1994, “Wilshire Fault: Earthquakes in Hollywood?,” Geology, Vol. 22, pp. 291-294.

Jennings, C. W., 1994, "Fault Activity Map of California and Adjacent Areas with Locations and Ages of Recent Volcanic Eruptions," California Division of Mines and Geology Map No. 6

Jennings, C. W., 2010, "Fault Activity Map of California,” California Geological Survey," Geologic Data Map No. 6

Kaiser Engineers, 1962, “Test Boring Program, Rapid Transit Backbone Route,” report dated June 1962, v.4, bks. 1, 2, and 3.

Lamar, D. L., 1970, “Geology of the Elysian Park-Repetto Hills Area, Los Angeles County, California,” California Division of Mines & Geology Special Report 101

Law/Crandall, 1991, “Report of Foundation Investigation, Proposed Apartment Building, 437-443 North Palm Drive, Beverly Hills, California,” September 24, 1991, Project Number L91263.AO-2101

Law/Crandall, 1991 "Report of Geotechnical Investigation Proposed Barneys California, 9570 Wilshire Blvd., Beverly Hills, California," September 27, 1991, Project Number L89380.AEC

Law/Crandall, 1992, "Report of Foundation Investigation, Proposed Lawry's Restaurant, 100 North La Cienega Blvd. Beverly Hills, California," March 21, 1992, Project Number L91038.AO

Law/Crandall, 1992, "Report of Foundation Investigation, Proposed Weyerhaeuser Atriums, 10585 and 10639 Santa Monica Blvd., West Los Angeles, California," August 31, 1992, Project Number L89387.AD

Law/Crandall, 1992, "Report of Geotechnical Investigation Proposed Retail Store, Southwest Corner of Wilshire Blvd. and Peck Drive, Beverly Hills, California," August 10, 1992, Project Number L91078.AEC

Law/Crandall, 1992, "Report of Geotechnical Investigation Proposed Retail Store, Southwest Corner of Wilshire Blvd. and Peck Drive, Beverly Hills, California," August 10, 1992, Project Number L97078.AEC

Law/Crandall, 1993, "Report of Potential Fault Displacements, Wastewater Treatment Plant Number 2, Huntington Beach, California," Project No. 2661.30140.0001.

Law/Crandall, 1994, "Report of Geotechnical Investigation Proposed Mid-City Segment Metro Rail Red Line Project, Volume 2-3," January 1994, Project Number 2661.30448.0001

Law/Crandall, 1994, "Report of Foundation Investigation Proposed Parking Structure, Wilshire Blvd. and Second Street, Santa Monica, California," June 22, 1994, Project Number 2661.40385.0001

Law/Crandall, 1994, "Review of Existing Data Mid-City Extension Reassessment Study, Metro Red Line – Segment 3, Volume 1-6, Los Angeles, California," June 1994, Project Number 2661.40134.0003

Law/Crandall, 1994, "Report of Foundation Investigation Proposed Saks Fifth Avenue Addition, 9600 Wilshire Blvd., Beverly Hills, California," August 4, 1994, Project Number 2661.40488.0001

Law/Crandall, 1994, "Report of Foundation Investigation, Proposed Narthex Extension, 504 North Carmen Drive, Beverly Hills, California," November 22, 1994, Project Number 2661.40735.0001

Law/Crandall, 1995, "Report of Geotechnical Investigation Proposed Building Development, 9200 Wilshire Blvd., Beverly Hills, California" May 8, 1995, Project Number 2661.50190.0001

Law/Crandall, 1996, "A Monte Carlo Approach in Estimating Uncertainty for a Seismic Hazard Assessment of Los Angeles, Ventura, and Orange Counties, California," Bulletin of Seismological Society of America, Vol. 86, Number 6, pp. 1681-1691.

Law/Crandall, 1997, "Report of Geotechnical Consultation Proposed New Safe Deposit Addition to the Existing Bank Vault, Existing Wells Fargo Bank , 2444 Wilshire Blvd., Santa Monica, California," April 7, 1997, Project Number 70131-7-0170.0001

Law/Crandall, 1997, "Report of Geotechnical Investigation Proposed Parking Structure, South West Corner of Wilshire Blvd. and Second Street, Santa Monica, California," August 6, 1997, Project Number 70131-7-0316.0001.

Law/Crandall, 1998, Proposed Constellation Place, Report of Preliminary Geotechnical Investigation, 10270 Constellation Boulevard, September 11, 1998, Project Number 70131-8-0375.

Law/Crandall, 1999, "Report of Environmental Site Assessment, Proposed Hotel Bel Jardin, Wilshire Blvd. Between Maple Drive and Palm Drive, Beverly Hills, California," June 9, 1999, Project Number 70131-9-0179

Law/Crandall, 2001, "Report of Preliminary Geotechnical Investigation Proposed New Office Building Development, 9748-9766 Wilshire Blvd., Beverly Hills, California," May 11, 2001, Project Number 70131-1-0132

LeRoy Crandall and Associates, 1955, "Report of Foundation Investigation, Proposed Office Building, Wilshire Blvd., Lorrain And Irvine Blvd., Los Angeles, California," July 14, 1955, Project Number 55114

LeRoy Crandall and Associates, 1956, "Report of Supplemental Foundation Investigation, Proposed Office Building, Wilshire Blvd., Lorrain and Irvine Blvd., Los Angeles, California," May 22, 1956, Project Number 56106

LeRoy Crandall and Associates, 1957, "Report of Foundation Investigation, Proposed Building, Northeast Corner Wilshire Blvd. and Gramercy Place, Los Angeles, California," June 24, 1957, Project Number 57173

LeRoy Crandall and Associates, 1958, "Report of Foundation Investigation, Proposed Building, Northeast Corner Wilshire Blvd. and Gramercy Place, Los Angeles, California," May 20, 1958, Project Number 57173

LeRoy Crandall and Associates, 1958, "Report of Foundation Investigation, Proposed Site, Southeast Corner Hobart and Wilshire Blvd., Los Angeles, California," July 9, 1958, Project Number 58100

LeRoy Crandall and Associates, 1960, "Report of Foundation Investigation, Proposed Office Building, Northwest Quadrant, 20th Century Property, Los Angeles, California," April 6, 1960, Project Number 59446

LeRoy Crandall and Associates, 1960, "Report of Supplementary Foundation Investigation, Proposed Welton Becket Building, 10200 Santa Monica Blvd., Los Angeles, California," January 21, 1960, Project Number 59556

LeRoy Crandall and Associates, 1960, "Preliminary Review of Foundation Conditions, Rapid Transit Program, Los Angeles, California," January 22, 1960, Project Number 59528

LeRoy Crandall and Associates, 1960, "Report of Foundation Investigation, Proposed Multi-Story Building, Wilshire Blvd. and Plymouth Avenue, Los Angeles, California," June 24, 1960, Project Number 59430

LeRoy Crandall and Associates, 1960, “Report of Foundation Investigation, Proposed Site Purchase, 638 Manhattan Place,” Los Angeles, California,” July 7, 1960, Project Number 62313

LeRoy Crandall and Associates, 1960, “Report of Foundation Investigation, Proposed Wilshire Blvd.-Comstock Apartments, Wilshire Blvd., and Comstock Avenue, Los Angeles, California,” November 25, 1960, Project Number 60423

LeRoy Crandall and Associates, 1962, “Report of Foundation Investigation, Proposed Building, 6400 Wilshire Blvd., Los Angeles, California” July 29, 1962, Project Number 62012

LeRoy Crandall and Associates, 1962, “Report of Foundation Investigation, Proposed Gateway Building East, Santa Monica Blvd. and Avenue of the Stars, Twentieth Century Property, Los Angeles, California” February 14, 1962, Project Number 62019

LeRoy Crandall and Associates, 1962, “Report of Foundation Investigation, Proposed Office Building, Wilshire Blvd. and Willaman Drive, Beverly Hills, California,” Technical November 8, 1962, Project Number 62217

LeRoy Crandall and Associates, 1962, “Report of Foundation Investigation, Proposed Apartment Building, Wilshire and Westholme Avenue, Los Angeles, California, “ December 5, 1962, Project Number A-62678.

LeRoy Crandall and Associates, 1963, “Report of Supplementary Foundation Investigation, Proposed St. Basil’s Church, Wilshire Blvd. and Kingsley Drive, Los Angeles, California” April 7, 1966, Project Number63800-B

LeRoy Crandall and Associates, 1963, “Report of Foundation Investigation, Proposed Ebell Townhouse, 820 Lucerne Blvd., Los Angeles, California” August 29.1963, Project Number 63561.

LeRoy Crandall and Associates, 1963, “Report of Foundation Investigation, Proposed St. Basil’s Church, Wilshire Blvd. and Kingsley Drive, Los Angeles, California” December 20, 1963, Project Number 63800

LeRoy Crandall and Associates, 1964, “Supplementary Foundation Data, Proposed Federal Office Building, Wilshire Blvd. Between Veteran Avenue and Sepulveda Blvd., West Los Angeles, California,” June 8, 1964, Project Number 63652

LeRoy Crandall and Associates, 1964, “Report of Foundation Investigation, Proposed Monte Mario Apartments, Wilshire Blvd. and Warner Avenue, Los Angeles, California,” June 19, 1964, Project Number 64193

LeRoy Crandall and Associates, 1964, “Report of Foundation Borings, Sampling, and Testing Proposed Federal Office Building, Wilshire Blvd. Between Veteran Avenue and Sepulveda Blvd., West Los Angeles, California,” July 10, 1964, Project Number 63506

LeRoy Crandall and Associates, 1965, “Report of Foundation Investigation, Proposed Beverly Hills Nation Bank Building, Wilshire Blvd. and Doheny Drive, Beverly Hills, California,” September 27, 1965, Project Number 64390

LeRoy Crandall and Associates, 1965, "Report of Foundation Investigation, Proposed Office Building and Parking Structure, 3470 Wilshire Blvd., Los Angeles, California," November 4, 1965, Project Number A-65343

LeRoy Crandall and Associates, 1966, "Report of Foundation Investigation, Proposed Horace Mann Elementary School Additions, Charleville Blvd. and Arnaz Drive, Beverly Hills, California," January 7, 1966, Project Number A-65386

LeRoy Crandall and Associates, 1966, "Report of Foundation Investigation ,Proposed Brentwood Regional Office, San Vicente and Wilshire Blvd., Los Angeles, California," July 15, 1966, Project Number A-66011.

LeRoy Crandall and Associates, 1966, "Report of Foundation Investigation ,Proposed Cole Porter Theater and Douglas Aircraft Office Building, Santa Monica Blvd. and Century Park East, Los Angeles, California," October 4, 1966, Project Number A-66248

LeRoy Crandall and Associates, 1967, "Report of Foundation Investigation, Proposed Office Building and Parking Structure, Wilshire Blvd. and Windsor Blvds, Los Angeles, California" March 7, 1967, Project Number A-66142-B

LeRoy Crandall and Associates, 1967, "Preliminary Report of Foundation Investigation, Proposed Theatre Development, Avenue of the Stars between Constellation and Olympic Blvds, Century City, Los Angeles, California" May 10, 1967, Project Number A-67065

LeRoy Crandall and Associates, 1967, "Report of Preliminary Foundation Investigation, Proposed Store Addition and Garage Addition, Wilshire Blvd. and Fairfax Avenue, Los Angeles, California" October 23, 1967, Project Number A-67263

LeRoy Crandall and Associates, 1967, "Report of Preliminary Soil Investigation, Proposed Medical Facility, Santa Monica Blvd. and Century Park East, Century City, Los Angeles, California" January 20, 1967, Project Number A-66362

LeRoy Crandall and Associates, 1968, "Report of General Site Investigation, Proposed Century City Future Developments, Century City, Los Angeles, California," July 15, 1968, Project Number A-68111

LeRoy Crandall and Associates, 1968, "Report of Foundation Investigation, Proposed Wilshire Blvd.-Doheny Office Building, Wilshire Blvd. and Doheny Drive, Beverly Hills, California," October 25, 1968, Project Number 64390-B

LeRoy Crandall and Associates, 1968, "Report of Foundation Investigation, Proposed Welton Becket Building, Santa Monica Blvd. and Moreno Drive, Los Angeles, California," November 29, 1968, Project Number 58327

LeRoy Crandall and Associates, 1968, "Report of Foundation Investigation, Proposed Office Building, Portion of Lot 4, Century Park East, Los Angeles, California," October 15, 1968, Project Number A-68203

LeRoy Crandall and Associates, 1969, "Report of Supplementary Foundation Investigation, Proposed Parking Structure, 1888 Century Park East, Los Angeles, California," March 20, 1969, Project Number A-68203-B

LeRoy Crandall and Associates, 1969, "Report of Foundation Investigation, Proposed Theme Building and Entertainment Center, Lot 8, Century City, Los Angeles, California," July 19, 1969, Project Number A-69036

LeRoy Crandall and Associates, 1969, "Preliminary Report of Foundation Investigation, Proposed Transportation Center and Office Buildings, Santa Monica Blvd. and Century Park East, Century City Los Angeles, California," April 28, 1969, Project Number A-69046

LeRoy Crandall and Associates, 1969, "Report of Preliminary Foundation Investigation, Proposed Building, Wilshire Blvd. and Santa Monica Blvd., Beverly Hills, California," July 14, 1969, Project Number A-69166

LeRoy Crandall and Associates, 1969, "Report of Foundation Investigation, Proposed Office Building,6434 Wilshire Blvd., Los Angeles, California" September 18, 1969, Project Number A-69235

LeRoy Crandall and Associates, 1969," Report of Soil Addition to existing Building, 9634 Wilshire Blvd., Beverly Hills, California," July 18, 1969, Project Number A-69157

LeRoy Crandall and Associates, 1970, "Report of Foundation Investigation, Proposed Office Building, Wilshire Blvd. and Oakhurst Drive, Beverly Hills, California," January 2, 1970, Project Number A-69300

LeRoy Crandall and Associates, 1970, "Report of Foundation Investigation, Proposed Office Building, Wilshire Blvd. and McCarthy Vista, Beverly Hills, California," January 19, 1970, Project Number A-69228

LeRoy Crandall and Associates, 1970, "Report of Foundation Investigation, Proposed Office Building, Wilshire Blvd. and Canon Drive, Beverly Hills, California," March 23, 1970, Project Number A69024

LeRoy Crandall and Associates, 1970, "Report of Foundation Investigation, Proposed Office Building and Parking Structure, Wilshire Blvd. and Midvale Avenue, Westwood District, Los Angeles, California," March 27, 1970, Project Number A-68074-B

LeRoy Crandall and Associates, 1970, "Report of Preliminary Soil Investigation, Proposed office Building and Parking structure, Wilshire Blvd. and Highland Avenue, Los Angeles, California" April 29, 1970, Project Number A-70115

LeRoy Crandall and Associates, 1970, "Report of Foundation Investigation, Proposed Wilshire Blvd.-Highland Office Building, Wilshire Blvd. and Highland Avenue, Los Angeles, California," December 15, 1970, Project Number A-70266

LeRoy Crandall and Associates, 1971, “Report of Preliminary Soil Investigation, Proposed Land Purchase, Wilshire Blvd. and Wilton Place, Los Angeles, California,” July 2, 1971, Project Number A-71117

LeRoy Crandall and Associates, 1971, “Report of Foundation Investigation, Proposed Resource Center, Portion of Parcel 7-B, Constellation Blvd. East of Century Park West, Century City, Los Angeles, California,” October 5, 1971, Project Number A-71174

LeRoy Crandall and Associates, 1972, “Report of Foundation Investigation, Proposed Office Building, Wilshire Blvd. and Harvard Street, Santa Monica, California,” April 20, 1972, Project Number A-71234

LeRoy Crandall and Associates, 1972, “Report of Foundation Investigation, Proposed Office Building, 1727-1741 North Highland Avenue, Los Angeles, California,” June 6, 1964, Project Number 64267

LeRoy Crandall and Associates, 1972, “Report of Foundation Investigation, Proposed Tower and Garage Additions 6434 Wilshire Blvd., Los Angeles, California,” August 29, 1972, Project Number A-72204

LeRoy Crandall and Associates, 1972, “Report of Foundation Investigation, Proposed Office Building, Wilshire Blvd. and Roxbury Drive, Beverly Hills, California,” November 16, 1972, Project Number A-70067-B

LeRoy Crandall and Associates, 1973, Report of Foundation Investigation, Proposed Westside Tower and Parking Structure, Wilshire Blvd. and Barry Avenue, Los Angeles, California," May 15, 1973, Project Number A-73070

LeRoy Crandall and Associates, 1973, “Report of Foundation Investigation and Geologic-Seismic Study, Proposed Blarney Castle Inn, Wilshire Blvd. and Manhattan Place, Los Angeles, California,” August 3, 1973, Project Number AD-73089

LeRoy Crandall and Associates, 1973, “Report of Preliminary Soil and Foundation Investigation, Proposed Development, Wilshire Blvd. and Spaulding Avenue, Los Angeles, California,” October 10, 1973, Project Number A-73186

LeRoy Crandall and Associates, 1977, “Report of Geotechnical Investigation, Proposed Elderly Housing Development Sixth Street and Burnside Avenue, Los Angeles, California,” November 16, 1977, Project Number ADE-77283

LeRoy Crandall and Associates, 1978, “Report of Geotechnical Investigation, Proposed Condominium, Wilshire Blvd. and Malcolm Avenue, Los Angeles, California,” February 3, 1978, Project Number AD-73253

LeRoy Crandall and Associates, 1978, “Report of Foundation Investigation, Proposed Department Store and Parking Structure, Wilshire Blvd. Between Roxbury and McCarty Drive, Beverly Hills, California,” August 8, 1978, Project Number A-77167

LeRoy Crandall and Associates, 1979, "Proposed Condominium Development, 10720 Wilshire Boulevard, Los Angeles, California," July 17, 1979, Project Number ADE-79168.

LeRoy Crandall and Associates 1979, "Report of Geotechnical Investigation, Proposed Office Building, Wilshire Boulevard near Midvale Avenue, Los Angeles, California," March 13, 1979, Project Number AD-79027.

LeRoy Crandall and Associates, 1979, "Preliminary Report of Foundation Investigation, Proposed Office Building and Parking Structure, South West Corner Wilshire Blvd. and Fairfax Avenue, Los Angeles, California," April 17, 1979, Project Number A-79069

LeRoy Crandall and Associates, 1979, "Report of Preliminary Foundation Investigation, Proposed Site Development, Wilshire Blvd. Between La Brea Avenue and Detroit Street, Los Angeles, California" October 5, 1979, Project Number A-79292

LeRoy Crandall and Associates 1979, "Report of Geotechnical Investigation, Proposed High-rise Building, 10720 Wilshire Boulevard, Los Angeles, California," December 26, 1979, Project Number AD-79320.

LeRoy Crandall and Associates, 1979, "Report of Foundation Investigation, Proposed Office Building, 120 South Spalding Drive, Beverly Hills, California," November 14, 1979, Project Number A-78363

LeRoy Crandall and Associates, 1980,"Proposed Condominium Development, Wilshire Boulevard and Malcolm Avenue, Los Angeles, California," November 4, 1980, Project Number ADE-79321.

LeRoy Crandall and Associates, 1980, "Report of Preliminary Foundation Investigation, Proposed Intercontinental Centre Wilshire Blvd. to 8th Street Between Ridgeley and Masselin Avenue," Los Angeles, January 21, 1980, Project Number A-79348

LeRoy Crandall and Associates, 1980, "Report of Foundation Investigation, Proposed Wilshire Blvd.-San Vincente Center, Wilshire Blvd. and San Vincente Blvd., Los Angeles, California," March 4, 1980, Project Number A-80041

LeRoy Crandall and Associates, 1980, "Report of Foundation Investigation, Proposed Wilshire Blvd. Office Annex Building Wilshire Blvd. and Rimpau Blvd., Los Angeles, California," August 19, 1980, Project Number A-80251

LeRoy Crandall and Associates, 1980, "Report of Foundation Investigation, Proposed Bank of America Wilshire Blvd.-Crenshaw Relocation, Wilshire Blvd. and Tremain Avenue Los Angeles, California," September 11, 1980, Project Number A-80280

LeRoy Crandall and Associates, 1980, "Report of Supplementary Exploration Borings, Proposed Wilshire House, Wilshire and Westholme Avenue, Los Angeles, California, December 5, 1980, Project Number ADE-79119.

LeRoy Crandall and Associates 1981, "Report of Geotechnical Investigation, Proposed One Westwood Office Building, Wilshire Boulevard and Veteran Avenue, Los Angeles, California," June 15, 1981, Project Number ADE-81162.

LeRoy Crandall and Associates, 1981, "Report of Foundation Investigation, Proposed Cadillac Fairview Tower, Wilshire Blvd. and San Vicente Blvd., Los Angeles, California," July 25, 1981, Project Number ADE-81230

LeRoy Crandall and Associates, 1981, "Report of Preliminary Foundation Investigation, Proposed Building Development, San Vicente Blvd., Los Angeles, California," August 26, 1981, Project Number A-81244

LeRoy Crandall and Associates, 1981, "Report of Foundation Investigation, Proposed Wilshire Blvd./Lorraine Office Building, 4200 Wilshire Blvd., Los Angeles, California," October 16, 1981, Project Number A-81313

LeRoy Crandall and Associates, 1981, "Report of Foundation Investigation, Proposed Additions, 5905 Wilshire Blvd., Los Angeles, California," December 18, 1981, Project Number A-81396

LeRoy Crandall and Associates, 1981, "Report of Foundation Investigation, Proposed F.B.I. Parking and Maintenance Facility, 11000 Wilshire Blvd., Los Angeles, California," December 21, 1981, Project Number A-81376

LeRoy Crandall and Associates, 1982, "Report of Foundation Investigation, Proposed International Bank of America, 9940-9944 Santa Monica Blvd., Beverly Hills, California," January 13, 1982, Project Number A-82309

LeRoy Crandall and Associates, 1982, "Report of Geotechnical Investigation, Proposed Office Building Number 2 and Parking Structure, Century Park East, Los Angeles, California," April 14, 1982, Project Number ADE-80038

LeRoy Crandall and Associates, 1982, "Report of Foundation Investigation, Proposed Building, San Vincent Blvd., Los Angeles, California," June 11, 1982, Project Number A-82069

LeRoy Crandall and Associates, 1982, "Report of Foundation Investigation, Proposed Museum Square Parking Structure, Sixth Street Between Masselin and Curson Avenue, Los Angeles, California," July 6, 1982, Project Number A-82168

LeRoy Crandall and Associates, 1983, "Report of Foundation Investigation, Proposed Hotel Site bounded by Santa Monica and Charleville Blvd.s and Lasky and Durant Drives, Beverly Hills, California," February 17, 1983, Project Number A-82314

LeRoy Crandall and Associates, 1983, "Report of Foundation Investigation, Proposed Office Building, Wilshire Blvd. Between Hudson and Keniston Avenue, Los Angeles, California," July 1, 1983, Project Number A-83165

LeRoy Crandall and Associates, 1983, "Report of Foundation Investigation, Proposed Office Building Wilshire Blvd. and Fremont Place West, Los Angeles, California," August 24, 1983, Project Number A-83215

LeRoy Crandall and Associates, 1984, "Report of Foundation Investigation, Proposed Office Building, Wilshire Blvd. and Fairfax Avenue, Los Angeles, California," January 16, 1984, Project Number A-83353

LeRoy Crandall and Associates, 1984, "Report of Foundation Investigation, Proposed Office Structure and Townhouse, Wilshire Blvd. Between Curson Street and Masselin Avenue, Los Angeles, California," February 27, 1984, Project Number A-84021

LeRoy Crandall and Associates, 1984, "Report of Foundation Investigation, Proposed Basement Addition, 351 North Beverly Drive, Beverly Hills, California," April 3, 1984, Project Number A-84081

LeRoy Crandall and Associates, 1984, "Completion of Exploration Program, Proposed Additions, 5905 Wilshire Blvd., Los Angeles, California," April 27, 1984, Project Number A-81396-B

LeRoy Crandall and Associates, 1984, "Report of Foundation Investigation, Proposed Central Plant Adjacent to Ahmanson Building, 5905 Wilshire Blvd., Los Angeles, California," April 27, 1984, Project Number A-81396-C

LeRoy Crandall and Associates, 1984, "Report of Geotechnical Investigation, Proposed Office Building and Parking Structure, Wilshire Blvd. and Granville Avenue, Los Angeles, California," December 7, 1984, Project Number ADE-84105.

LeRoy Crandall and Associates 1986, "Report of Geotechnical Investigation, Proposed Office Building, Wilshire and Santa Monica Boulevards, Los Angeles, California," April 8, 1986, Project Number ADE-86050.

LeRoy Crandall and Associates, 1987, "Report of Geotechnical Investigation, Proposed High-Rise Development, Wilshire Blvd. and Veteran Avenue, Westwood District, Los Angeles, California," July 28, 1987, Project Number A-83229.

LeRoy Crandall and Associates, 1987, "Report of Geotechnical Investigation, Proposed Office Building, 1999 Avenue of the Stars, Century City, Los Angeles, California," November 30, 1987, Project Number ADE-84277-B.

LeRoy Crandall and Associates, 1987, "Report of Preliminary Geotechnical Investigation, Proposed Wilshire Blvd.-Hauser Office Building, 5601 Wilshire Blvd., Los Angeles, California," September 25, 1987, Project Number ADE-87316.

LeRoy Crandall and Associates, 1987, "Report of Foundation Investigation, Proposed Office Building, 436 North Bedford Drive, Beverly Hills, California," December 15, 1987, Project Number A-79244-B.

LeRoy Crandall and Associates, 1987, "Report of Geotechnical Evaluation for Environmental Impact Report, Proposed Development Project, Wilshire Blvd. Between Hauser Blvd. and Ridgely Drive, Los Angeles, California," Project Number E-87316-B

LeRoy Crandall and Associates, 1988, “Review of Subdrain Drawings, Proposed Office Building, Wilshire Blvd. and Santa Monica Blvd.s, Beverly Hills, California,” February 16, 1988, Project Number A-86050-B

LeRoy Crandall and Associates, 1988, “Report of Geotechnical Investigation, Proposed Armand Hammer Museum, Westwood Blvd. and LindBrook Drive Westwood District, Los Angeles, California,” October 26, 1988, Project Number AE-88055

LeRoy Crandall and Associates, 1989, “Report of Foundation Investigation and Environmental Audit, Proposed Building Development, 4141 Wilshire Blvd., Los Angeles, California,” March 1, 1989, Project Number L89100.AFO

LeRoy Crandall and Associates, 1989, “Report of Preliminary Foundation Investigation Proposed Building Development, 9348 Santa Monica Blvd., Beverly Hills, California,” April 11, 1989, Project Number L89137.AO

LeRoy Crandall and Associates, 1989, “Report of Geotechnical Investigation, Proposed High-Rise Apartment Development, 10720 Wilshire Blvd., Westwood District, Los Angeles, California,” May 3, 1989, Project Number AD-79320

LeRoy Crandall and Associates, 1989, “Report of Geotechnical Investigation, Proposed Office Building, 9420 Wilshire Blvd., Beverly Hills, California,” July 21, 1989, Project Number L89285.AEB

LeRoy Crandall and Associates, 1989, “Environment Assessment Asphaltic Soil, Proposed Wilshire Blvd. Place Project 5601 Wilshire Blvd., Los Angeles, California,” September 1, 1989, Project Number L89396.FB

LeRoy Crandall and Associates, 1989, “Report of Preliminary Foundation Investigation, Proposed Building Development, 9570-9584 Wilshire Blvd., Beverly Hills, California,” September 5, 1989, Project Number L89380.AO

LeRoy Crandall and Associates, 1989, "Completion of Exploration Program, Proposed Armand Hammer Museum, 10889 Wilshire Blvd., Westwood District, Los Angeles, California,” September 8, 1989, Project Number L89154.AB

LeRoy Crandall and Associates, 1989, “Report of Geotechnical, Investigation, Proposed Chartwell Headquarters Building, 9990 Santa Monica Blvd., Beverly Hills, California,” November 2, 1989, Project Number L89463.AEO

LeRoy Crandall and Associates, 1989, “Report of Geotechnical Investigation Proposed Triad Project, Wilshire Blvd. and Barrington Avenue, Los Angeles, California,” October 19, 1989, Project Number L89378.AEO

LeRoy Crandall and Associates, 1990, “Report of Preliminary Foundation Investigation, Proposed Building Development, Wilshire Blvd. and Cochran Avenue, Los Angeles, California,” January 24, 1990, Project Number L89624.AO

LeRoy Crandall and Associates, 1990, "Report of Preliminary Geotechnical Investigation, Proposed Craft and Folk Art Center Museum Development, Southwest Corner Wilshire Blvd. and Curson Avenue, Los Angeles, California," March 2, 1990, Project Number. L90022.AEO

LeRoy Crandall and Associates, 1990, "Report of Geotechnical Investigation Parcel D, Proposed Park La Brea Project, Los Angeles, California," May 11, 1990, Project Number L90123.ADEO

LeRoy Crandall and Associates, 1990, "Environmental Site Assessment and Methane Gas Monitoring Parcel C, Proposed Park La Brea Project, Los Angeles, California," May 18, 1990, Project Number L90122.FO

LeRoy Crandall and Associates, 1990, "Environmental Site Assessment and Methane Gas Monitoring Parcel D, Proposed Park La Brea Project, Los Angeles, California," May 18, 1990, Project Number L90123.FO

LeRoy Crandall and Associates, 1990, "Report of Geotechnical Investigation, Proposed Barneys California, 9570 Wilshire Blvd., Beverly Hills, California," December 19, 1990, Project Number L89380.ADEB

LeRoy Crandall and Associates, 1991, "Report of Geotechnical Investigation, Proposed Condominium Development, 10580 Wilshire Blvd., Los Angeles, California," January 9, 1991, Project Number ADE-87143

LeRoy Crandall and Associates, 1991, "Report of Geotechnical Investigation, Proposed Building Development, Wilshire Blvd. Between Fairfax Avenue and Crescent Heights Blvd., Los Angeles, California," January 15, 1991, Project Number L90192.AEO

LeRoy Crandall and Associates, 1991, "Report of Foundation Investigation, Proposed Hotel Site bounded by Santa Monica and Charleville Blvd.s and Lasky and Durant Drives, Beverly Hills, California," March 8, 1991, Project Number A-82314-B

LeRoy Crandall and Associates, 1991, "Completion of Exploration Program for Proposed Building Development,Carnation Site, 5045 Wilshire Blvd., Los Angeles, California" May 29, 1991, Project Number L89452.AC

LeRoy Crandall and Associates, 1991, "Report of Foundation Investigation-Phase I, Proposed Building, 408-414 North Rodeo Drive, Beverly Hills, California," June 12, 1991, Project Number L91095.AO

LeRoy Crandall and Associates, 1991, "Report of Geotechnical Investigation, Proposed Devonhill Apartments, 10351 Wilshire Blvd., Los Angeles, California," December 17, 1991, Project Number AE-87462

Los Angeles Metro, 2010, Metro Rail Design Criteria.

Los Angeles County Metropolitan Transportation Authority: Environmental Engineering Service, 1996, "Phase II- Western Extension Reassessment Study, Los Angeles, California," March 29, 1996, Project Number ENO27-011

Los Angeles County Metropolitan Transportation Authority, 1994, “Alignment Reassessment for Metro Red Line Segment 3 Mid-City (R83) and Western Extension (G87),” June 1994, Project Number ENO27-008

Los Angeles, City of, 1996, “Safety Element of the Los Angeles City General Plan,”Department of City Planning, Los Angeles, California

Los Angeles, County of, 1990, "Technical Appendix to the Safety Element of the Los Angeles County General Plan," Draft Report by Leighton and Associates with Sedway Cooke Associates.

MACTEC, 2002, “Report of Geotechnical Consultation Proposed Sixty-Three Unit Apartment Building, 740 South Masselin Avenue, Los Angeles, California,” July 8, 2002 , Project Number 70131-2-0047

MACTEC, 2003, “Report of Supplemental Geotechnical Investigation Proposed High-Rise Condominium Building, 10808 Wilshire Blvd., Los Angeles, California,” January 31, 2003, Project Number 70131-2-0276.0001

MACTEC, 2003, “Report of Geotechnical Consultation, Proposed Seismic Retrofit of Existing 11-story Building, 8601 Wilshire Blvd., Beverly Hills, California,” March 28, 2003, Project Number 4953-03-0621

MACTEC, 2003, “Report of Geotechnical Investigation, Proposed Montage Hotel, 203-221 North Cannon Drive, 214-222 North Beverly Drive, Beverly Hills, California,” August 5, 2003, Project Number 4953-03-1791

MACTEC, 2003, “Report of Geotechnical Consultation, Proposed Conversion to Residential Apartments and Seismic Retrofit of Existing 22-Story Building, 3800 Wilshire Blvd., Los Angeles, California,” September 29, 2003, Project Number 4953-03-2571

MACTEC, 2003, "Report of Geotechnical Consultation Proposed Penthouse Addition to Existing Building, 273 Rodeo Drive, Beverly Hills, California," October 8, 2003, Project Number 4953-03-3121

MACTEC, 2003, “Report of Geotechnical Consultation, Proposed Expansion and Seismic Retrofit of Existing Parking Structure, 3800 Wilshire Blvd., Los Angeles, California,” November 11, 2003 , Project Number 4953-03-2572

MACTEC, 2005, “Report of Geotechnical Investigation Proposed Condominiums, 2055 Avenue of The Stars, Century City District, Los Angeles, California,” September 6, 2005, Project Number 4953-05-1851

MACTEC, 2006, “Report of Geotechnical Investigation, Proposed Wilshire Blvd. Beverly Center, 265 North Beverly Drive, Beverly Hills, California,” May 26, 2006, Project Number 4953-06-0561.

MACTEC, 2006, “Report of Methane Soil Gas Testing, Proposed Renovation of the Beverly Hilton, 9876 Wilshire Boulevard, Beverly Hills, California,” November 1, 2006, Project Number 4953-06-0771.

MACTEC, 2007, "Report of Geotechnical Investigation, Proposed Cheesecake Factory Restaurant, Westfield Shopping-town-Century City, 10250 Santa Monica Blvd., Los Angeles, California," February 7, 2007, Project Number 4953-05-3162

MACTEC, 2007, "Report of Phase I Environmental Site Assessment, Fifield Companies Property, 1200 South Club View Drive, Los Angeles California," February 14, 2007; Project Number 4951-07-0111.

MACTEC, 2007, "Revised Report of Geotechnical Investigation, Proposed Phase II Expansion, Westfield Shopping-town-Century City, 10250 Santa Monica Blvd., Los Angeles, California," April 25, 2007, Project Number 4953-05-3161

MACTEC, 2007, "Report of Environmental Document Review, Proposed Wilshire Blvd. and Hobart Mix-Used Development, 3670 Wilshire Blvd., Los Angeles, California," August 15, 2007, Project Number 4951-07-1541.

MACTEC, 2008, "Report of Geotechnical Investigation, Proposed Lotus Development, 9900 Wilshire Boulevard, Beverly Hills, California," September 2, 2008, Project Number 4953-08-1181.

MACTEC, 2010, "Final Geotechnical and Environmental Report for Advanced Conceptual Engineering, Proposed Westway Subway Extension, Los Angeles, California," November 15, 2010, Project Number 4953-09-0472.

Mendenhall, W.C. 1905, "Development of Underground Waters in the western Coastal Plain Region of Southern California," U.S. Geol. Survey Water Supply Paper 139.

Metro, 2011, Century City Area Tunneling Safety Report and Fault Investigation Report, Proposed Westside Subway Extension, report dated October 19, 2011.

Metropolitan Water District of Southern California (MWD), 2007a,, "Groundwater Assessment Study, Report No. 1308, Chapter 4 - Groundwater Basin Report, Los Angeles County Plain, Central Basin," website: http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater, accessed September 17, 2007.

Metropolitan Water District of Southern California (MWD), 2007b, "Groundwater Assessment Study, Report No. 1308, Chapter 4 - Groundwater Basin Report, Los Angeles County Plain Basins, Santa Monica Basin," website: http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater, accessed September 17, 2007.

Petersen, M. D. and Wesnousky, S. G., 1994, "Fault Slip Rate and Earthquake Histories for Active Faults in Southern California," *Bulletin of the Seismological Society of America,* Vol. 84, pp. 1608-1649

Petersen, M. D., Bryant, W. A., Cramer, C. H., Cao, T., Reichle, M. S., Frankel, A. D., Lienkaemper, J. J., McCrory, P. A., and Schwatz, D. P., 1996, "Probabilistic Seismic Hazard Assessment for the State of California," California Division of Mines and Geology Open File Report 96-08.

Poland, J.R., Garrett A. A, and Sinnott A., 1959, "Geology, Hydrology, and Chemical Character of Groundwaters in the Torrance–Santa Monica Area, California," U.S. Geological Survey Water Supply Paper 1461

Pratt, T. L., Dolan, J. F., Odum, J. K., Stephenson, W. J., Williams, R. A., and Templeton, M. E., 1998, "Multiscale Seismic Imaging of Active Fault Zones for Hazard Assessment: A Case Study of the Santa Monica Fault Zone, Los Angeles, California," *Geophysics*, Vol. 63, No. 2.

Sabatini, et al., 2002, Geotechnical Engineering Circular Number 5: Evaluation of Soil and Rock Properties, Report FHWA-IF-02-034, Geosyntec Consultants report sponsored by U.S. DOT, Office of Bridge Technology, Federal Highway Administration, Washington, D.C. 226 pp.

Shaw, J. H., Plesch, A., Dolan, J. F., Pratt, T. L. and Fiore, P., 2002, "Puente Hills Blind – Thrust System, Los Angeles, California," *Bulletin of the Seismological Society of America*, Vol. 92, No. 8, pp 2946-2960

Southern California Seismographic Network, 2011, "Southern California Earthquake Catalog," http://www.scecdc.scec.org/ftp/catalogs/SCSN/

State of California Department of Conservation, Division of Oil, Gas, and Geothermal Resources, 2006, "Oil and Gas Wildcat Well Maps 116, 117, 118, and W1-5", June 29, 2006.

TRC, 2007, "3rd Quarter 2007 Well Box/Wellhead Maintenance, Monitoring and Sampling Report, Metro Mid City Corridor between Fairfax Avenue and Blvd.Crenshaw Blvd., Los Angeles, California," October 2, 2007

TRC, 2007, "Well Box/Wellhead Maintenance, Monitoring, and Sampling Summary Report, Metro Mid City Corridor between Fairfax Avenue and Blvd.Crenshaw Blvd., Los Angeles, California," dated June 29, 2007

Tsutsumi, H., 1996, Evaluation of seismic hazards from the Median Tectonic Line, Japan, and blind thrust faults in the Los Angeles metropolitan area, California: Corvallis, Oregon State University Ph.D. Dissertation, 129 p.

Tsutsumi, H., Yeats, R.S., and Huftile, G.J., 2001, "Late Cenozoic Tectonics of the Northern Los Angeles Fault System," Geological Society of America Bulletin, Vol. 113, No 4, pp. 454-468.

Ultra-Systems Environmental, 2004, "Phase II Environmental Site Assessment, Proposed Science and Technology Center, Beverly Hills High School, 241 Moreno Drive, Beverly Hills, California," July 2004.

United States Geological Survey and California Geological Survey, 2005, "Preliminary Geologic Map of the Los Angeles 30' X 60' Quadrangle, Southern California," 2005, Version 1.0

URS, 2002, "Mid-City Monitoring Well/Probe Location Map, MTA," Figure 2 and Table 1, March 2002

U. S. Geological Survey, 1934, "Sawtelle Quadrangle, Los Angeles County," 6-Minute Series Topographic Map.

U. S. Geological Survey, 2011, "2008 Interactive Deaggregation," Website: https://geohazards.usgs.gov/deaggint/2008/index.php

Weber, F. H., Bennett, J. H., Chapman, R. H., Chase, G. W., and Saul, R. B., 1980, "Earthquake Hazards Associated with the Verdugo-Eagle Rock and Benedict Canyon Fault Zones, Los Angeles County, California," California Division of Mines and Geology Open File Report 80-lOLA.

Woodward-Clyde Consultants, 1977, "Drilling Services for Rapid Transit Starter Line," Job No. 410211, J, report dated December 1977. 2 p. and logs

Yerkes, R.F., T.H McCulloh, J.E Schoellhamer, and J.G Vedder, 1965, "Geology of the Los Angeles Basin – an Introduction," U. S. Geological Survey Professional Paper 420-A

Ziony, J.I., ed., 1985, "Evaluating Earthquake Hazards in the Los Angeles Region–An Earth Science Perspective," U.S. Geological Survey Professional Paper 1360

Ziony, J. I., and Jones, L. M., 1989, "Map Showing Late Quaternary Faults and 1978–1984 Seismicity of the Los Angeles Region, California," U.S. Geological Survey Miscellaneous Field Studies Map MF-1964

THIS PAGE INTENTIONALLY LEFT BLANK

EXPLANATION
EXPLORATION SYMBOLOGY
Geotechnical Rotary-Wash Boring
Gas Monitoring Well
Dual Geotechnical Boring/Gas Monitoring Well
CPT [Geotechnical + Gas - BAT]
CPT [Geotechnical]
Geotechnical Sonic Core
Pump Test
Environmental Boring [Direct Push]
Fault Investigation Hollow Stem Auger Boring
AMEC Environmental Exploration (2009)
AMEC Geotechnical Exploration (2009)
Prior AMEC Fault Investigation Sonic Core (2009)
Geotechnical boring to be completed as part of PE phase investigation
Gas monitoring well to be completed as part of PE phase investigation
Sonic core boring to be completed as part of PE phase investigation
CPT to be completed as part of PE phase investigation
LINE SYMBOLOGY
Proposed Station
Metro Westside Subway Extension Locally Preferred Alignment (LPA)
Metro Westside Subway Extension Santa Monica Blvd Alternate Alignment
Metro Westside Subway Extension Constellation Blvd Alternate Alignment
Geophysical Survey Location for oil well location screening
Oil Field Administrative Boundary (DOGGR, 2011)
City Boundaries
0 500 1,000 2,000 Feet
N
WESTWOOD/VA STATION WITH NO. 645R DOUBLE CROSSOVER
WESTWOOD/UCLA STATION
CENTURY CITY SANTA MONICA STATION WITH NO. 10 DOUBLE CROSSOVER
CENTURY CITY CONSTELLATION STATION WITH NO. 10 DOUBLE CROSSOVER
WILSHIRE/RODEO STATION WITH NO. 15 DOUBLE CROSSOVER
WILSHIRE/LA CIENEGA STATION WITH NO. 10 DOUBLE CROSSOVER
WILSHIRE/FAIRFAX STATION
WILSHIRE/LA BREA STATION WITH NO. 10 DOUBLE CROSSOVER
EXISTING WILSHIRE/WESTERN STATION (PURPLE LINE)
LIMITS OF FEDERAL LAND
FEDERAL VA
WESTWOOD
West Los Angeles
CENTURY CITY
BEVERLY HILLS
MID WILSHIRE
Beverly Hills
Cheviot Hills
San Vicente
Salt Lake
South Salt Lake
Las Cienegas
GEOPHYSICAL SURVEY LOCATIONS
GEOPHYSICAL SURVEY LOCATION
Wilshire Blvd
Westwood Blvd
Santa Monica Blvd
Rodeo Dr
Beverly Dr
Robertson Blvd
La Cienega Blvd
Fairfax Ave
San Vicente Blvd
La Brea Ave
Crenshaw Blvd
Western Ave
AMEC ENVIRONMENT & INFRASTRUCTURE
5628 EAST SLAUSON AVE.
LOS ANGELES, CALIFORNIA 90040
(323) 889-5300 fax (323) 889-5398
PLATE 1 - Exploration Map
Metro Westside Subway Extension
Los Angeles County, California
JOB NO.: 4953-10-1561
DATE: 6-30-11
SCALE: 1 inch = 1,000 feet
DRAWN BY: PER
CHECKED BY: JAG
REVISIONS:
12/5/2011 11:26:15 AM

Proposed Geotechnical / Soil-Gas Investigation for PE Phase:

G-207	Geotechnical Rotary-Wash Boring
M-124	Gas Monitoring Well
G-199/M-122	Dual Geotechnical Boring / Gas Monitoring Well
CB-105	CPT [Geotechnical + Gas - BAT]
C-127	CPT [Geotechnical]
S-115	Geotechnical Sonic Core
P-103	Pump Test
E-135	Environmental Boring [Direct Push]
T2E-B9	Fault Investigation [Hollow Stem Auger]

Prior ACE Phase Investigations:

M-15	AMEC Environmental Exploration
G-3	AMEC Geotechnical Exploration
SB-2	Prior Fault Investigation Boring

Prior Investigations (depth >70') : ● = Geotechnical ● = Gas Well or CPT w/ Gas Reading

M 4953-05-1851	AMEC Geotechnical Exploration
CPT9G	AMEC CPT Exploration (1994)
P-43	AMEC Environmental Exploration (1992)
MW2C	AMEC Geotechnical Exploration (1990)
CWDD 18-2	CWDD Converse Ward Davis Dixon (1981)
CWDD 18	CWDD Dual Geotechnical / Environmental Exploration (1981)
MC-2	Converse Consultants West (1992)
RC-17, GW-1	EnviroRail 1994 (1996)
WWC 4	Woodward Clyde Consultants (1977)
R-09-014	Rotary Wash borings by others for I-405 widening (2009)
CPT-09-054	CPT by others for I-405 widening (2009)

Symbol Labels:

(MW)	Ground water monitoring (observation) well
(NV)	Boring with noise and vibration testing
(P)	Boring with pressure meter testing

Symbols Legend:

- Site view of station. Alignment based on data provided by PB (7/15/2011)
- Profile view of station (red) with tunnel outline (black) and track (blue)
- Site view showing center of tracks (blue), tunnel outlines (magenta dash) with perpendicular of cross passage.
- Cross passage (profile view).
- NV-185 — Noise and Vibration Point of Interest.
- (12-24-08) — Ground-water depth measured during 2009 to 2011 in an observation well, drilled by AMEC and date of measurement.
- Overnight Ground-water depth measured in a 2011 boring, drilled by AMEC.
- Ground-water depth measured during drilling of a boring in 2011, by AMEC.
- Geologic contact line.
- Top of tar impregnated soil.
- Geotechnical boring completed as a part of PE phase investigation.
- Geotechnical boring to be completed as a part of PE phase investigation.
- ? ← → ? — Final Fault trace Location to be refined during final design.

Geologic Units:

af	ARTIFICIAL FILL (undocumented)
Qal	YOUNGER ALLUVIUM (Holocene) - predominantly sand, silt and clay
Qalo	OLDER ALLUVIUM - varying layers of Silty Sand, Clayey/Silty Clay, and Silt with occasional gravel
Qlw	LAKEWOOD FORMATION (late Pleistocene) - interbedded Silty sands, Silts, and Clays with clayey Sand Layers
Qsp	SAN PEDRO FORMATION (mid Pleistocene) - predominately greenish gray and bluish gray fine-grained Sands, medium to coarse Sands and some Silt Layers.
Tf	FERNANDO FORMATION (Pliocene) - predominately massive Siltstone with some Claystone interbeds

REV	DATE	BY	APP	REG NO	EXPIRES	SEAL HOLDER	DESCRIPTION

DESIGNED BY ELLIOTT / MUNRO
DRAWN BY L. MORLEY
CHECKED BY JAG / HP
IN CHARGE MBH / PM
DATE 12/02/2011

Metro
PB
PROJECT MANAGER

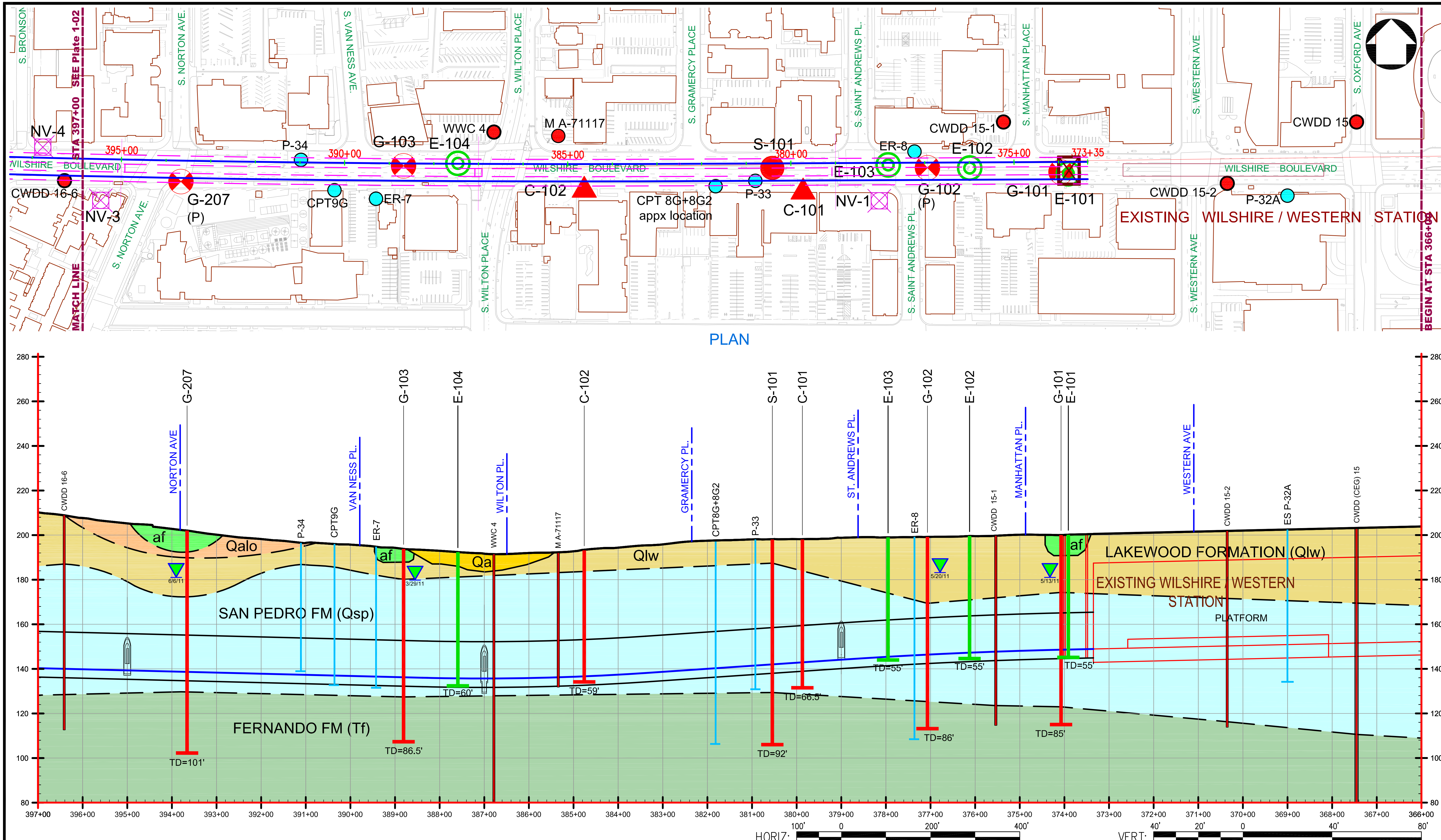
LOS ANGELES COUNTY
METROPOLITAN TRANSPORTATION AUTHORITY

WESTSIDE SUBWAY EXTENSION
PRELIMINARY ENGINEERING
BORING PLAN AND GEOLOGIC PROFILE

LEGEND & EXPLANATION SHEET

CONTRACT NO
DRAWING NO Plate 1-00
REV
SCALE
SHEET NO

FILE NAME: G:\4953_Geotech\2011\111421_MetroWestside\CAD\4953-11-1421_P&P-Plates(11.11).dwg [00] DATE: December 02, 2011 TIME: 12:29 AM



DESIGNED BY	ELLIOTT / MUNRO
DRAWN BY	L. MORLEY
CHECKED BY	JAG / HP
IN CHARGE	MBH / PM
DATE	12/02/2011

REV | DATE | BY | APP | REG NO | EXPIRES | SEAL HOLDER | DESCRIPTION

Metro

LOS ANGELES COUNTY
METROPOLITAN TRANSPORTATION AUTHORITY

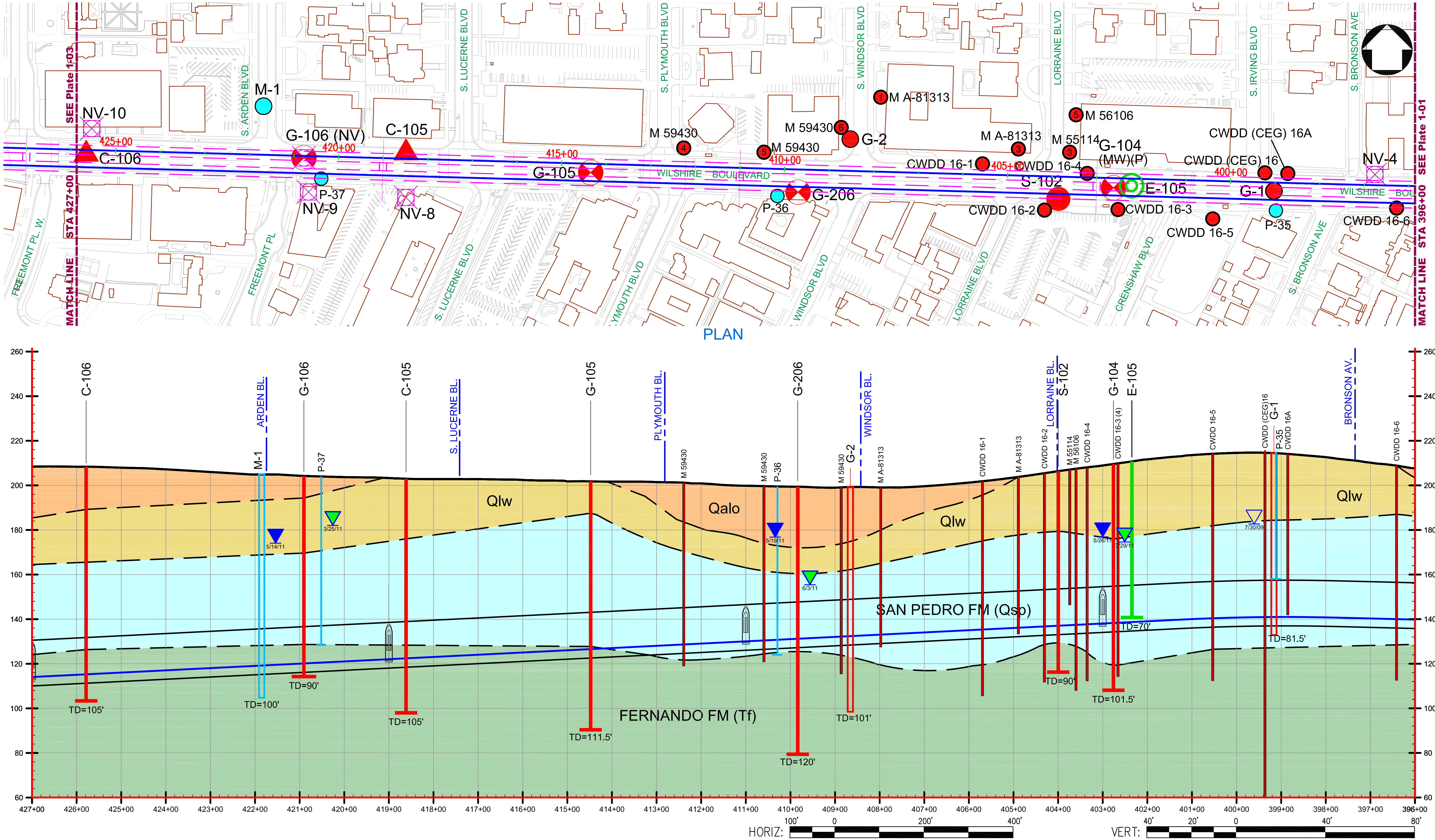
PROJECT MANAGER

WESTSIDE SUBWAY EXTENSION
PRELIMINARY ENGINEERING
BORING PLAN AND GEOLOGIC PROFILE

STATION 366+00 to 397+00

CONTRACT NO	
DRAWING NO	Plate 1-01
REV	
SCALE	AS NOTED
SHEET NO	

TIME: 1:35 PM
DATE: December 07, 2011
FILE NAME: C:\Users\LAMorley\Documents\CAD\4953-11-1421_WSE\4953-11-1421_P&P-Plates(11.11).dwg [01]



REV	DATE	BY	APP	REG NO	EXPIRES	SEAL HOLDER	DESCRIPTION

DESIGNED BY: ELLIOTT / MUNRO
DRAWN BY: L. MORLEY
CHECKED BY: JAG / HP
IN CHARGE: MBH / PM
DATE: 12/02/2011

Metro

LOS ANGELES COUNTY
METROPOLITAN TRANSPORTATION AUTHORITY

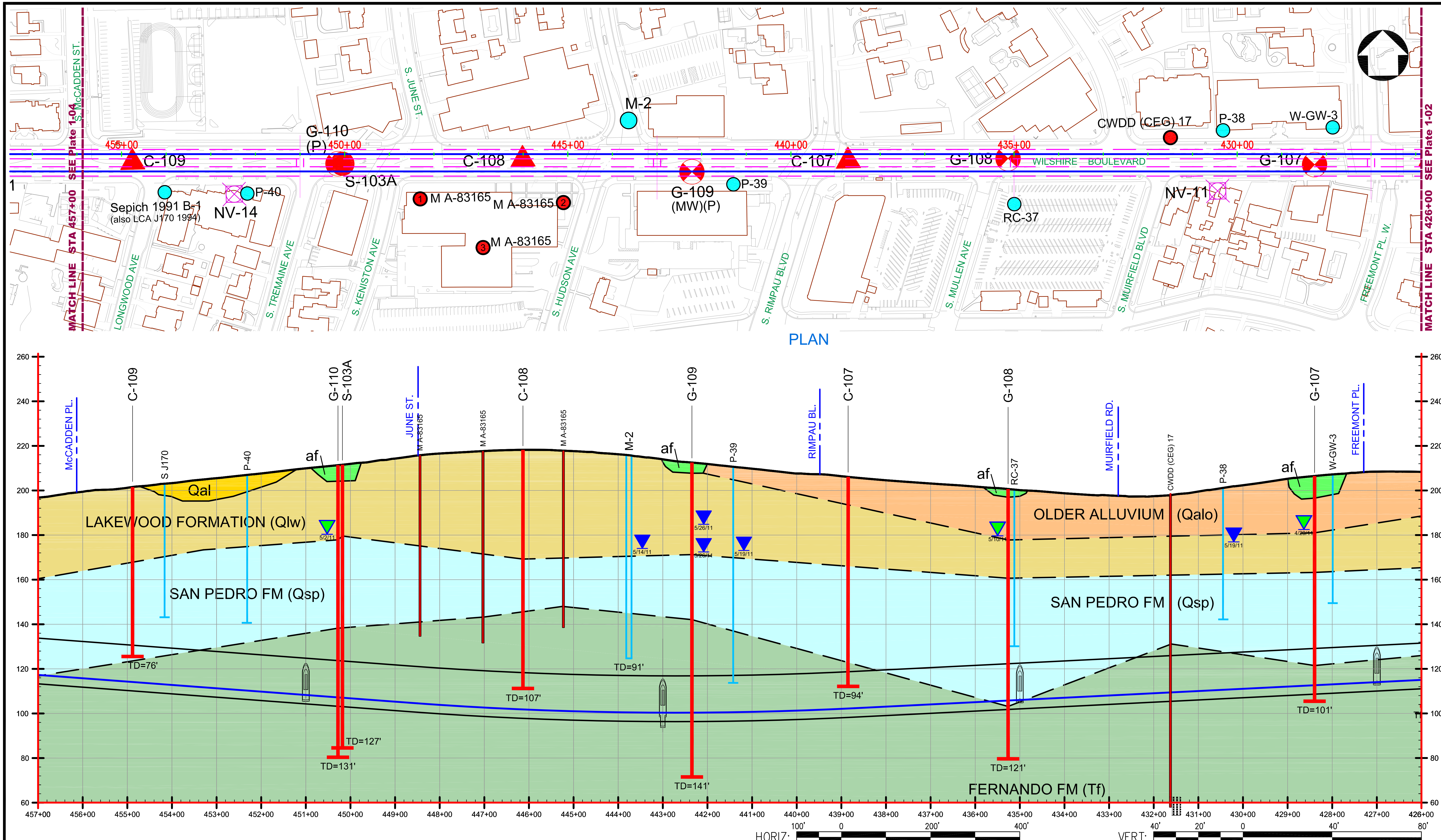
PROJECT MANAGER

WESTSIDE SUBWAY EXTENSION
PRELIMINARY ENGINEERING
BORING PLAN AND GEOLOGIC PROFILE

STATION 386+00 to 427+00

CONTRACT NO
DRAWING NO: Plate 1-02
REV
SCALE: AS NOTED
SHEET NO

TIME: 1:42 PM
DATE: December 07, 2011



DESIGNED BY	ELLIOTT / MUNRO
DRAWN BY	L. MORLEY
CHECKED BY	JAG / HP
IN CHARGE	MBH / PM
DATE	12/02/2011

REV | DATE | BY | APP | REG NO | EXPIRES | SEAL HOLDER | DESCRIPTION

Metro

LOS ANGELES COUNTY
METROPOLITAN TRANSPORTATION AUTHORITY

PROJECT MANAGER

WESTSIDE SUBWAY EXTENSION
PRELIMINARY ENGINEERING
BORING PLAN AND GEOLOGIC PROFILE

STATION 426+00 to 457+00

CONTRACT NO

DRAWING NO Plate 1-03

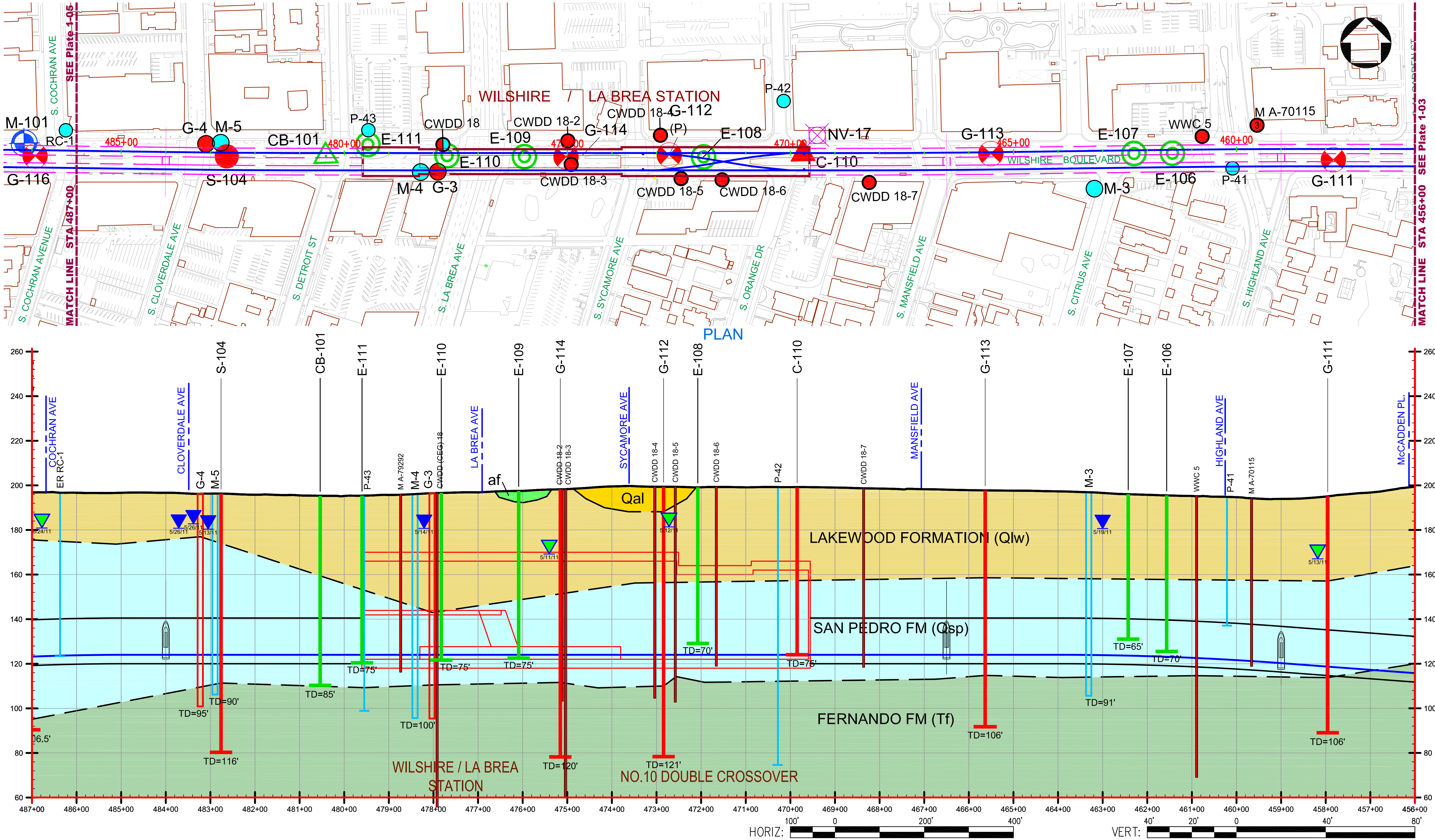
REV

SCALE AS NOTED

SHEET NO

DATE: December 07, 2011 TIME: 1:49 PM

FILE NAME: C:\Users\LAMorley\Documents\CAD\4953-11-1421_WSE\4953-11-1421_P&P-Plates(11.11).dwg [03]



TIME: 1:52 PM

DATE: December 07, 2011

FILE NAME: C:\Users\LAMorley\Documents\CAD\4953-11-1421_WSE\4953-11-1421_P&P-Plates(11.11).dwg [04]

REV	DATE	BY	APP	REG NO	EXPIRES	SEAL HOLDER	DESCRIPTION

DESIGNED BY: ELLIOTT / MUNRO
DRAWN BY: L. MORLEY
CHECKED BY: JAG / HP
IN CHARGE: MBH / PM
DATE: 12/02/2011

Metro

LOS ANGELES COUNTY
METROPOLITAN TRANSPORTATION AUTHORITY

PB

PROJECT MANAGER ____________

WESTSIDE SUBWAY EXTENSION
PRELIMINARY ENGINEERING
BORING PLAN AND GEOLOGIC PROFILE

STATION 456+00 to 487+00

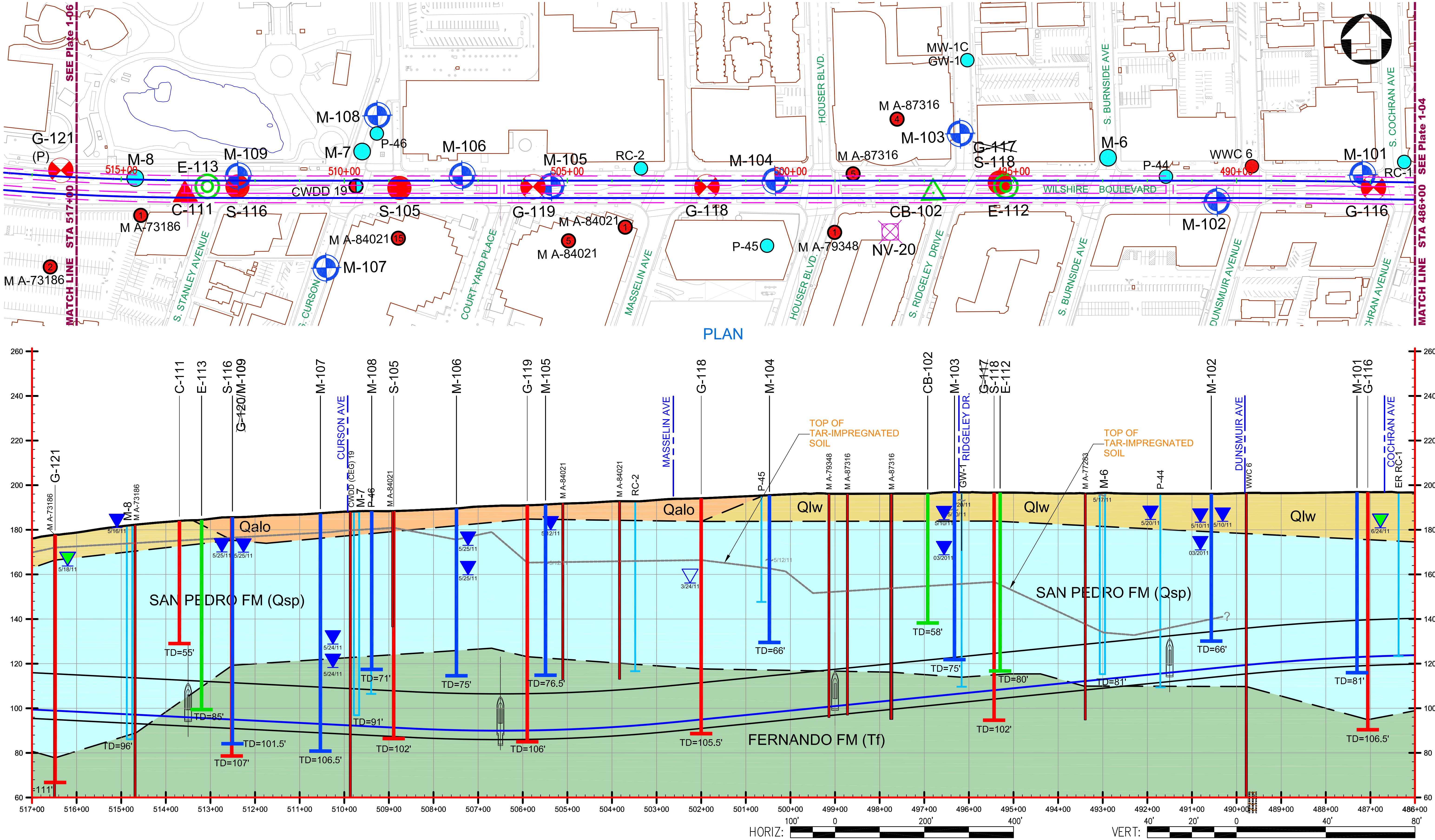
CONTRACT NO

DRAWING NO: Plate 1-04

REV

SCALE: AS NOTED

SHEET NO



REV	DATE	BY	APP	REG NO	EXPIRES	SEAL HOLDER	DESCRIPTION	

DESIGNED BY ELLIOTT / MUNRO
DRAWN BY L. MORLEY
CHECKED BY JAG / HP
IN CHARGE MBH / PM
DATE 12/02/2011

Metro

LOS ANGELES COUNTY
METROPOLITAN TRANSPORTATION AUTHORITY

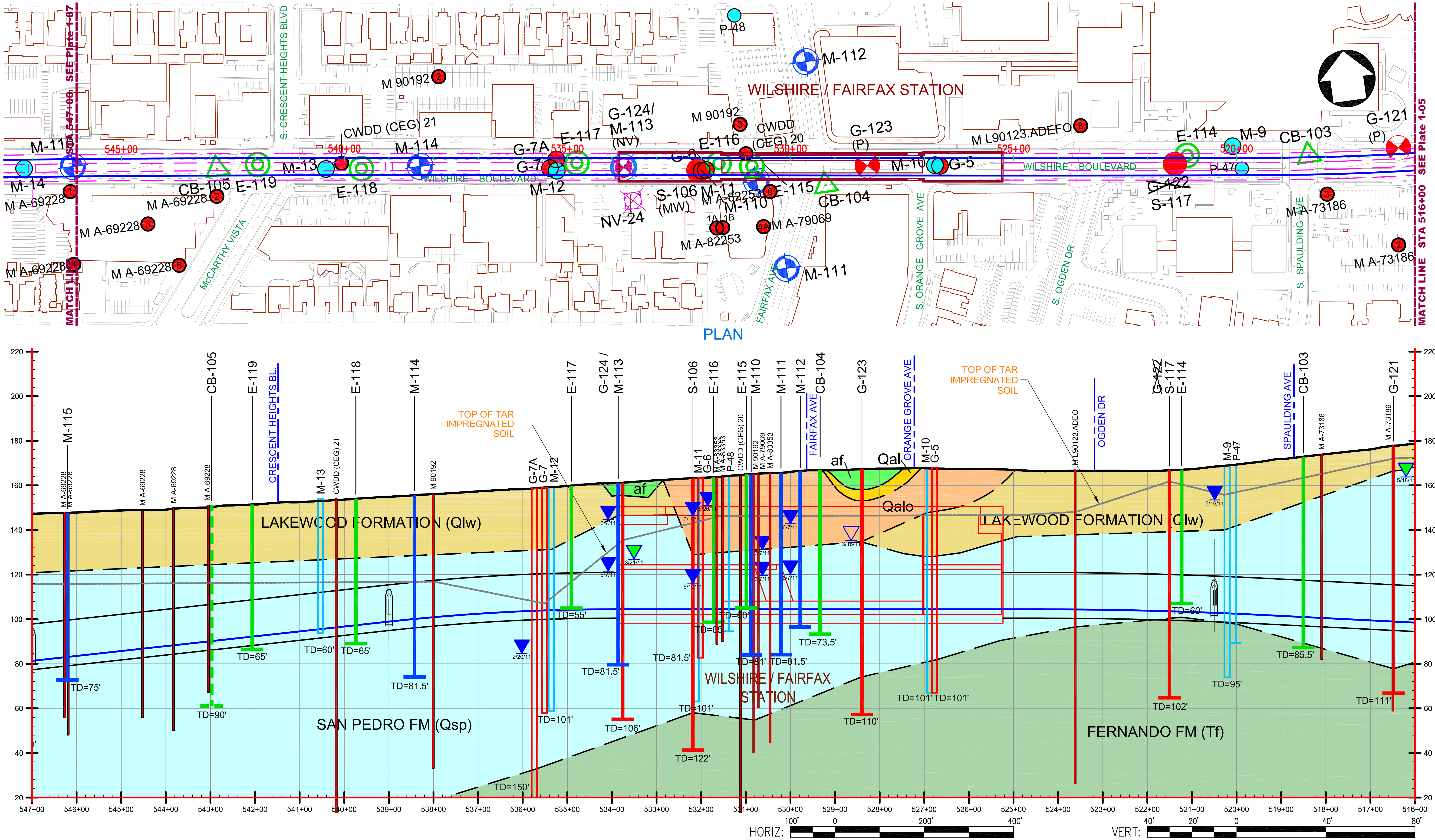
PROJECT MANAGER

WESTSIDE SUBWAY EXTENSION
PRELIMINARY ENGINEERING
BORING PLAN AND GEOLOGIC PROFILE

STATION 486+00 to 517+00

CONTRACT NO
DRAWING NO Plate 1-05
REV
SCALE AS NOTED
SHEET NO

TIME: 1:58 PM
DATE: December 07, 2011



DESIGNED BY	ELLIOTT / MUNRO
DRAWN BY	L. MORLEY
CHECKED BY	JAG / HP
IN CHARGE	MBH / PM
DATE	12/02/2011

REV | DATE | BY | APP | REG NO | EXPIRES | SEAL HOLDER | DESCRIPTION

Metro

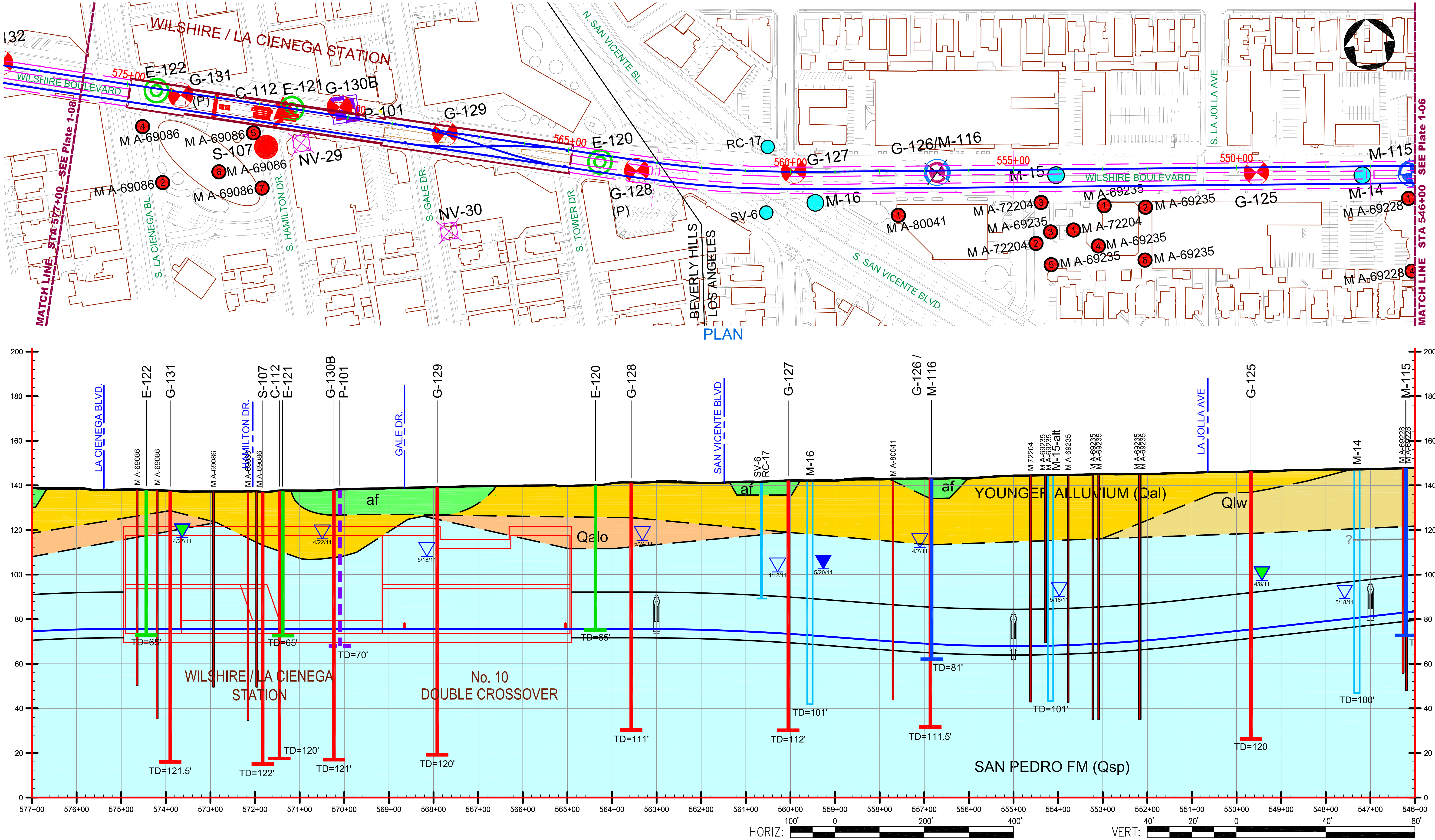
LOS ANGELES COUNTY METROPOLITAN TRANSPORTATION AUTHORITY

PROJECT MANAGER

WESTSIDE SUBWAY EXTENSION
PRELIMINARY ENGINEERING
BORING PLAN AND GEOLOGIC PROFILE

STATION 516+00 to 547+00

CONTRACT NO	
DRAWING NO	Plate 1-06
REV	
SCALE	AS NOTED
SHEET NO	



						DESIGNED BY	ELLIOTT / MUNRO
						DRAWN BY	L. MORLEY
						CHECKED BY	JAG / HP
						IN CHARGE	MBH / PM
REV	DATE	BY	APP	REG NO / EXPIRES	SEAL HOLDER	DESCRIPTION	DATE 12/02/2011

Metro

LOS ANGELES COUNTY
METROPOLITAN TRANSPORTATION AUTHORITY

PB

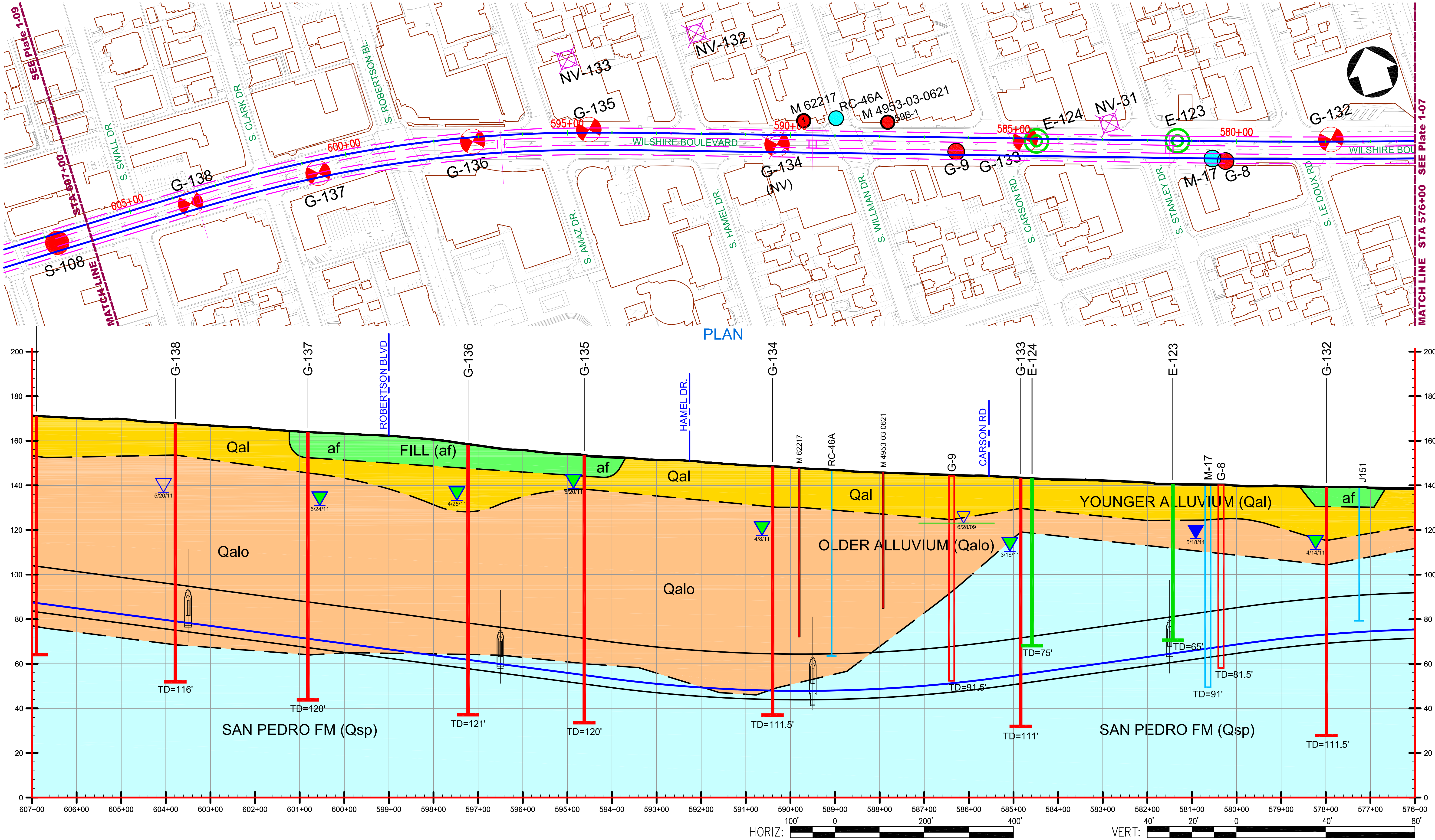
PROJECT MANAGER

WESTSIDE SUBWAY EXTENSION
PRELIMINARY ENGINEERING
BORING PLAN AND GEOLOGIC PROFILE

STATION 546+00 to 577+00

CONTRACT NO
DRAWING NO Plate 1-07
REV
SCALE AS NOTED
SHEET NO

TIME: 2:00 PM
DATE: December 07, 2011
FILE NAME: C:\Users\LAMorley\Documents\CAD4953-11-1421_WSE4953-11-1421_P&P-Plates(11.11).dwg [07]



REV	DATE	BY	APP	REG NO	EXPIRES	SEAL HOLDER	DESCRIPTION

DESIGNED BY: ELLIOTT / MUNRO
DRAWN BY: L. MORLEY
CHECKED BY: JAG / HP
IN CHARGE: MBH / PM
DATE: 12/02/2011

Metro

LOS ANGELES COUNTY
METROPOLITAN TRANSPORTATION AUTHORITY

PB

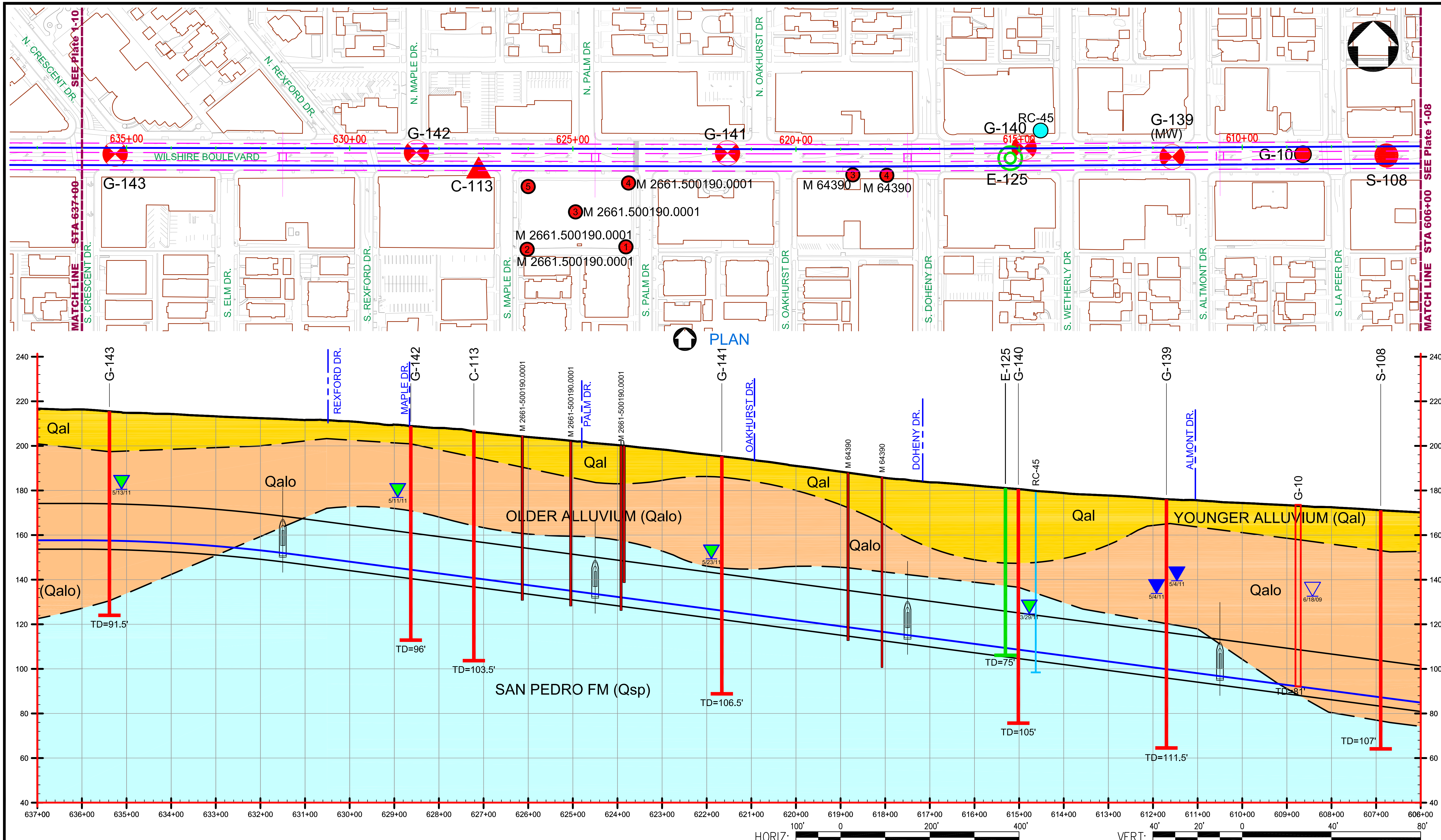
PROJECT MANAGER ____________

WESTSIDE SUBWAY EXTENSION
PRELIMINARY ENGINEERING
BORING PLAN AND GEOLOGIC PROFILE

STATION 576+00 to 607+00

CONTRACT NO
DRAWING NO: Plate 1-08
REV
SCALE: AS NOTED
SHEET NO

TIME: 2:01 PM
DATE: December 07, 2011
FILE NAME: C:\Users\LAMorley\Documents\CAD\4953-11-1421_WSE\4953-11-1421_P&P-Plates(11.11).dwg [08]



REV	DATE	BY	APP	REG NO	EXPIRES	SEAL HOLDER	DESCRIPTION

DESIGNED BY ELLIOTT / MUNRO
DRAWN BY L. MORLEY
CHECKED BY JAG / HP
IN CHARGE MBH / PM
DATE 12/02/2011

Metro

LOS ANGELES COUNTY
METROPOLITAN TRANSPORTATION AUTHORITY

PB

PROJECT MANAGER

WESTSIDE SUBWAY EXTENSION
PRELIMINARY ENGINEERING
BORING PLAN AND GEOLOGIC PROFILE

STATION 606+00 to 637+00

CONTRACT NO

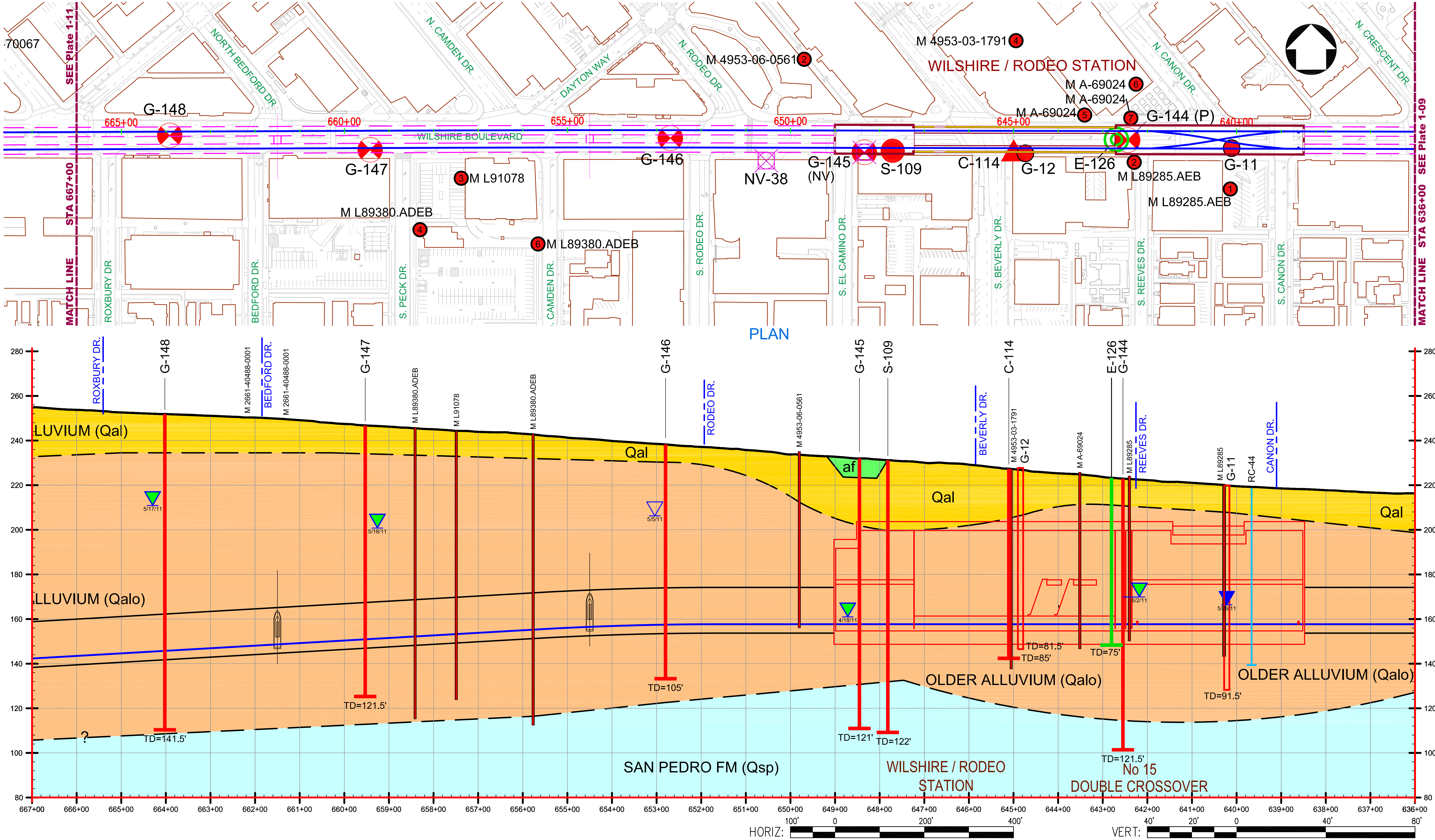
DRAWING NO Plate 1-09

REV

SCALE AS NOTED

SHEET NO

FILE NAME: C:\Users\LAMorley\Documents\CAD\4953-11-1421_WSE\4953-11-1421_P&P-Plates(11.11).dwg [09]
DATE: December 07, 2011
TIME: 2:03 PM



REV	DATE	BY	APP	REG NO	EXPIRES	SEAL HOLDER	DESCRIPTION

DESIGNED BY: ELLIOTT / MUNRO
DRAWN BY: L. MORLEY
CHECKED BY: JAG / HP
IN CHARGE: MBH / PM
DATE: 12/02/2011

Metro
PB
PROJECT MANAGER

LOS ANGELES COUNTY METROPOLITAN TRANSPORTATION AUTHORITY

WESTSIDE SUBWAY EXTENSION
PRELIMINARY ENGINEERING
BORING PLAN AND GEOLOGIC PROFILE

STATION 636+00 to 667+00

CONTRACT NO
DRAWING NO: Plate 1-10
REV
SCALE: AS NOTED
SHEET NO

TIME: 2:04 PM
DATE: December 07, 2011
FILE NAME: C:\Users\LAMorley\Documents\CAD\4953-11-1421_WSE\4953-11-1421_P&P-Plates(11.11).dwg [10]