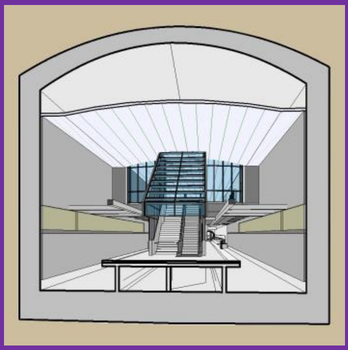
LOS ANGELES COUNTY METROPOLITAN TRANSPORTATION AUTHORITY

WESTSIDE PURPLE LINE EXTENSION PROJECT, SECTION 2
ADVANCED PRELIMINARY ENGINEERING

Contract No. PS-4350-2000



Assessment of Tunneling and Station Excavation Risks Associated with Subsurface Gas Section 2 – Revision 1

Task No. 52.04.030.05B

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Table of Contents

List of Figures

List of Tables

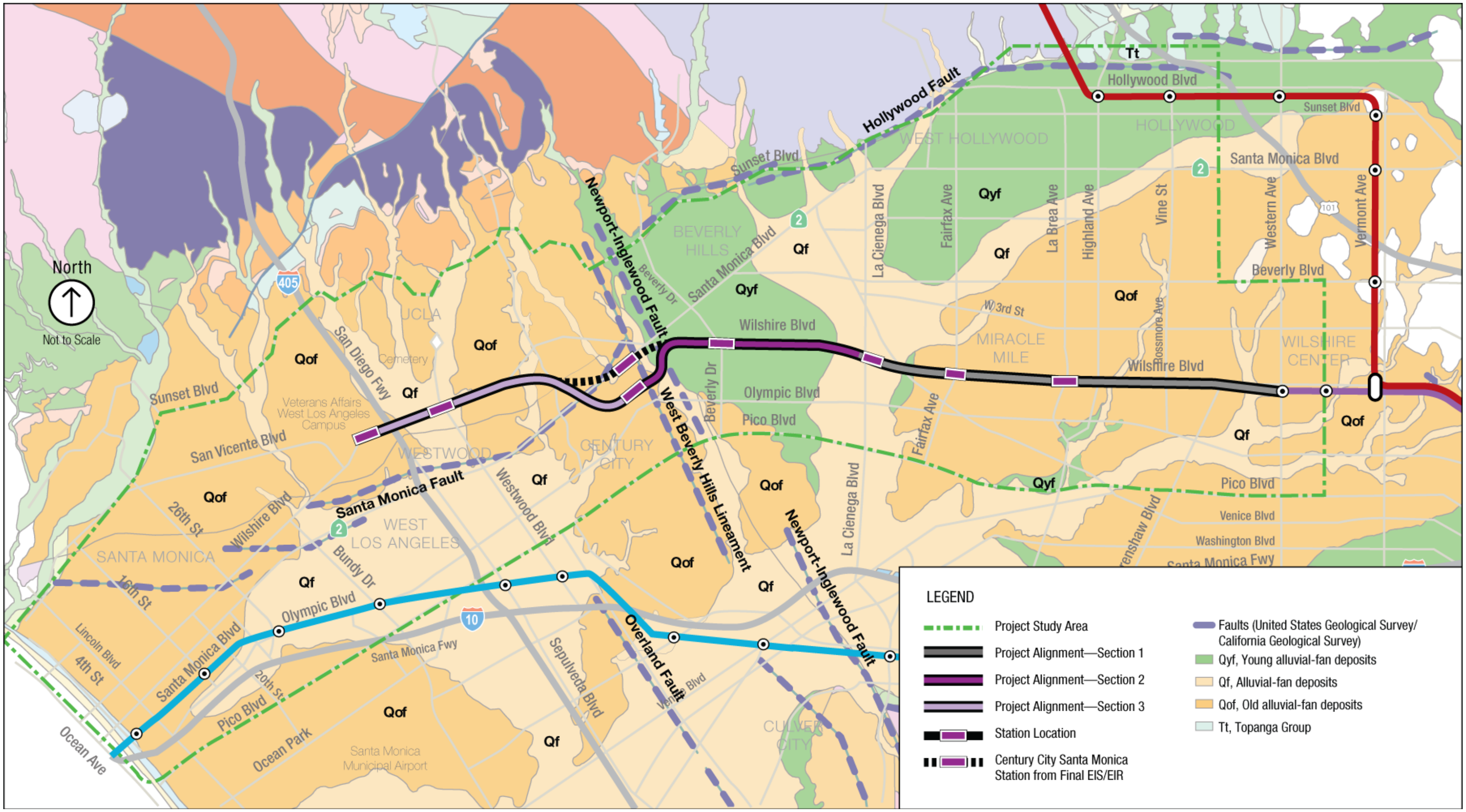
PREFACE

The Assessment of Tunneling and Station Excavation Risks Associated with Subsurface Gas Section 2 Memorandum was shared with the City of Beverly Hills and the Beverly Hills Unified School District in March 2017 as part of the Section 4(f) consultation process for the publicly used recreational facilities at Beverly Hills High School. This revised version of the memo addresses comments and concerns received in letters from the City of Beverly Hills on April 4, 2017 and BHUSD on April 7, 2017.

1.0 INTRODUCTION

This memorandum has been prepared for Section 2 of the proposed Westside Purple Line Extension project (WPLE) (formerly referred to as the Westside Subway Extension) as part of the Advanced Preliminary Engineering (Adv. PE) phase for the Los Angeles County Metropolitan Transportation Authority (Metro). Section 2 of the WPLE Project will extend from the western “End Structure” of the Wilshire/La Cienega Station (at the western end of Section 1) to the eastern “End Structure” of the Century City Constellation Station. Section 2 will include two new stations: the Wilshire/Rodeo Station and the Century City Constellation Station, and tunnels extending from Section 1 to the Century City Constellation Station. The project alignment, including Section 2, is shown in Figure 1-1. As part of geotechnical investigations performed for Section 2, Metro has performed subsurface gas investigations to evaluate the potential for methane and hydrogen sulfide gas to be present along the alignment. The *Westside Subway Extension Geotechnical and Environmental Report* (Metro 2011a) and the Geotechnical Data Reports for Section 2 (Metro 2016a, b, and c) contain the soil boring logs, gas monitoring well diagrams, and detailed geologic profiles from these studies along the WPLE. In addition, other entities have performed subsurface gas investigations to evaluate the potential for gases at Beverly Hills High School (BHHS). This memorandum provides a summary of the Metro investigations, BHHS investigations by others, and an evaluation of the potential risks related to encountering subsurface gases along Section 2.

Figure 1-1: Surface Geology and Section 2 Tunnel Alignment



2.0 PROJECT SETTING

Section 2 of the Project consists of two stretches of tunnel – Tunnel Reach 4 between the Wilshire/La Cienega Station and the Wilshire/Rodeo Station and Tunnel Reach 5 between the Wilshire/Rodeo Station and the Century City Constellation Station. Tunnel Reach 4 is about 6,282 feet long, extending from the west end of the Wilshire/La Cienega Station to the east end of the Wilshire/Rodeo Station. The tunnels, each about 21 feet in diameter, have a crown as shallow as about 45 feet below ground surface (bgs), and an invert as deep as about 135 feet bgs. The Wilshire/Rodeo Station is about 900 feet long, from 30 feet west of Crescent Drive to 15 feet west of Beverly Drive, and extends to a depth of about 85 to 100 feet below Wilshire Boulevard.

Tunnel Reach 5 is about 5,808 feet long extending from the west end of the Wilshire/Rodeo Station to the east end of the Century City Constellation station. The tunnels have a crown (top of tunnel) as shallow as about 45 feet bgs, and an invert (bottom of tunnel) as deep as about 135 feet bgs. BHHS is located near the southwest end of Tunnel Reach 5, about 450 ft before the west end of Tunnel Reach 5; the top of the tunnel will be as shallow as 55 and the bottom of the tunnel as deep as about 100 feet bgs at BHHS. The Century City Constellation Station and associated double crossover structure No. 10 is about 1,225 feet long, from 85 feet west of the west edge of Century Park East to 365 feet west of the west edge of Avenue of the Stars, and extends to a depth of about 85 to 90 feet below Constellation Boulevard.

An aerial photograph of the BHHS site is provided as Figure 2-1. The proposed alignment of the WPLE beneath the 0.25 acre BHHS site is shown in this figure. As shown in Figure 2-2, the BHHS property lies within the limits of the Beverly Hills Oil Field as it has been mapped by the California Department of Conservation - Division of Oil, Gas, & Geothermal Resources (DOGGR). This oil field was discovered in July of 1900 and has been in active production since that time (California Department of Conservation, 1991). The primary oil bearing zone within the Beverly Hills Oil field is referred to as the Wolfskill member of the Lower Pliocene Repetto formation. That production zone occurs at depths ranging from approximately 2,000 to 6,000 feet bgs.

As shown in Figure 2-3, nineteen active oil production, water injection, or idle oil wells are located within the 0.6-acre Venoco Inc. oil production facility at the southwest corner of the BHHS site (California Division of Oil, Gas & Geothermal Resources, 2006; California Division of Oil, Gas & Geothermal Resources, 2016). These are the only active wells on the BHHS property. The Venoco wells are located approximately 485 feet to the south of the proposed subway tunnel alignment. Venoco leases the production facility from BHHS. That lease expires in 2016 and BHHS has reportedly indicated it will not be renewed or extended (Environmental Audit, Inc. 2016b and 2016c). Upon lease termination, Venoco is required to abandon all wells in accordance with DOGGR requirements and obtain a No Further Action letter for the parcel from an appropriate regulatory agency.

As shown in Figure 2-3, there are six abandoned oil wells on the BHHS property outside the limits of the Venoco facility (California Division of Oil, Gas & Geothermal Resources, 2006 and 2016). Most of these wells were abandoned between 1969 and 1979 in accordance with the applicable DOGGR standards. The closest abandoned well on the BHHS property to the proposed subway alignment (Chevron USA Inc. Rodeo 107) is shown to be located approximately 35 feet to the south of the proposed southern tunnel on the DOGGR field maps.

Three additional isolated abandoned oil wells (Wolfskill 1, 23, & 36), and the former 20th Century Fox drill site with 25 abandoned oil wells, are shown to be located between the western BHHS property line and Century Park East to the west on the DOGGR field maps. Some of the wells on and adjacent to the BHHS site can be seen in the historic aerial photographs presented as Figure 2-4 through Figure 2-15.

Figure 2-1: Recent Aerial Photograph of Beverly Hills High School Campus

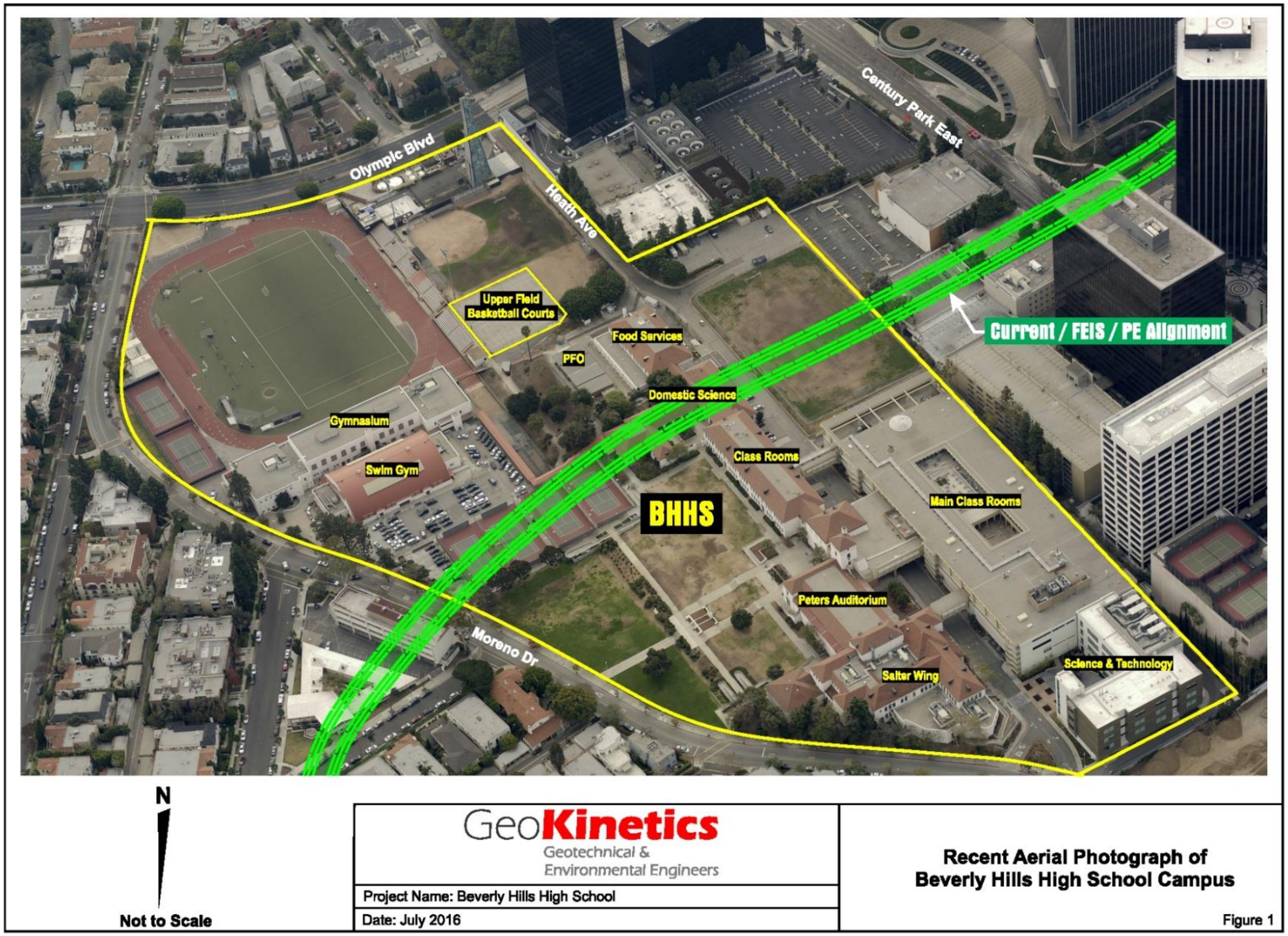


Figure 2-2: Oil Field Limits

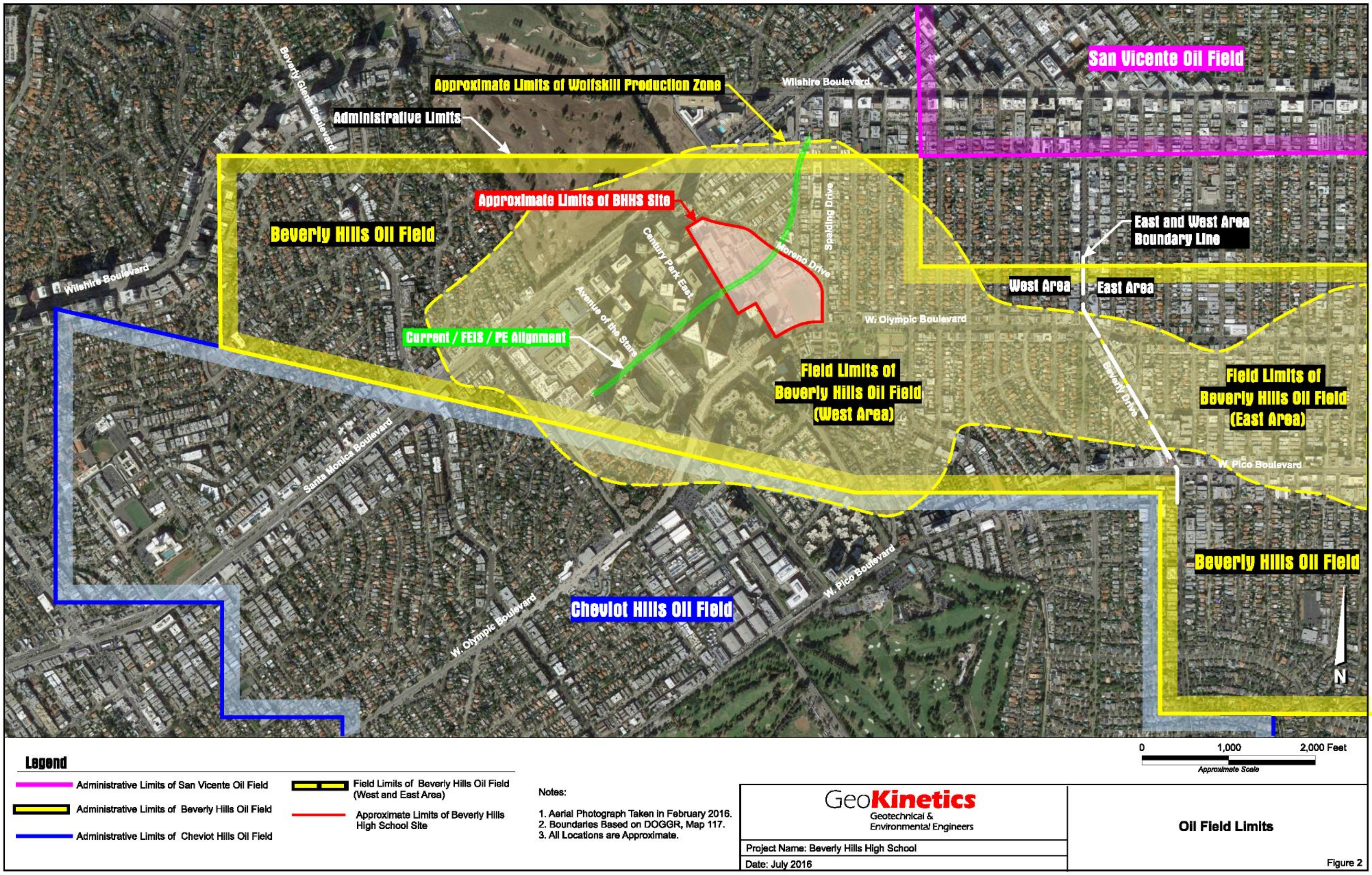
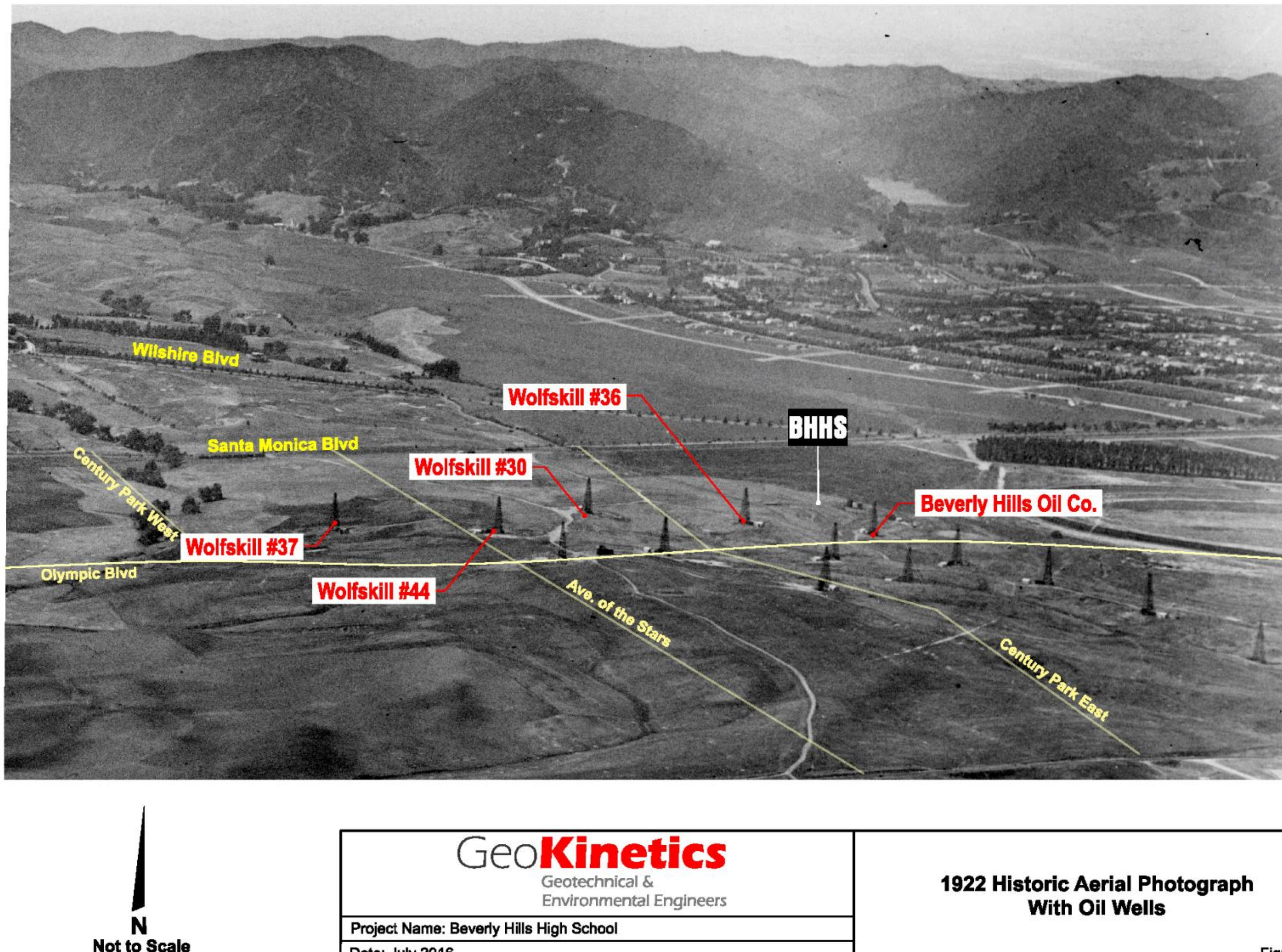


Figure 2-3: Oil Wells at Beverly Hills High School and Vicinity

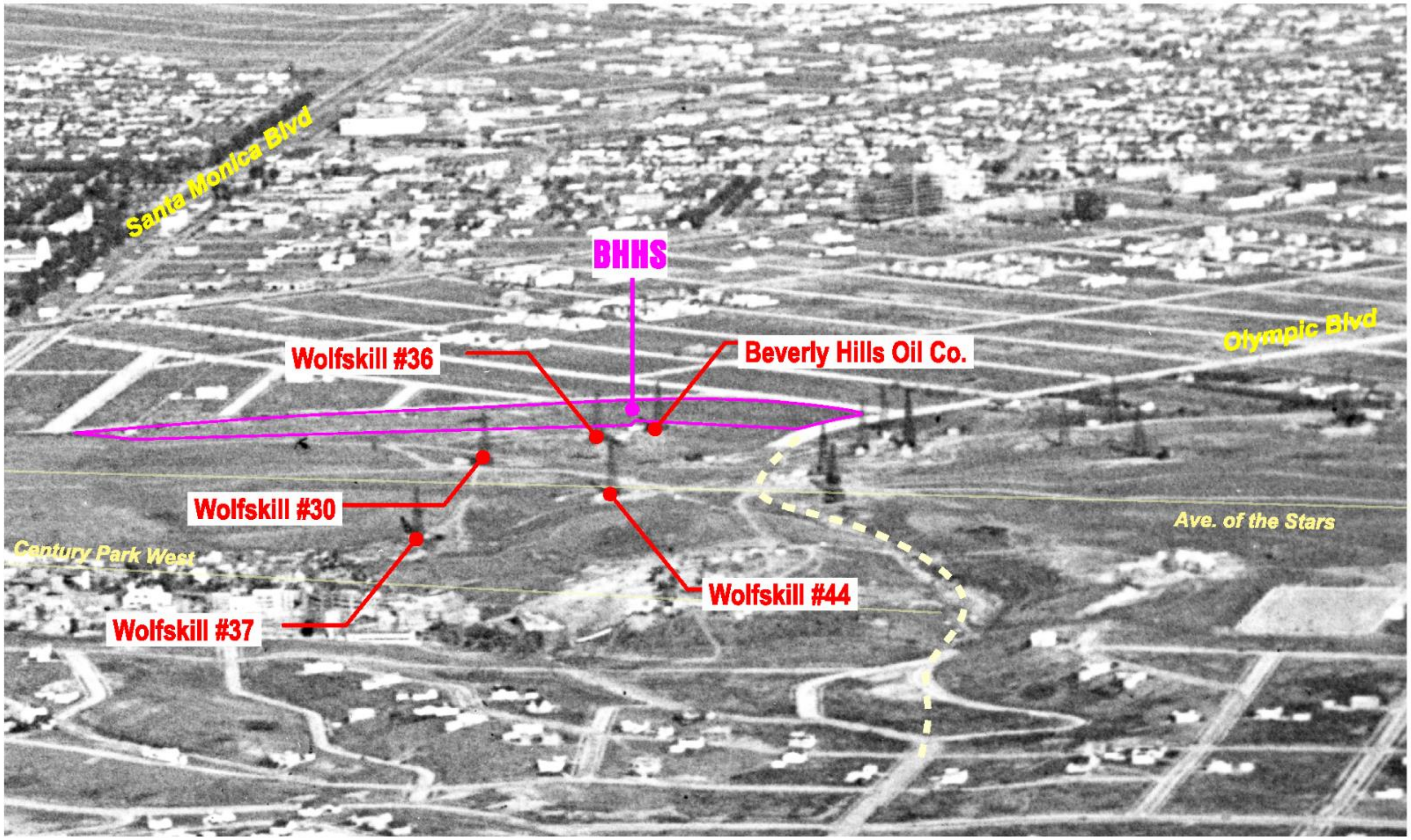
Metro

Figure 2-4: 1922 Historic Aerial Photograph with Oil Wells



GeoKinetics Geotechnical & Environmental Engineers	1922 Historic Aerial Photograph With Oil Wells
Project Name: Beverly Hills High School	
Date: July 2016	Figure 4

Figure 2-5: 1926 Historic Aerial Photograph with Oil Wells



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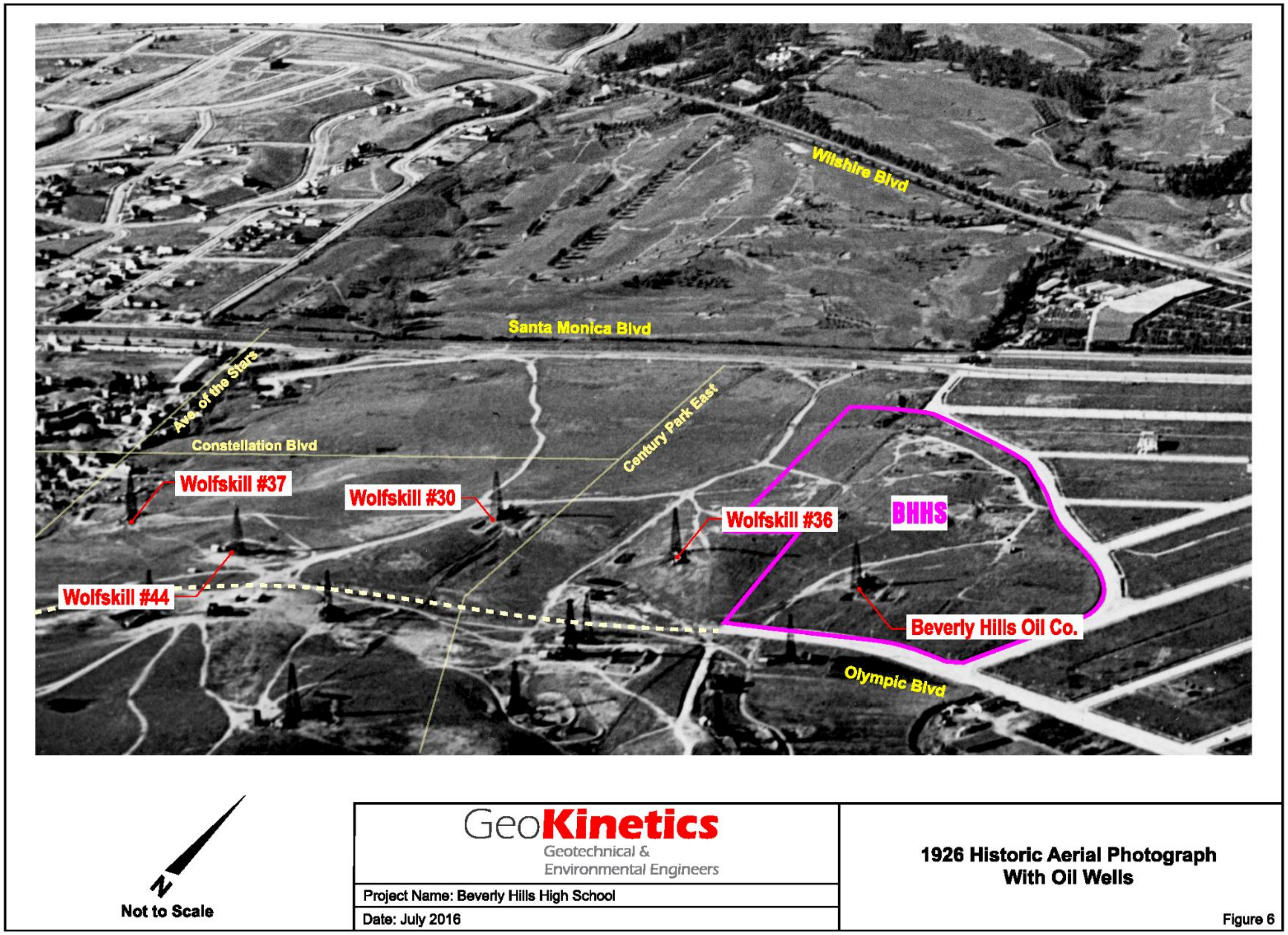
Geotechnical & Environmental Engineers

Project Name: Beverly Hills High School
Date: July 2016

1926 Historic Aerial Photograph With Oil Wells

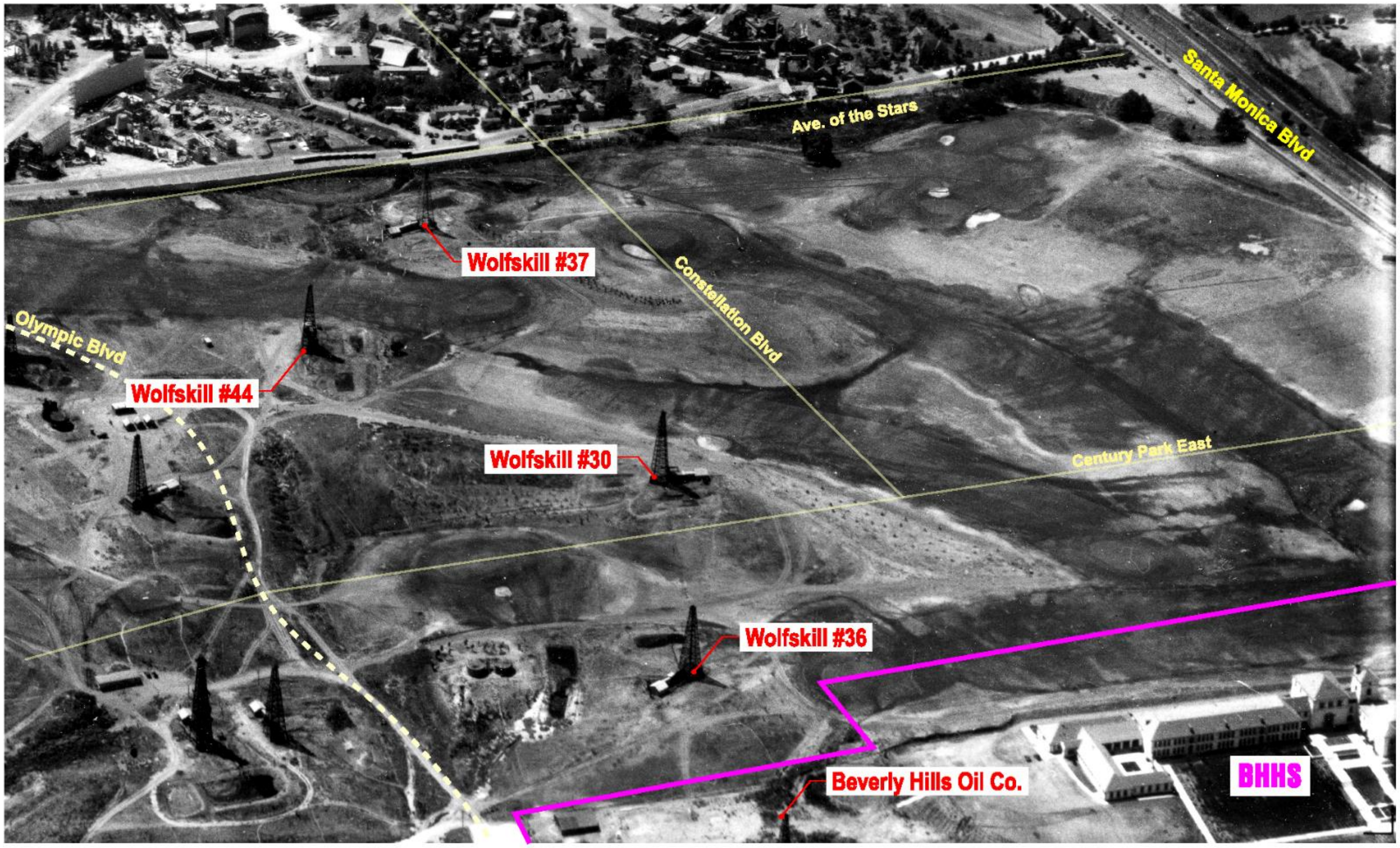
Figure 5

Figure 2-6: 1926 Historic Aerial Photograph with Oil Wells



GeoKinetics Geotechnical & Environmental Engineers	1926 Historic Aerial Photograph With Oil Wells
Project Name: Beverly Hills High School	
Date: July 2016	Figure 6

Figure 2-7: 1929 Historic Aerial Photograph with Oil Wells



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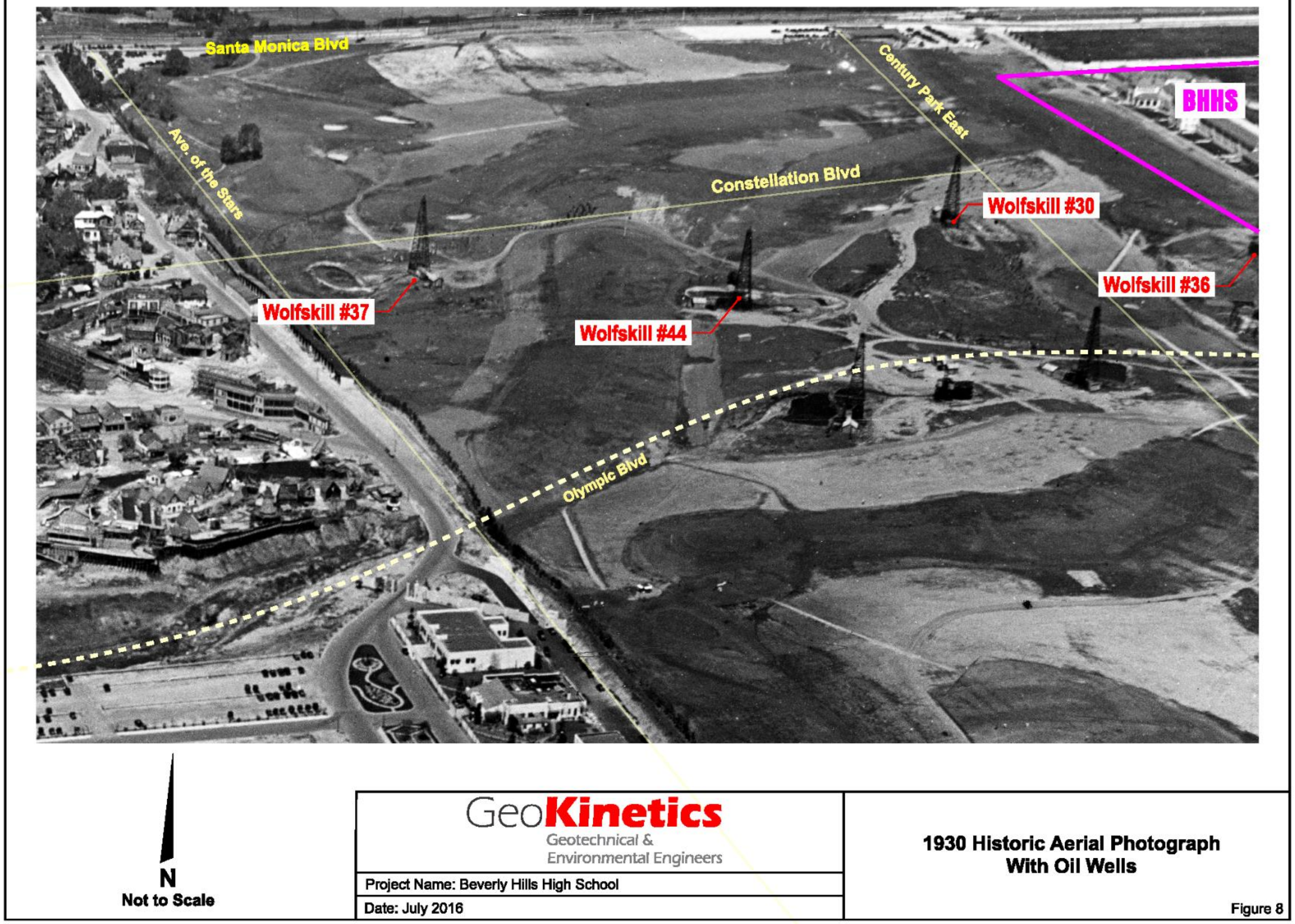
Date: July 2016

1929 Historic Aerial Photograph With Oil Wells

Figure 7

Figure 2-8: 1930 Historic Aerial Photograph with Oil Wells



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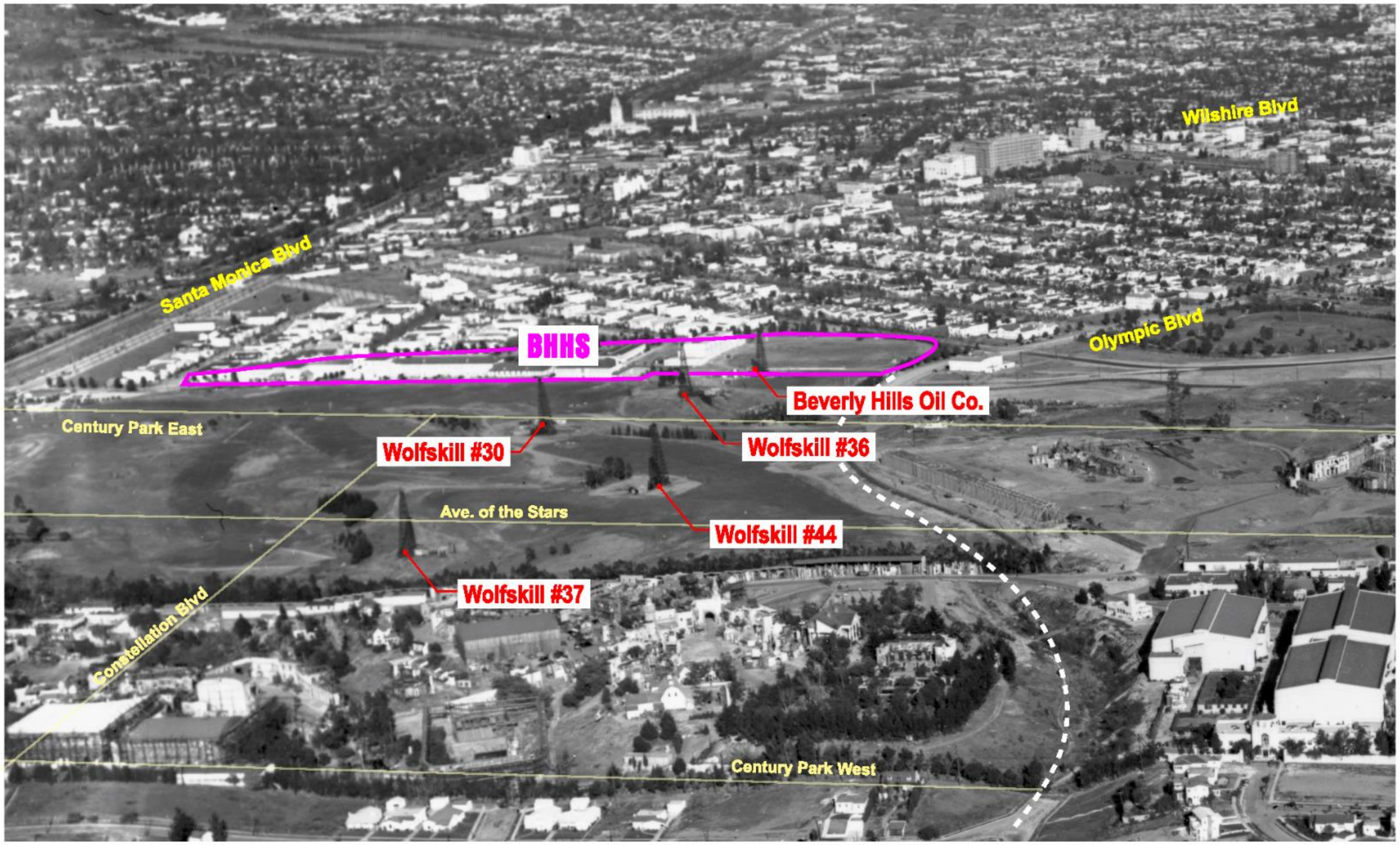
Project Name: Beverly Hills High School
Date: July 2016

1930 Historic Aerial Photograph With Oil Wells

Figure 8

Figure 2-9: 1937 Historic Aerial Photograph with Oil Wells



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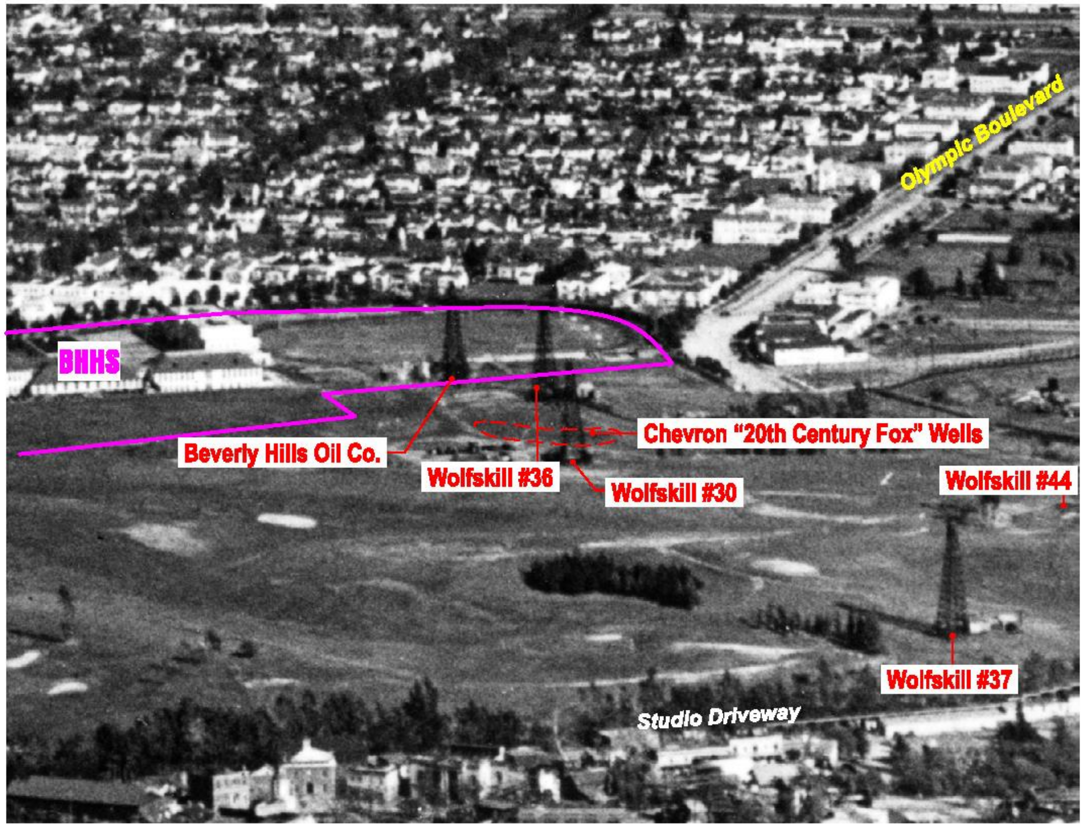
Date: July 2016

Not to Scale

1937 Historic Aerial Photograph With Oil Wells

Figure 9

Figure 2-10: 1939 Historic Aerial Photograph with Oil Wells



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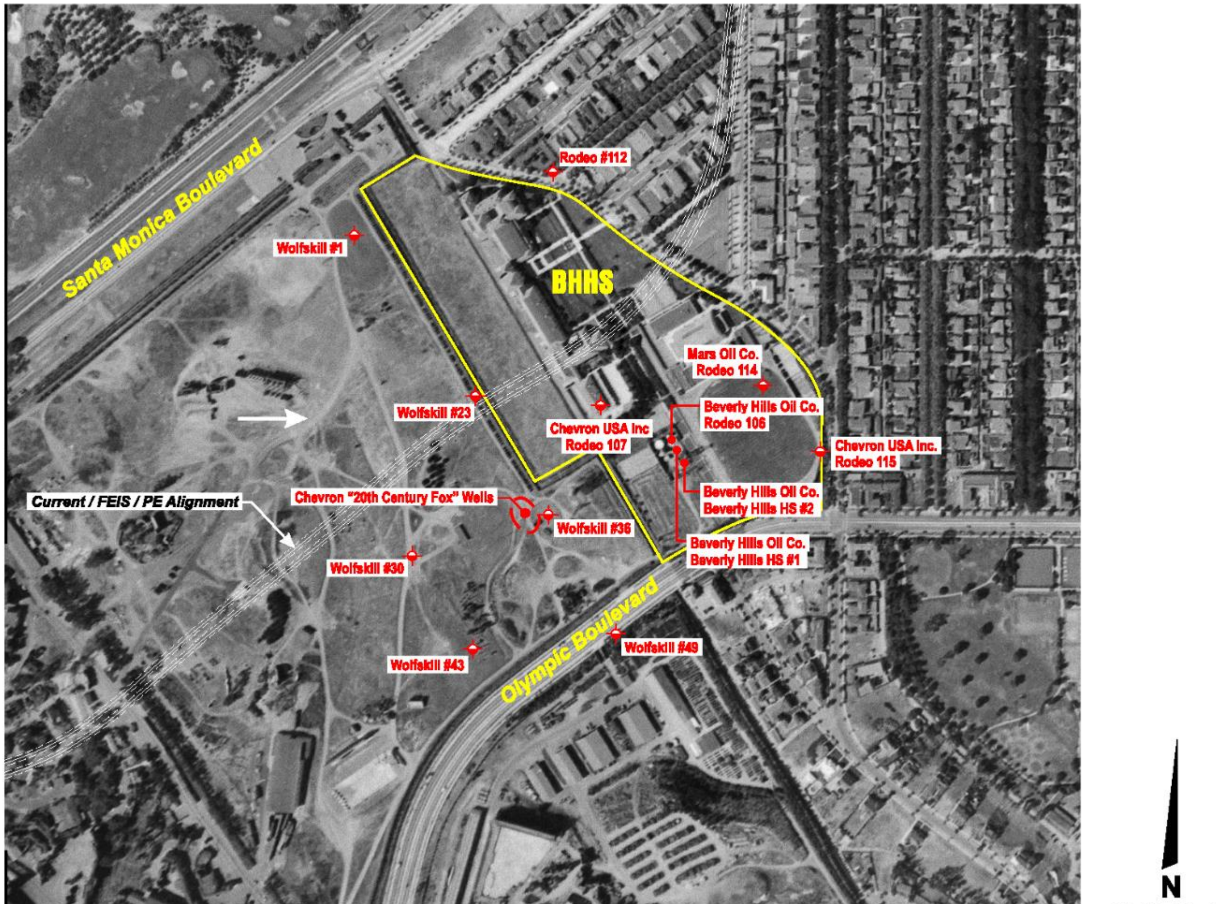
Date of Photograph: 1-31-1939

GeoKinetics Geotechnical & Environmental Engineers	1939 Historic Aerial Photograph With Oil Wells
Project Name: Beverly Hills High School	
Date: July 2016	Figure 10

Figure 2-11: 1947 Historic Aerial Photograph with Oil Wells



Note: Oil well locations based DOGGR Map 117 (2001)

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Project Name: Beverly Hills High School

Date: July 2016

1947 Historic Aerial Photograph With Oil Wells

Figure 11

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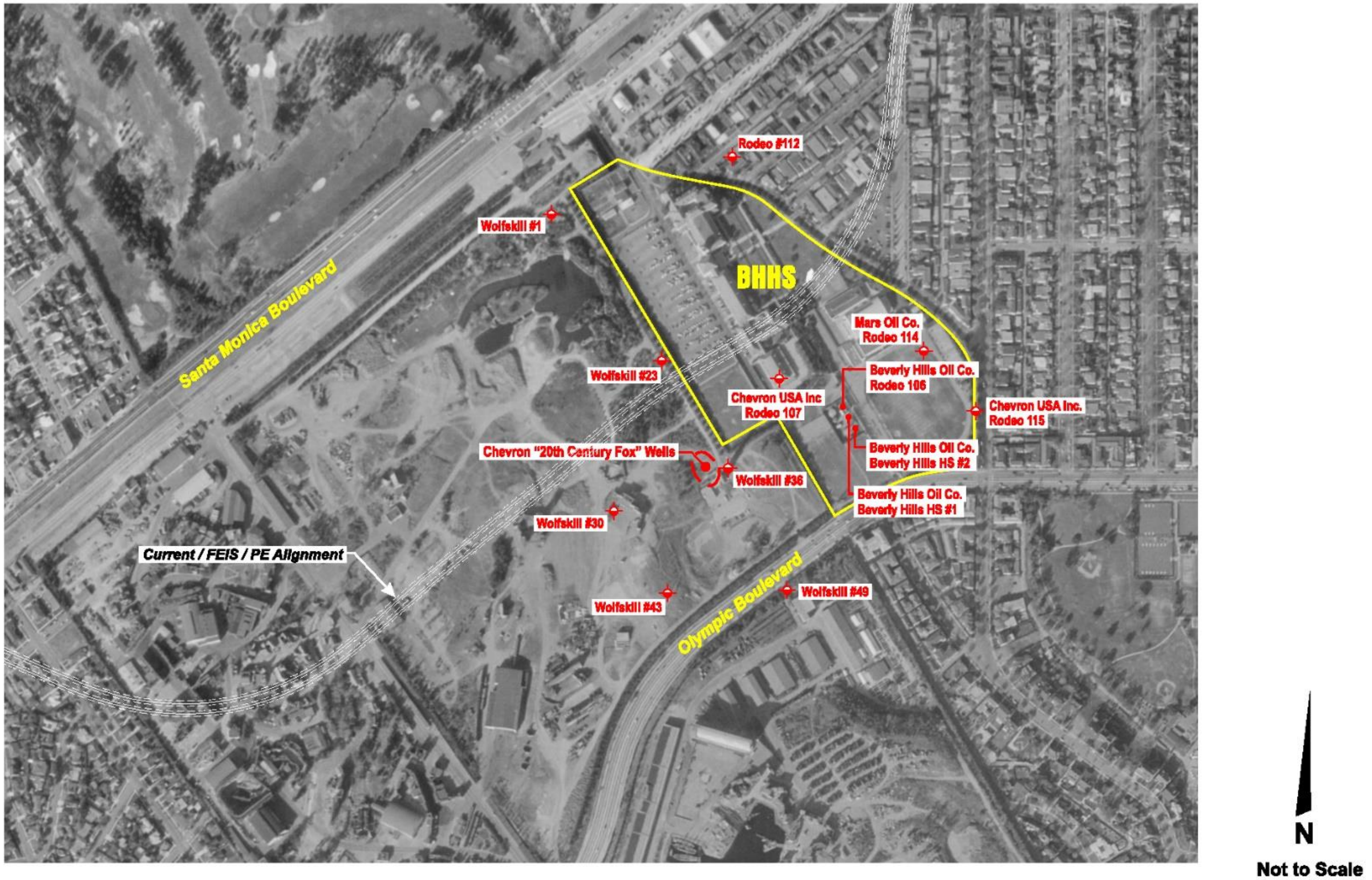
Figure 2-12: 1953 Historic Aerial Photograph with Oil Wells



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Note: Oil well locations based DOGGR Map 117 (2001)

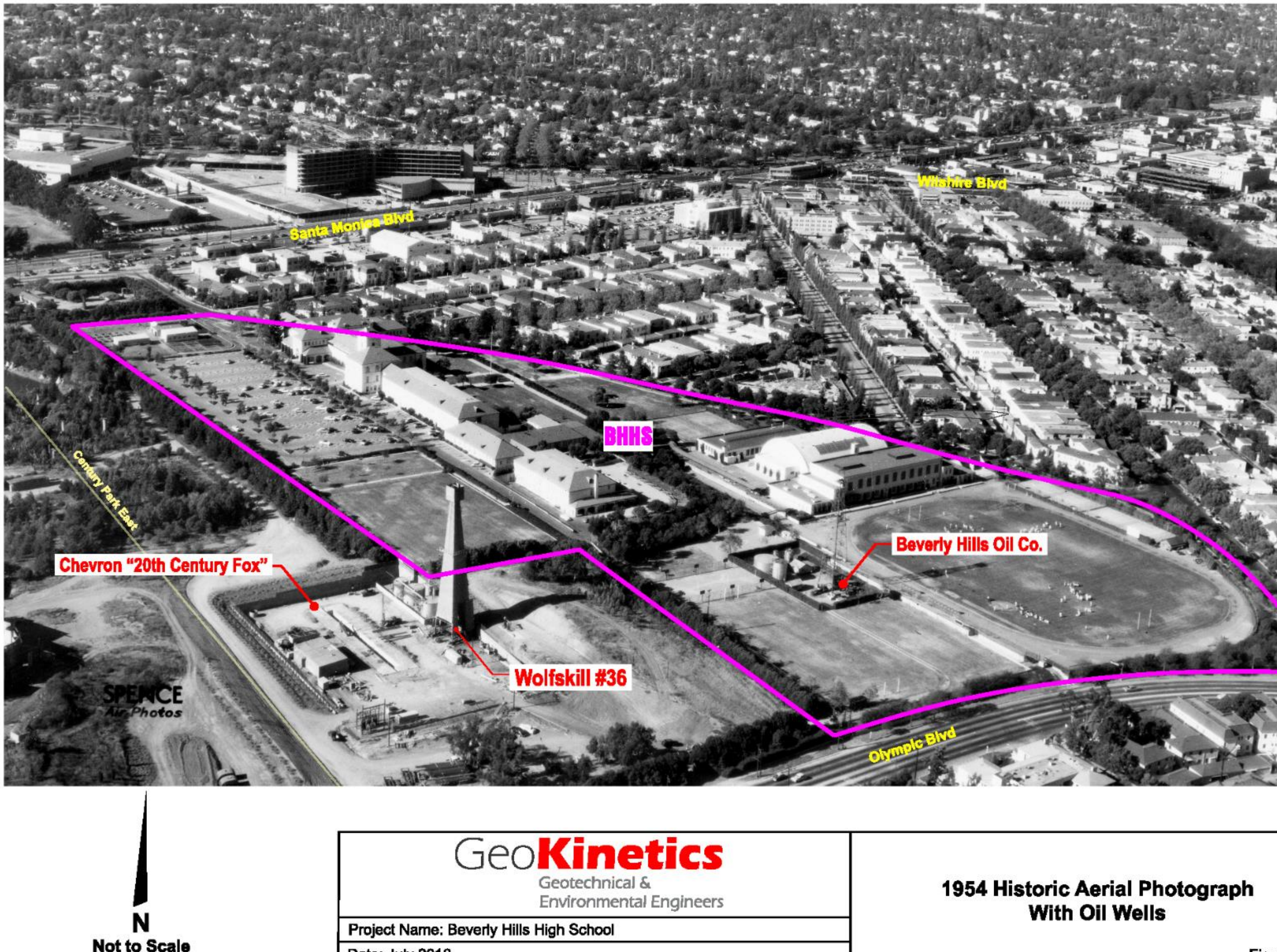
Project Name: Beverly Hills High School

Date: July 2016

1953 Historic Aerial Photograph With Oil Wells

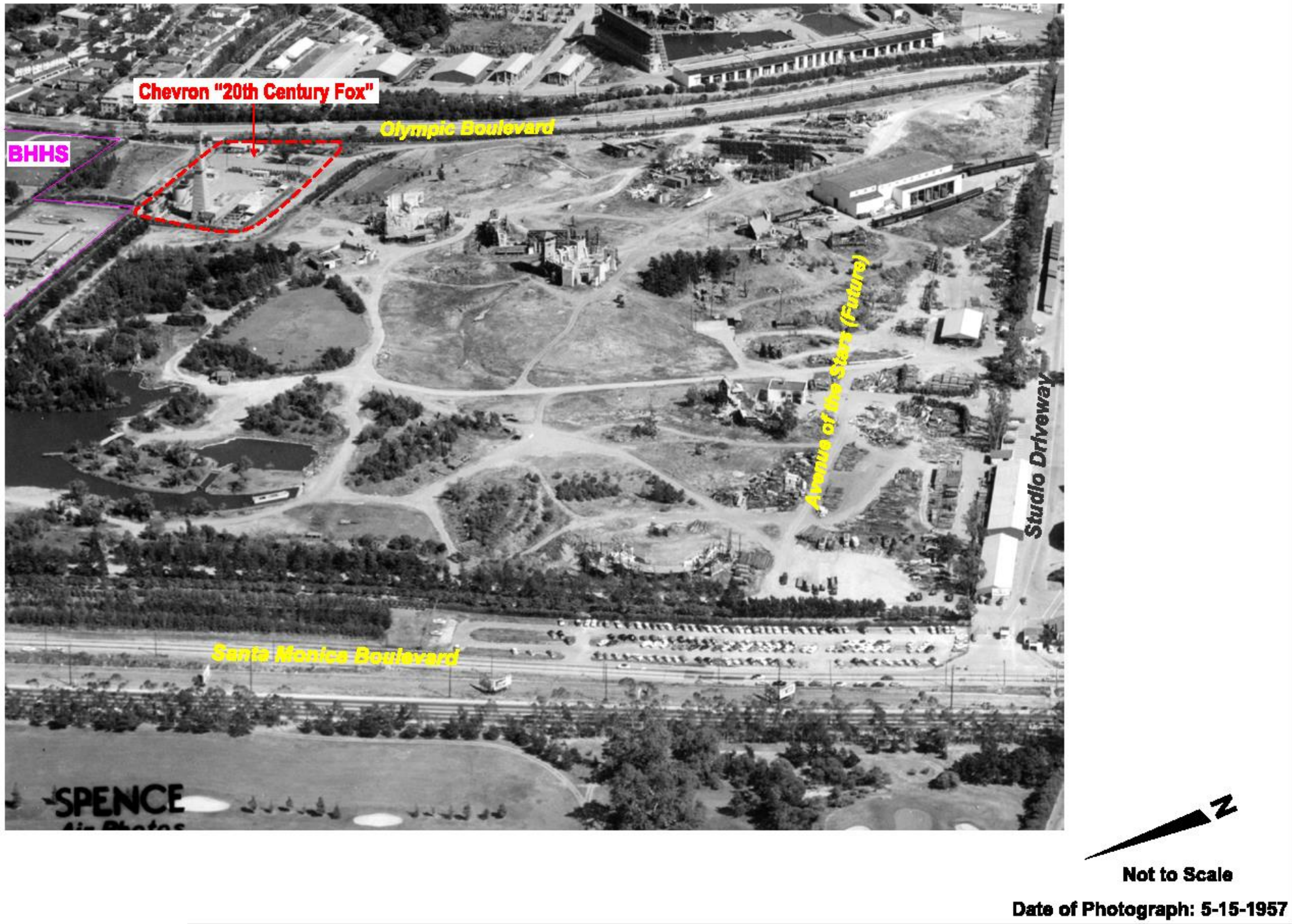
Figure 12

Figure 2-13: 1954 Historic Aerial Photograph with Oil Wells



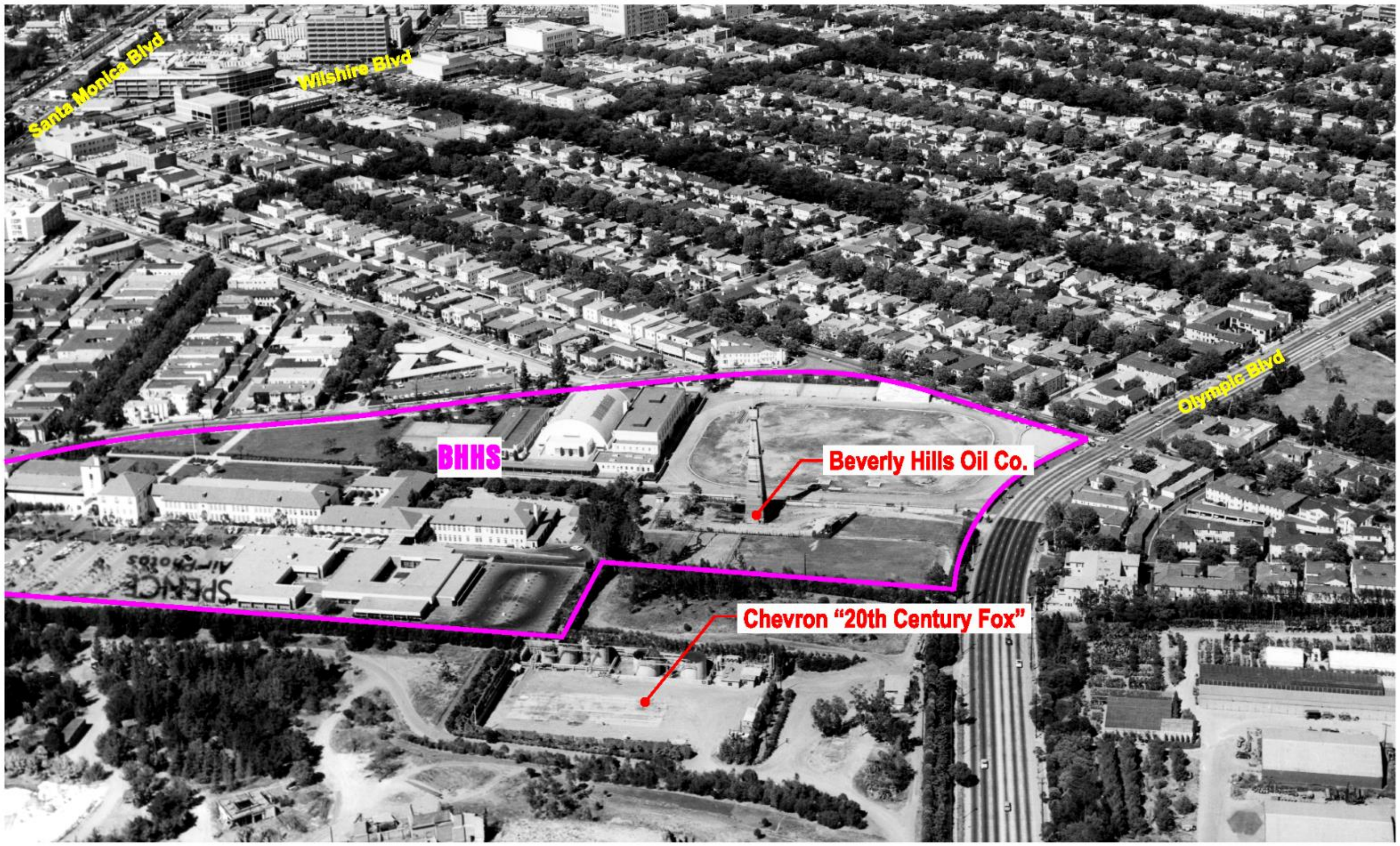
GeoKinetics Geotechnical & Environmental Engineers	1954 Historic Aerial Photograph With Oil Wells
Project Name: Beverly Hills High School	
Date: July 2016	Figure 13

Figure 2-14: 1957 Historic Aerial Photograph with Oil Wells



GeoKinetics Geotechnical & Environmental Engineers	1957 Historic Aerial Photograph With Oil Wells
Project Name: Beverly Hills High School	
Date: July 2016	Figure 14

Figure 2-15: 1960 Historic Aerial Photograph with Oil Wells



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Geotechnical & Environmental Engineers

Project Name: Beverly Hills High School
Date: July 2016

1960 Historic Aerial Photograph With Oil Wells

Figure 15

There are four geologic units within the tunnel and station depth horizon of Section 2 of the Study Area, as shown in Table 2-1. Geology in Section 2 of the Project in relation to the Project tunnel is shown in Figure 2-16. Geology in relation to the Project tunnel in the vicinity of BHHS is shown in Figure 2-17.

Table 2-1: Geologic Units within Depth Range of Tunnel and Station

Age	Geologic Formation (age)	Age (Thousands of years)	Symbol	Composition	Location in Project Area
Youngest	Younger Alluvium (Holocene)	Recent to 11	Qal	Poorly consolidated, interlayered silts, clays, and silty sands with some sand layers and gravel	Beverly Hills east of the vicinity of Moreno Drive
	Older Alluvium/ Alluvial Fan (Late Pleistocene)	11-500	Qalo	Non-marine sediments	All areas
	Lakewood (Pleistocene)	350-500	Qlw	Sands, silty sands with some clayey sand layers	Century City and Beverly Hills west of Lasky Drive
Oldest	San Pedro (Pleistocene)	500+	Qsp	Fine-grained sand and silty sand with few interbeds of medium- to course-grained sand and some local silt layers. Some asphaltic sand	Century City and Beverly Hills west of Lasky Drive and east of vicinity of Roxbury Drive

Sources: Metro 2016 a,b, and c

Note: Geologic Units = units appearing at any depths ranging from the ground surface to bottom of the tunnel

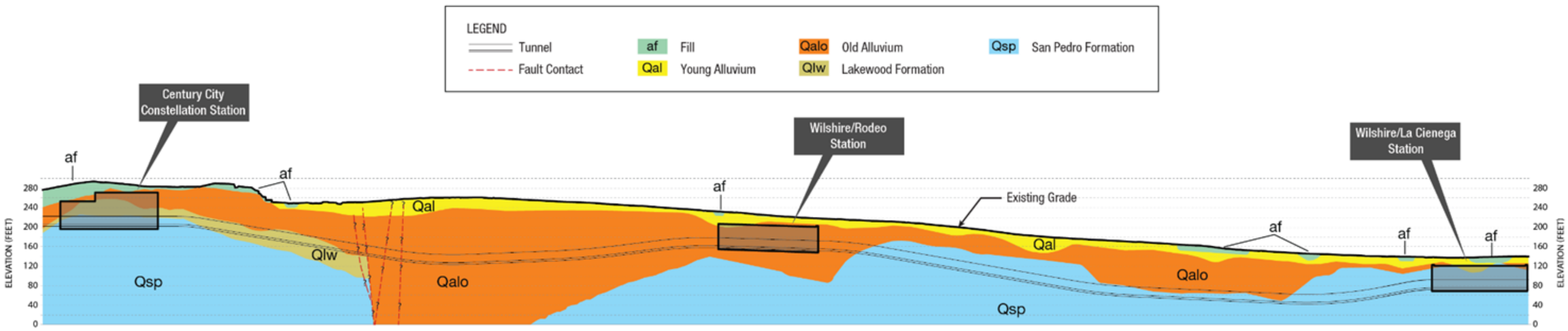
Along Tunnel Reach 4, the tunnel will be excavated in the Older Alluvium, San Pedro Formation and mixed-face conditions of these two formations. The anticipated ground conditions in the tunnel excavation along different stretches of Reach 4 are presented in Table 2-2.

Table 2-2: Anticipated Ground Conditions in Reach 4

Approximate Cross-streets	Geologic Formation	Approximate Tunnel Length (miles)	Comments*
190± feet west of S. Le Doux Road Blvd to 30± feet east of S. Willman Drive	San Pedro	0.15	Tunnel entirely in San Pedro Formation
30± feet east of S. Willman Drive to S. La Peer Drive	Mixed-Face (San Pedro and Older Alluvium)	0.37	Less than 10 feet of the upper portion of the tunnel is in Older Alluvium and the remaining bottom portion of the tunnel is in San Pedro Formation
S. La Peer Drive to 120± feet west of N. Rexford Drive	San Pedro	0.45	Tunnel entirely in San Pedro Formation
120± feet west of N. Rexford Drive to 250± feet east of N. Crescent Drive	Mixed-Face (San Pedro and Older Alluvium)	0.03	The Older Alluvium/San Pedro Formation contact cuts the tunnel diagonally
250± feet east of N. Crescent Drive to 230± feet west of N. Crescent Drive	Older Alluvium	0.09	Tunnel entirely in Older Alluvium

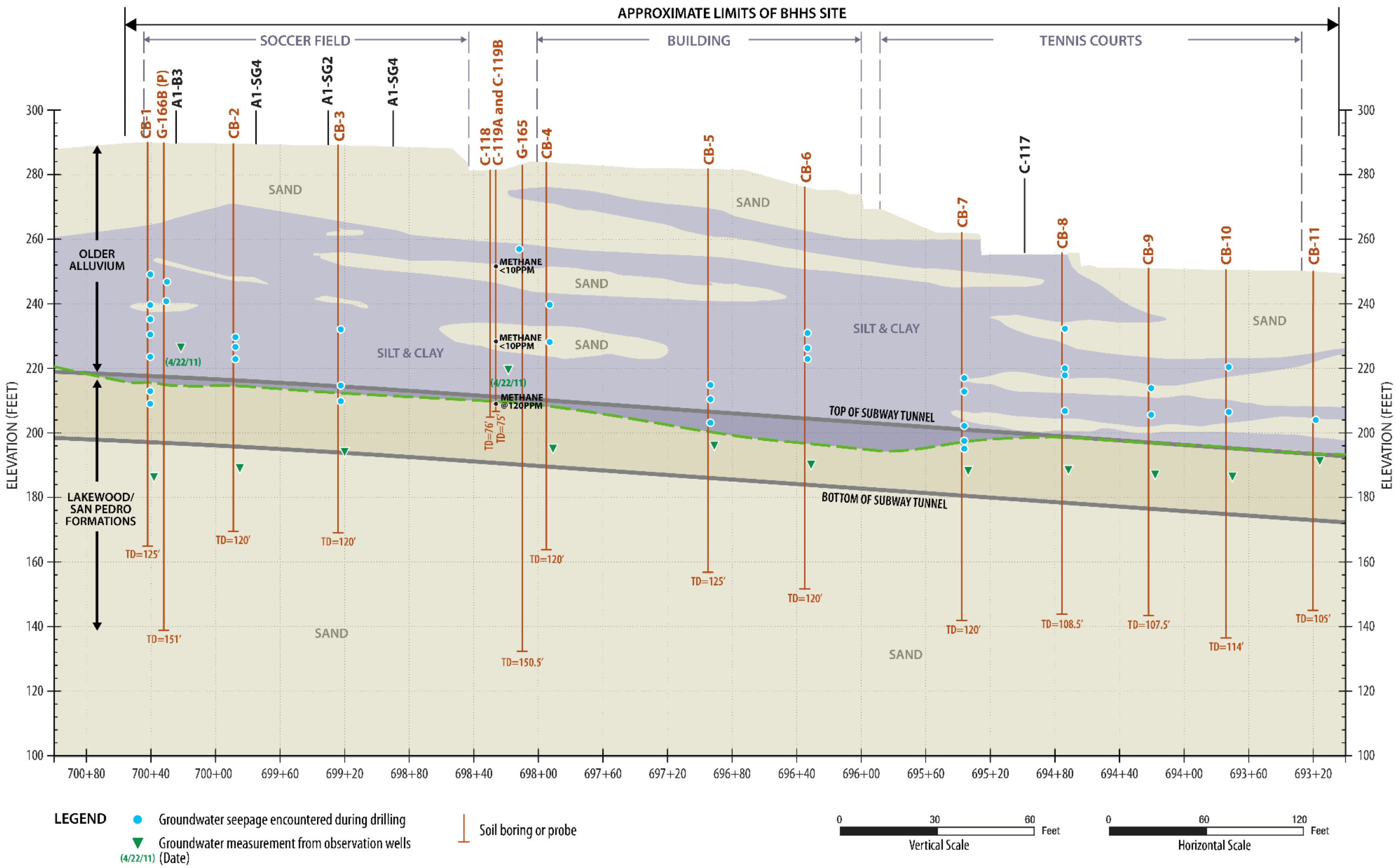
* based on plans dated June 2015, included in GDR (Metro, 2016a).

Figure 2-16: Geologic Cross-Section for Section 2 Tunnel Alignment



Sources: Metro 2017 and 2016a

Figure 2-17: Stratigraphic Cross Section long Proposed Tunnel Alignment beneath BHHS and Vicinity



Based on current groundwater conditions, planned tunnel diameter and tunnel invert depths, the tunnel invert is expected to be under a hydrostatic head of about 15 to 85 feet.

Along Tunnel Reach 5, the tunnel will be excavated predominantly in the Older Alluvium and to some extent in Lakewood Formation as well as in mixed-face conditions of Older Alluvium/San Pedro and Lakewood/San Pedro Formations. The anticipated ground conditions in the tunnel excavation along different stretches of Reach 5 are presented in Table 2-3.

Table 2-3: Anticipated Ground Conditions in Reach 5

Approximate Cross-streets	Geologic Formation	Approximate Tunnel Length (miles)	Comments*
100± feet west of N. Beverly Drive to 250± feet north of Young Drive	Older Alluvium	0.76	Tunnel entirely in Older Alluvium
250± feet north of Young Drive to 50± feet northeast of S. Moreno Drive	Mixed-Face (Older Alluvium/Lakewood)	0.10	Older Alluvium/Lakewood contact cuts the tunnel diagonally
50± feet northeast of S. Moreno Drive to 140± feet southwest of S. Moreno Drive	Lakewood	0.04	Tunnel entirely in Lakewood Formation
140± feet southwest of S. Moreno Drive to 310± feet northeast of Century Park East	Mixed-Face (Older Alluvium/Lakewood)	0.13	Less than 10 feet of the upper portion of the tunnel is in Older Alluvium and the remaining bottom portion of the tunnel is in Lakewood Formation
310± feet northeast of Century Park East to 190± feet northeast of Century Park East	Lakewood	0.02	Tunnel entirely in Lakewood Formation
190± feet northeast of Century Park East to 100± feet southwest of Century Park East	Mixed-Face (Lakewood/San Pedro)	0.06	Lakewood/San Pedro contact cuts the tunnel diagonally

* based on plans included in Metro Geotechnical Data Report (GDR) for Tunnel Reaches 4 and 5 of Section 2 (Metro, 2016a).

Based on current groundwater conditions, planned tunnel diameter and tunnel invert depths, the tunnel invert is expected to be under a hydrostatic head of about 35 to 100 feet. A stratigraphic cross section along the Section 2 tunnel alignment is provided as Figure 2-16.

The nearest oil wells to the Section 2 alignment are near Reach 5 and near the Century City Constellation Station, as shown on the DOGGR Online Mapping System (California Division of Oil, Gas & Geothermal Resources, 2015). Chevron U.S.A. Inc. Rodeo Well No. 107 is the nearest mapped oil well to the Reach 5 alignment and is shown approximately 75 feet southeast of the alignment at the City boundary between Beverly Hills and Los Angeles, just west of BHHS (California Division of Oil, Gas & Geothermal Resources, 2015). The next nearest well to the Reach 5 alignment is Chevron U.S.A. Inc. Wolfskill Well No. 23, located approximately 150 feet northwest of the intersection of Constellation Boulevard and Century Park East. According to DOGGR, the locations of oil wells shown on DOGGR maps are approximate and could vary by up to 200 feet. The following Table 2-4 provides additional details regarding the oil wells that are mapped by DOGGR within Reaches 4 and 5.

Table 2-4: Summary of Oil Wells Closest to Reach 5

Oil Well APN.	Operated By	Location Shown on Plate 1	Status of Oil Well per DOGGR Data
03701069 #107	Chevron U.S.A.	About 75 feet southeast from the alignment and about 300 feet east-northeast of the west end of Reach 5	No well data details or abandonment records available. Status noted as "plugged" on DOGGR database online.
03701104 #23	Chevron U.S.A.	About 150 feet northwest from intersection of Constellation Boulevard and Century Park East at the west end of Reach 5	No well data details or abandonment records available. Status noted as "plugged" on DOGGR database online.

GeoVision was retained to perform oil well surveys within the tennis courts at BHHS to attempt to locate Rodeo 107 and at the lacrosse field at BHHS and at the 1950 Century Park East property to attempt to locate Wolfskill 23. Based upon the results of the geophysical surveys, there is no definitive evidence that the Wolfskill 23 well and Rodeo No. 107 well are in the immediate vicinity of the Reach 5 alignment. However, those wells could still be located near the alignment.

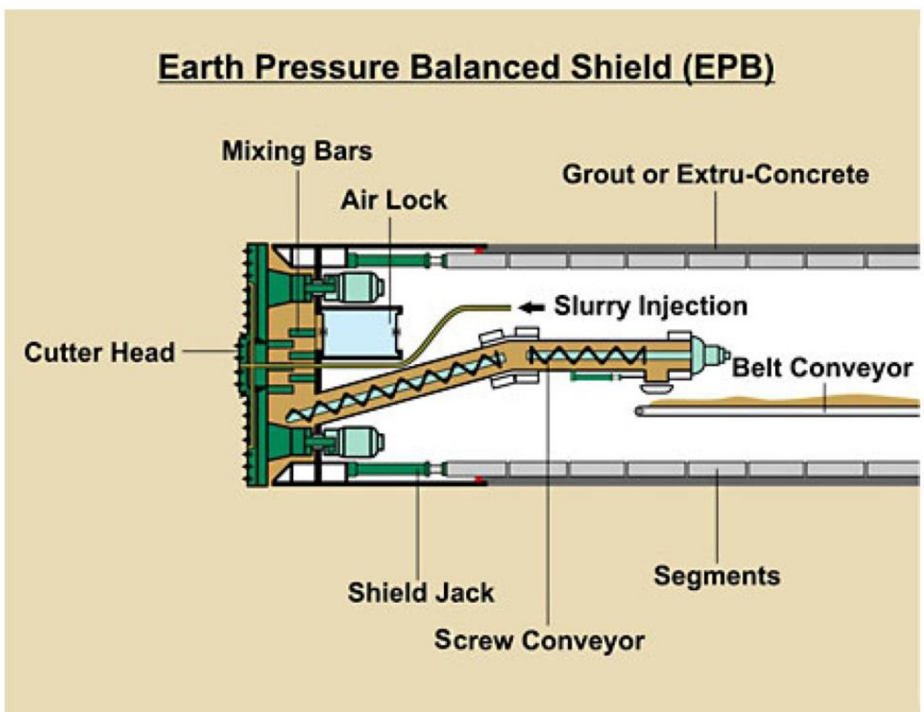
The Century City Constellation Station is located within the limits of the Beverly Hills Oil Field area according to oil field boundary maps published by the California Division of Oil, Gas, and Geothermal Resources (California Division of Oil, Gas & Geothermal Resources, 2006). It is an east-west trending field that is approximately four miles in length and one-half mile in a north to south direction. The eastern portion of the field was discovered in 1966 and contains two active producing areas located adjacent to Pico Boulevard, which contain directionally drilled oil wells. Active oil production at the western portion of the field consists of the oil well site at the southwestern part of the BHHS Campus where there are 15 producing wells and three water injection wells.

A series of oil field boundary maps, prepared by the State of California DOGGR, show the locations of oil wells drilled in the various oil fields of California. The oil field maps indicate the approximate locations and status of the oil wells based on the available records on file with DOGGR. A cluster of 29 abandoned oil wells are shown on DOGGR Oil Field Map 117 W I-5 (dated October 17, 2006) in the area north of the Century City Constellation Station, adjacent to the east side of the Avenue of the Stars. Communication with DOGGR personnel indicates that the accuracy of the well locations shown on the maps is on the order of 100 to 200 feet. Based on DOGGR Oil Field Map 117 W I-5, 29 abandoned and plugged oil wells are shown in the area of the planned station entrance structure.

3.0 TUNNELING METHODS

An Earth Pressure Balance (EPB) Tunnel Boring Machine (TBM) will be used to excavate the tunnels in Section 2. A schematic of a typical EPB TBM is provided as Figure 3-1. As indicated in this diagram, soil and formational materials along the bore will be excavated and mixed with conditioners by a rotating cutter head. The soil-conditioner mixture containing various additives will be injected at the cutter head to transform the excavated material into a semi-liquid paste. The fluidized cuttings will be maintained under a specific pressure by the combination of hydraulic jacks that force the cutting head forward and a screw conveyor that removes the cuttings at a controlled rate as the machine advances. The pressure is maintained to "balance" the in-situ lateral earth and water pressures at the face of the excavation to minimize ground deformation during the tunneling activities. The reinforced concrete lining for the subway tunnel is installed behind the cutting head as the TBM advances. EPB TBMs have been used extensively and successfully within Los Angeles, the United States, and throughout the world over the past three decades.

Figure 3-1: Schematic of a Potential Type of Earth Pressure Balance Tunnel Boring Machine



GeoKinetics Geotechnical & Environmental Engineers	Schematic of a Potential Type of Earth Pressure Balance Tunnel Boring Machine
Project Name: Beverly Hills High School	
Date: July 2016	Figure 17

4.0 SOIL GAS CHARACTERISTICS

Methane and hydrogen sulfide are the primary gases of concern that could be encountered during the tunneling activities. The general characteristics of both of these gases are summarized below:

Methane: Methane is common in oil and gas fields and is often found with hydrogen sulfide gas. Methane gas is explosive when its concentration is between 5 and 15 percent at atmospheric oxygen levels, but is not toxic. Methane has a Lower Explosive Level (LEL) of 53,000 parts per million (ppm) [5.3 percent by volume] in the presence of oxygen at atmospheric levels. Methane has an upper explosive limit of 150,000 ppm [15 percent by volume]. At higher percentages in air, it can be an asphyxiant as it displaces oxygen. Under normal atmospheric conditions, the oxygen content in air is approximately 21 percent by volume. Methane (density ~0.72 g/l at atmospheric pressure) is approximately 40% lighter than air and it tends to rise through the ground and dissipate. Methane is moderately soluble in water. Approximately 40 to 50 cubic centimeters (cm^3) of methane can be dissolved in a liter of water at atmospheric pressure.

There are no published Permissible Exposure Limits (PELs) for methane, but a total weighted average exposure of 1,000 parts per million (ppm) (0.1 percent) has recently been added to the American Conference of Governmental Industrial Hygienists' recommended practices.

Hydrogen Sulfide (H_2S): Hydrogen sulfide is produced by the anaerobic decomposition of organic and inorganic matter that contains sulfur. Hydrogen sulfide is a flammable, highly toxic gas, in certain concentrations when inhaled, with a characteristic odor of rotten eggs. Its LEL is approximately 40,000 ppm (4 percent by volume), and an upper explosive limit of 46 percent by volume. It is also highly corrosive. Hydrogen sulfide has an Occupational Safety and Health Administration (OSHA) PEL of 20 ppm and a National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) of 10 ppm. NIOSH defines the level of Hydrogen Sulfide gas at or above 100 ppm as Immediately Dangerous to Life and Health (IDLH). According to the American Conference of Governmental Industrial Hygienists (ACGIH 2001), hydrogen sulfide gas has an exposure limit or threshold limit value-time weighted average (TLV) of 10 ppm for continuous exposure and 15 ppm for Threshold Limit Value—Short Term Exposure Limit. This threshold limit value is the concentration to which it is believed that workers can be exposed continuously for a short period of time without suffering from irritation, chronic or irreversible tissue damage, or narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue ability, or materially reduce work efficiency, and provided that the daily exposure limit is not exceeded. A Short Term Exposure Limit is defined as a 15-minute total weighted average exposure that should not be exceeded at any time during a workday. For most people, hydrogen sulfide has an odor threshold of approximately 0.3 ppm. For many people, the odor has been described as objectionable at concentrations above approximately 1 ppm. Table 4-1 below provides a description of the effects of Hydrogen Sulfide at various concentrations. 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 and, at high concentrations within the ground tends to accumulate just above the groundwater table and within stratigraphic depressions. Approximately 2,800 cm^3 of hydrogen sulfide can be dissolved in a liter of water at atmospheric pressure. Hydrogen sulfide is typically oxidized rapidly in the subsurface under neutral pH conditions when exposed to even low levels of oxygen. Hydrogen sulfide can persist in the subsurface for extended periods of time under anaerobic and/or acidic conditions.

Methane Threshold Levels: In environmental science, the term "threshold level" refers to some condition at or beyond which an action, or remedial or corrective measure must be taken. Methane threshold levels may be based upon scientific principles, or they may be arbitrary. Threshold levels may refer to methane conditions in a confined / habitable space. Many methane codes for new construction on undeveloped sites identify threshold levels based upon the concentration of methane found in the soil at a building site.

Early regulations (United States Environmental Protection Agency / Resource Conservation and Recovery Act "RCRA" 1976) used the methane lower explosive limit "LEL" concentration of 50,000 ppmv methane in air as a soil gas threshold level. Today some agencies prescribe methane soil gas action levels in low parts per million by volume "ppmv" (City of Los Angeles 2002). Ultra-low methane soil gas threshold levels are arbitrary and not tied to engineering or scientific criteria. Methane pressures in the soil and available volumes of the gas are as important as methane concentrations, but are less often cited in regulations.

For properties in the City of Los Angeles, the L.A. Department of Building and Safety (LADBS) methane codes apply to building construction. The City's Department of Water and Power (DWP) has separate standards for electrical utility installations.

Table 4-1: Hydrogen Sulfide Effects

H_2S Concentration (ppm)	Symptoms/Effects
0.00011-0.00033	Typical background concentrations
0.01-1.5	Odor threshold (when rotten egg smell is first noticeable to some). Odor becomes more offensive at 3-5 ppm. Above 30 ppm, odor described as sweet or sickeningly sweet.
2-5	Prolonged exposure may cause nausea, tearing of the eyes, headaches or loss of sleep. Airway problems (bronchial constriction) in some asthma patients.
20	Possible fatigue, loss of appetite, headache, irritability, poor memory, dizziness.
50-100	Slight conjunctivitis ("gas eye") and respiratory tract irritation after 1 hour. May cause digestive upset and loss of appetite.
100	Coughing, eye irritation, loss of smell after 2-15 minutes (olfactory fatigue). Altered breathing, drowsiness after 15-30 minutes. Throat irritation after 1 hour. Gradual increase in severity of symptoms over several hours. Death may occur after 48 hours.
100-150	Loss of smell (olfactory fatigue or paralysis).
200-300	Marked conjunctivitis and respiratory tract irritation after 1 hour. Pulmonary edema may occur from prolonged exposure.
500-700	Staggering, collapse in 5 minutes. Serious damage to the eyes in 30 minutes. Death after 30-60 minutes.
700-1000	Rapid unconsciousness, "knockdown" or immediate collapse within 1 to 2 breaths, breathing stops, death within minutes.
1000-2000	Nearly instant death

Source: Department of Labor

For jurisdictions outside of the City of Los Angeles, such as Beverly Hills, the LADBS code does not apply. There are no specific City of Beverly Hills methane requirements, except for public schools where the State of California Department of Toxic Substances Control (DTSC) has promulgated a threshold level of 5,000 ppmv methane in the soil, requiring further study or mitigation. DTSC encourages the use of scientific study and mathematical analyses of methane soil gas conditions in determining whether risk exists above 5,000 ppmv methane soil gas.

A 2016 ASTM guidance document suggests action levels of 50,000 ppmv in the soil when pressure (≥2" H2O) exists, and 300,000 ppmv with no pressure (<2" H2O). (ASTM E2993 – 2016, *Standard Guide for Evaluating Potential Hazard as a Result of Methane in the Vadose Zone*)

All of the above action levels are related to concentrations of gas below ground surface in the soil. For confined spaces it is common to use one fourth of the LEL, or 12,500 ppmv as an absolute maximum allowable gas concentration (threshold level) in the confined space air. Interior air spaces of buildings or even vaults in the ground are considered hazardous above these levels.

Metro's approach incorporates all of the above consideration, and as a result, Metro has performed gas investigations and mitigation with regard to soil gas along the WPLE alignment. In *Geotechnical Baseline Report* (Metro 2014), Metro has defined "Elevated" gas conditions as area where gas monitoring readings have shown methane levels greater than five percent (corresponding to the LEL), or hydrogen sulfide levels above five ppm (corresponding to the OSHA PEL). Chapter 4 of the *Westside Purple Line Draft Supplemental Environmental Impact Statement* (May 2017) describes monitoring of the working environment for elevated gas conditions during tunneling.

5.0 OCCURRENCE OF SOIL GASES

Portions of the WPLE will involve tunneling through soil and formational materials that contain high concentrations of methane and hydrogen sulfide gas. For example, oil-bearing deposits essentially extend up to the ground surface along Wilshire Boulevard in the area of the La Brea Tar Pits, east of Section 2 of the WPLE. The tunnel in tar pits area will be excavated through deposits containing close to 100% (1,000,000 ppm) methane gas and up to approximately 6,000 ppm hydrogen sulfide. In contrast, the oil-bearing deposits along Section 2 occur at depths of thousands of feet bgs. Considerable subsurface testing has been performed at the BHHS site to screen for methane and/or hydrogen sulfide gas. Metro examined existing data along the Section 2 alignment and installed new soil borings and gas monitoring wells along the Section 2 alignment to evaluate soil, groundwater conditions, and the presence of hazardous gases and their potential to affect construction and design of the WPLE. A summary of soil gas measurements along Section 2 are provided below, and the highest measured values, along with the date measured, are shown in Figure 5-1 and Figure 5-2 for methane gas and Figure 5-3 and Figure 5-4 for hydrogen sulfide gas. At least 194 soil gas samples have been collected at various locations along Section 2 of the WPLE, of which 111 detected methane and 21 detected hydrogen sulfide. The Metro soil gas samples were obtained at depths similar to the planned tunnel depths. Some of the samples obtained by others were at depths shallower than the planned tunnel, but were also considered as an indicator of general soil gas conditions. Metro 2016a, Metro 2016b, and Metro 2016c provide further data and information on sampling and testing.

Tunnel Reach 4

Tunnel Reach 4 is about 1.1 miles long, extending from the Wilshire/La Cienega Station to the Wilshire/Rodeo Station (Reach 4). A total of 42 soil gas samples from 6 wells (shown in Figure 5-2) were collected by Metro and analyzed for methane and other constitutes in Tunnel Reach 4. Methane was detected at concentration of 0.1 percent (1,000 ppm) or greater in 14 of the 42 samples that were analyzed, but only three samples were detected over the concentration of 5% (50,000 ppm), all from M-17 located at Wilshire Boulevard and Stanley Drive in the City of Beverly Hills (see Figure 5-2) . The highest recorded methane concentration measured with field instruments along Reach 4 was 6.3 percent (63,000 ppm) in M-17, east of Stanley Drive, at a depth of 15 feet bgs. The highest measured methane level from samples analyzed in a lab was 0.254 percent (2,540 ppm) also in M-17. Hydrogen sulfide was detected at concentration of 1 ppm or greater in 6 of the 42 samples that were analyzed in Tunnel Reach 4. The highest recorded hydrogen sulfide concentration measured with field instruments along Reach 4 was 4 ppm in M-17 at a depth of 15 feet bgs. The highest recorded gas pressure along Reach 4 was 2.6 inches of water in M-402 (Metro, 2016a).

Wilshire/Rodeo Station

A total of 38 soil gas samples from 5 wells (shown in Figure 5-2) were collected by Metro and analyzed for methane and other constitutes at the location of the Wilshire/Rodeo Station. Methane was detected at concentration of 0.001 percent (10 ppm) or greater in 10 of the 38 samples that were analyzed. The highest recorded methane concentration measured with field instruments at Wilshire/Rodeo Station was 0.1 percent (equivalent to 1,000 ppm) in M-404 at a depth of 50 feet bgs and M-405 at a depth of 34 feet bgs. The highest measured methane concentration from samples analyzed in a lab was 0.0057 percent (57 ppm) in OB-307 at a depth of 80 feet bgs. Hydrogen sulfide was not detected in any of the 38 samples that were analyzed in the Station. The highest recorded gas pressure in probes and standpipes near the station site was 0.18 inches water in M-404. At several depths in the wells, negative probe pressure was observed indicating that the geologic formation at the screened probe and standpipe depths is under vacuum (relative to the atmospheric pressure) at the time of monitoring (Metro, 2016a).

Tunnel Reach 5

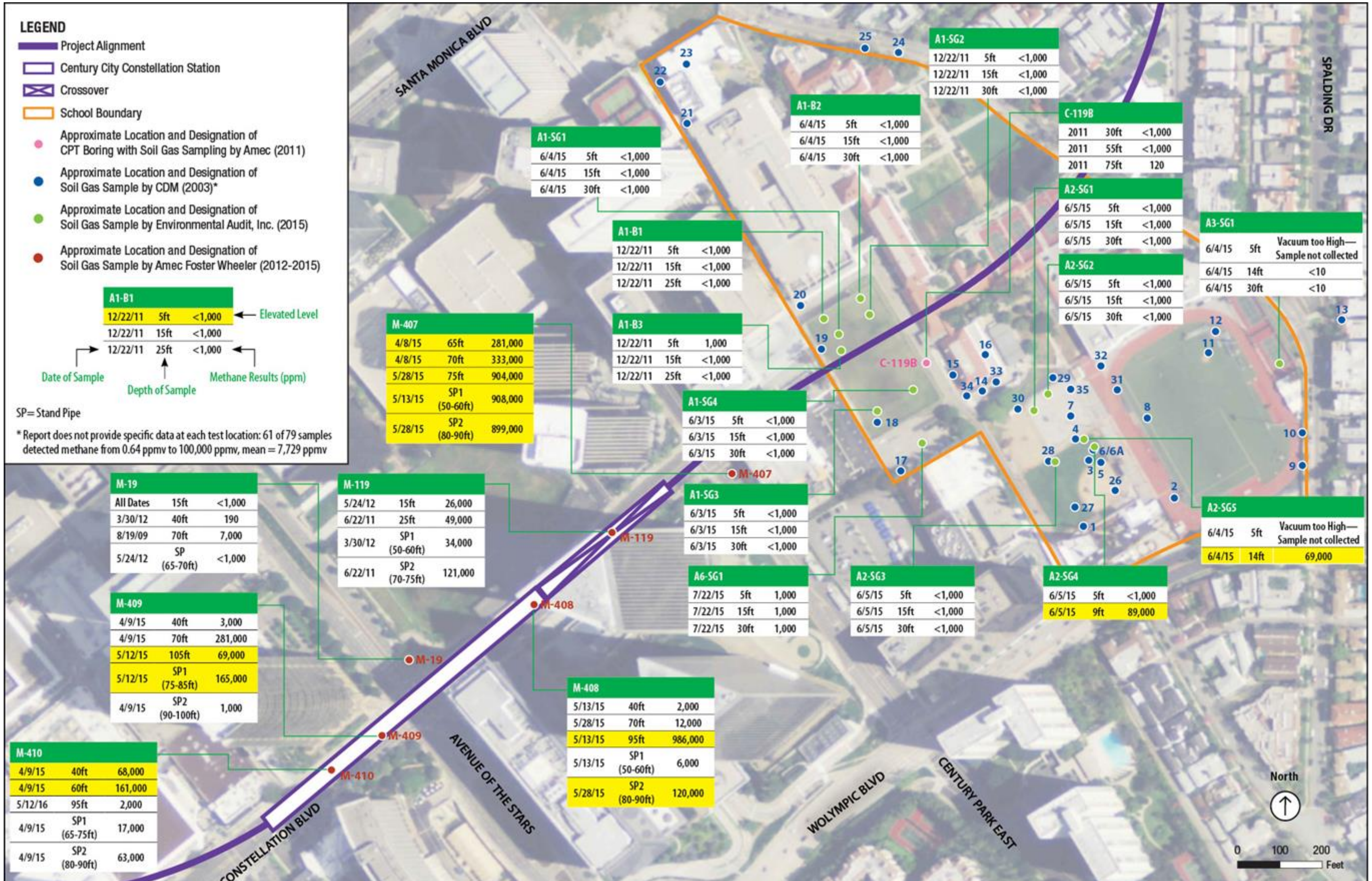
Tunnel Reach 5 is about 1.1 miles long, extending from the Wilshire/Rodeo Station to the Century City Constellation Station (Reach 5). A total of 20 soil gas samples (from 2 wells M-406 and M-407) were collected by Metro and analyzed for methane and other constitutes in Tunnel Reach 5. Methane was detected at concentration of 5 percent (50,000 ppm) or greater in 14 of the 20 samples that were analyzed. The highest recorded methane concentration measured with field instruments along Reach 5 was 90.8 percent (908,000 ppm) in well M-407 inside the standpipe (screened from 50 to 60 feet bgs). The highest measured methane level from samples analyzed in a lab was 43 percent (430,000 ppm) also in M-407. Hydrogen sulfide was not detected in any of the 20 samples that were analyzed in Tunnel Reach 5. The highest recorded gas pressure along Reach 5 was 0.72 inches of water in M-406. All 14 methane hits were from monitoring well M-407, which is located about 300 feet west of BHHS (Metro, 2016a)

Beverly Hills High School Area

Soil gas investigations have been performed at the BHHS site in 2003 by Camp Dresser & McKee (Camp Dresser & McKee, 2003), in 2004 by Ultra Systems (Ultra Systems Environmental, 2004), in 2011 by Metro (Metro, 2011a), in 2012 by Environmental Audit Inc. (EAI / Refs. 23 & 25), in 2015 by EAI (Environmental Audit Inc. 2015a and 2015b), in 2016 by EAI (Environmental Audit Inc. 2016b, 2016c, and 2016d) and in 2016 as shown in the Metro Geotechnical Data Report (GDR) for Tunnel Reaches 4 and 5 of Section 2 (Metro, 2016a). These investigations are summarized below:

2003: A total of 79 soil gas samples were reportedly collected and analyzed for methane and other constitutes by CDM in 2003 (Camp Dresser & McKee, 2003). The available summary report for this investigation shows the soil gas sampling locations and describes the results but does not provide the specific testing data. The CDM soil gas testing locations are shown in Figure 5-1. Methane was reportedly detected at a concentration of 2 ppm or greater in 61 of the 79 samples that were analyzed. The mean and maximum reported concentrations were 7,729 ppm and 100,000 ppm, respectively. With the exception of five locations in the vicinity of the upper field basketball courts, soil gas methane concentrations were reported to be at or below 1,000 ppm. Those courts are located approximately 150 feet to the south of the proposed southern tunnel alignment. The CDM report indicated that methane gas was not detected near any of the buildings. CDM concluded that methane gas did not pose a hazard and that no remedial measures were necessary.

Figure 5-1: Methane Readings in Century City and on Beverly Hills High School Campus



WESTSIDE PURPLE LINE EXTENSION PROJECT

Figure 5-2: Methane Readings Along Section 2 Alignment East of Lasky Drive

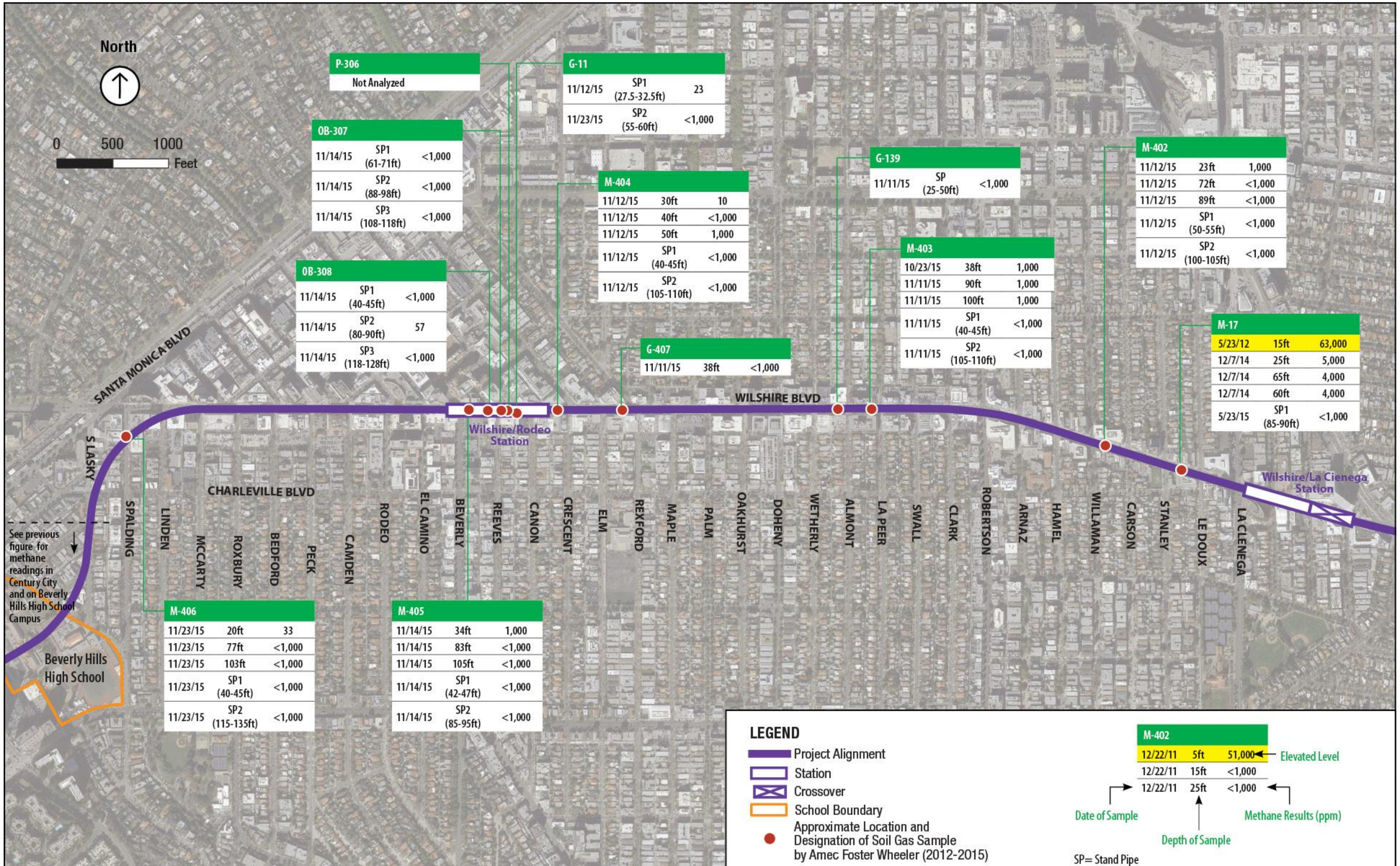


Figure 5-3: Hydrogen Sulfide Readings on in Century City and on Beverly Hills High School Campus

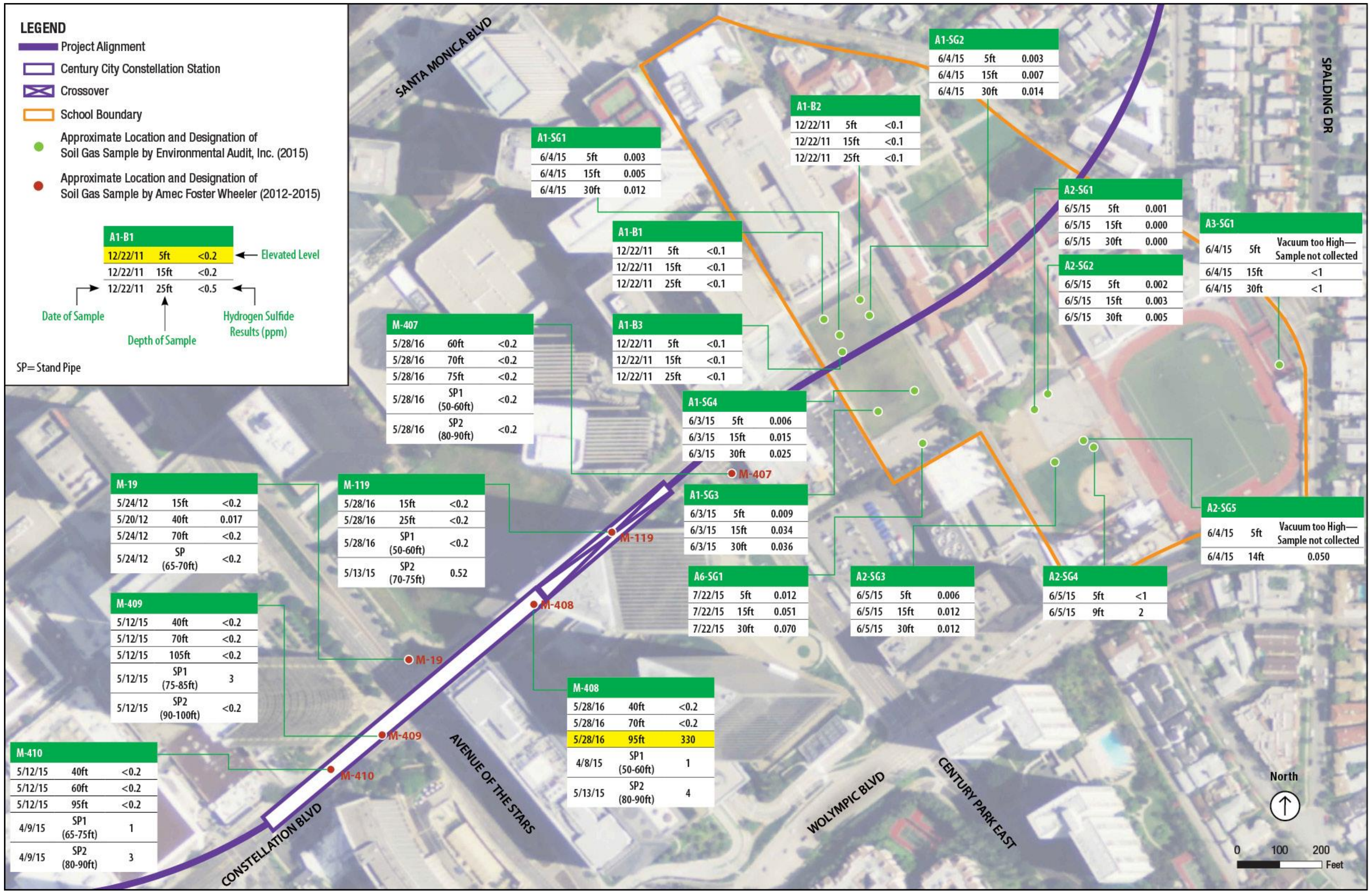
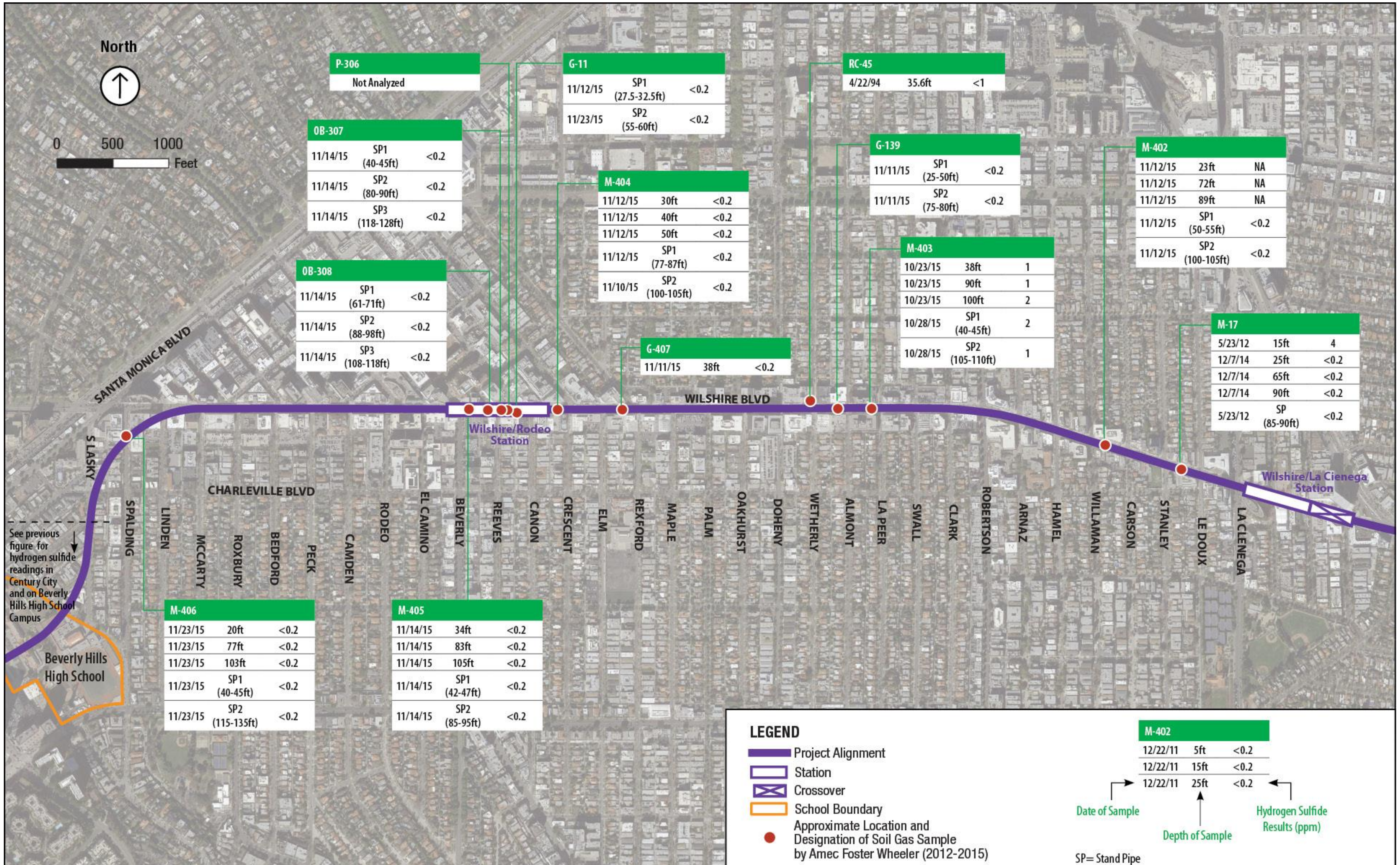


Figure 5-4: Hydrogen Sulfide Readings Along Section 2 Alignment East of Lasky Drive



2004: Ultra Systems collected soil gas samples from 23 borings within four Areas of Potential Concern (AOPC) at the BHHS site in conjunction with the construction of a new 18,000 square-foot multi-story building (Building L) at the northwest corner of the site (Ultra Systems, 2004). The building site was located approximately 500 feet to the north of the proposed subway alignment. As with the CDM report described above, the available summary report for this investigation describes the soil gas testing results but does not provide the specific testing data. The summary report indicates elevated levels (more than 5 percent by volume or 50,000 ppm, the LEL) of methane gas (82,000 ppm at 5 feet bgs and 130,000 ppm at 10 feet bgs) were detected in one boring (B-6) near the northeast corner of the BHHS site. Methane was not detected in five borings that were subsequently excavated approximately 20 feet apart around B-6. Ultra Systems concluded that the methane and hydrogen sulfide gas concentrations near the proposed structure were at acceptable and safe levels.

2011: Soil gas samples were collected using BAT equipment from CPT boring C-119B by Metro in March of 2011. C-119B was located along the proposed subway alignment in the central portion of the BHHS site. Soil gas samples were collected at depths of 30, 55, and 75 feet bgs (with the bottom sample corresponding approximately to the depth of the planned top of tunnel). Detectible levels of methane were not present in the 30 and 55 foot bgs samples. The detection limit was reported to be 10 ppm. Methane was detected at a concentration of 120 ppm in the 75 foot bgs sample (Metro 2016a). The data from the CPT indicates the 75 foot bgs sample was collected in a coarse-grained material.

2012: Environmental Audit Inc. (EAI) collected and analyzed a total of 34 soil gas samples from three areas where trenching was proposed in conjunction with a fault investigation. The samples were collected from depths of 5, 15, and 25 feet bgs. Significant concentrations of methane or hydrogen sulfide were reportedly not detected in any of the samples (Environmental Audit, Inc., 2015b and 2015c).

2015: A Preliminary Endangerment Assessment (PEA) was performed by EAI for the BHHS site in 2015 under DTSC oversight. A total of 44 soil gas samples were collected at depths of approximately 5, 15, and 30 feet bgs. The sample locations are shown in Figure 2-16. Methane was detected in two of these samples at concentrations of 69,000 ppm and 89,000 ppm near the southeast corner of the upper field basketball courts. Hydrogen sulfide was detected in 21 of the 42 soil gas samples at a maximum concentration of 2.0 ppm. EAI concluded that mitigative measures to address potential methane impacts were not warranted (Environmental Audit, Inc., 2015b and 2015c)

2016: A PEA was performed by EAI for Area of Interest (AOI) 5 in 2016 under DTSC oversight in support of proposed seismic retrofit projects and other improvements. Six multi-stage soil gas sampling probes were installed and sampled as part of this assessment. Soil gas samples were collected from depths of 5, 15, 25, and 30 feet bgs and analyzed for methane, hydrogen sulfide, carbon dioxide, oxygen, and nitrogen. Soil gas pressures were also measured. Methane was detected in 11 of the 36 samples that were analyzed at a maximum concentration of 4,000 ppm. Hydrogen sulfide was detected in 14 of the 36 samples that were analyzed at a maximum concentration of 0.21 ppm. Elevated soil gas pressures (more than 2 inches of water) were not found at any of the gas probe installations. EAI concluded that methane and hydrogen sulfide had not been detected at problematic levels but proposed additional monitoring during the proposed projects as a precautionary measure (Environmental Audit, Inc., 2016b and 2016c).

As described above, a significant amount of soil gas testing has been performed at the BHHS site since 2003. More than 200 soil gas samples have been collected at various locations across the property during this time period. Elevated levels (more than 5 percent by volume or 50,000 ppm) of methane gas have not been identified at any locations outside of the upper field basketball court area (over 400 feet south of the tunnel alignment) and the southeast corner of the northern parking lot. Elevated concentrations of hydrogen sulfide gas (above the OSHA PEL of 5 ppm) have not been identified at any location on the BHHS property. The highest subsurface hydrogen sulfide gas concentration reported at the site in the referenced reports is 2 ppm.

Century City /Constellation Station

A total of 70 soil gas samples (from 5 wells, not including M-407 which was part of Reach 5) were collected and analyzed for methane and other constitutes in Century City/ Constellation Station. Methane was detected at concentration of 0.0013 percent (13 ppm) or greater in 53 of the 70 samples that were analyzed, of which 12 samples were over 5 percent (50,000 ppm). The highest recorded methane concentration measured with field instruments at Century City /Constellation Station was 98.6 percent (986,000 ppm) in M-408 at a depth of 95 feet bgs. The highest measured methane level from samples analyzed in a lab was 94 percent (940,000 ppm) also in M-408 at 95 feet bgs. Hydrogen sulfide was detected in 13 of the 70 samples at concentrations ranging from 0.017 ppm to 330 ppm, of which 3 samples were over 5 ppm. The highest recorded hydrogen sulfide concentration measured with field instruments of 316 ppm was in M-408 at 95 feet bgs. The highest measured hydrogen sulfide level from samples analyzed in a lab was 330 ppm, measured in M-408. The highest recorded gas pressure in probes and standpipes near the station site was 0.55 inches of water in well M-410 at a depth of 95 feet bgs and well M-409 at a depth of 105 feet bgs. At several depths in the wells, negative probe pressure was observed indicating that the geologic formation at the screened probe and standpipe depths is under vacuum (relative to the atmospheric pressure) at the time of monitoring; this condition can exist when the atmospheric pressure is higher based on current weather conditions, and under these conditions, excavation into the formation would initially result in air being pulled into the formation rather than soil gas being released into the atmosphere until the pressure conditions equilibrated between the pores in the soil and the pressure within the excavation (Metro, 2016c).

Summary of Soil Gas Measurements in Section 2

As described above, a significant amount of soil gas testing has been performed along Section 2 of the WPLE. Over 170 soil gas samples have been collected from 19 wells along Section 2 (not including BHHS), of which 91 detected methane and 19 detected hydrogen sulfide. Elevated levels of methane gas (29 samples over 5% or 50,000 ppm) have been identified at various locations, including along Tunnel Reach 5 and around the Century City Constellation Station. At BHHS, elevated levels of methane gas have not been identified at any locations outside of the upper field basketball court area and the southeast corner of the northern parking lot. Significantly elevated concentrations of hydrogen sulfide gas (above OSHA PEL of 5 ppm) have not been identified at any location on the BHHS property. Three samples in Section 2 (Century City/ Constellation Station) had concentrations over OSHA PEL limit of 5 ppm, reaching values up to 330 ppm of hydrogen sulfide gas in M-408 (between Century Park East and Avenue of the Stars) at 95 feet bgs. The testing performed along Section 2 is shown in Figure 5-1 through Figure 5-4 for both methane and hydrogen sulfide gases.

6.0 ASSESSMENT OF RISKS

The primary questions or issues that have been evaluated in conjunction with assessing potential soil gas risks associated with the Section 2 tunneling project are described below.

Are elevated levels of methane and/or hydrogen sulfide gas present along the proposed Section 2 tunnel alignment?

Assessment: As outlined above, elevated levels of methane and/or hydrogen sulfide have been identified along the eastern and western portions of the Section 2 alignment, but elevated levels of methane and/or hydrogen sulfide have not been identified along the portion of the Section 2 alignment beneath BHHS. In contrast to other portions of the WPLE alignment where the tunnels will extend through oil-bearing formations, the oil production zones at the subject property are located 2,000 feet or more below the ground surface. At BHHS, the geotechnical / geologic setting at BHHS is not one in which high concentrations (above the LEL) are likely to be present along the proposed tunnel alignment. The available monitoring results are consistent with that expectation. As such, the overall level of risk associated with the potential presence of methane or hydrogen sulfide gas at the BHHS site is low. However, along other portions of Section 2; like at eastern end of Tunnel Reach 4 (at M-17) and portions of Tunnel Reach 5 west of BHHS and within the Century City Constellation Station, there is a risk of encountering methane and/or hydrogen sulfide gas.

Are there mechanisms by which gas (if present along the alignment) could be released at the ground surface or buildings as a result of the proposed tunneling?

Assessment: The potential for subsurface gases to migrate is related to the pressure and concentration of those gases (documented under existing conditions) as well as to the soil and groundwater conditions. Along Section 2, tunneling will take place through either saturated or unsaturated soils (above and below the groundwater level). The risks of gas migration associated with each of these soil types is described in the following paragraphs. Refer to section 3.0 for a description of tunneling methods.

In saturated soils (below the groundwater table), the pores between soil grains are filled with groundwater (Figure 6-1). When a TBM cutting head moves through a soil, the groundwater pressures in saturated soils can temporarily increase in the vicinity of the TBM. This increase in pressure is controlled and limited through operation and continuous monitoring of the TBM. The increase is greatest at the location of the TBM cutting head and dissipates rapidly as the distance from the TBM increases. The TBM operation is designed to balance the existing soil and groundwater pressure so

Soil is a three-phase material, composed of:

- Solids
- Liquid
- Gas

When there is no gas component, the soil is known as "saturated." Note, however, that the liquid phase can contain dissolved gas.

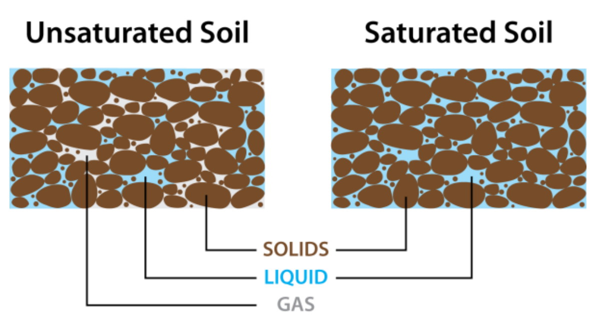


Figure 6-1. Saturated and Unsaturated Soils

that it does not add or remove soil or groundwater outside of the machine as part of tunneling. Monitoring of the pressure within the TBM cutting head chamber and pressures above and around the shield provides confirmation that the balanced condition is maintained. After the TBM has passed, the pressures in the ground return to pre-tunneling levels.

The temporary pressure increase that occurs in saturated soils (when tunneling through saturated soils) will not affect soil gas below the groundwater table since soil gas is not present because the soils are saturated with water. A rise in the surface of the groundwater table above the TBM could provide a potential for pressurization or displacement of soil gas above the groundwater table to exist. However, the proposed tunneling procedures, by design, will not alter the level of the groundwater table. It should also be noted that fluctuations in groundwater levels and related movement of soil gases above the groundwater table occur naturally due to seasonal or cyclical rises and drops in groundwater. As with the pressures around the TBM, instrumentation will be installed to monitor groundwater pressures prior to, and during, tunneling operations. Therefore, the act of tunneling will not have an impact on the groundwater table and resulting potential changes in gas pressures/concentrations above the groundwater table.

Unsaturated soils have a combination of water and gas in the pores (Figure 6-1). The gases in the pores contain constituents found in the air, and in some cases could also include methane and/or hydrogen sulfide as discussed above. The gas contained within the pore space of unsaturated soils is compressible. As a result, for unsaturated soils through which some of the tunneling will occur, the incremental pressure produced by the TBM will not propagate outward in the same way it can with saturated soils.

A simple analogy involves the propagation of a wave. A wave can be created by a disturbance or pressure pulse in a body of water. Because of the incompressibility of water, the wave can propagate outward radially a significant distance from the point where it was created. The same mechanism does not occur with compressible fluids such as soil gases. The compressibility of gas limits its outward propagation.

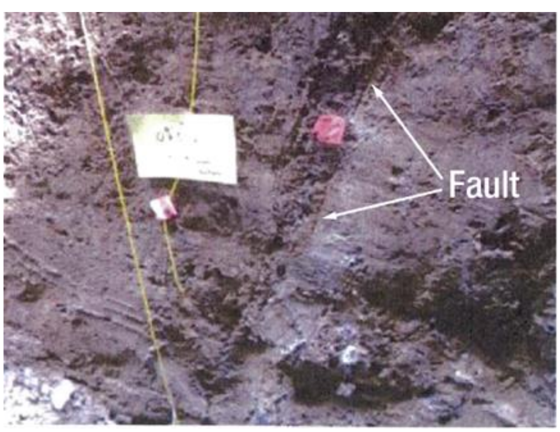
The “fluid” that is maintained at the TBM cutting head would have to flow into and through the soil pore space in order to displace and potentially pressurize any soil gas that is present. That fluid consists of the soil that is excavated from the tunnel bore and mixed with additives (surfactants) to make it less abrasive and a more uniform consistency. Due to the nature and consistency of that fluid, it will not flow through the types of soil deposits that are present along the alignment (silty sand, silts, and clays). As such, there is not a mechanism by which measurable displacement of soil gases could occur away from the TBM with the proposed tunneling method.

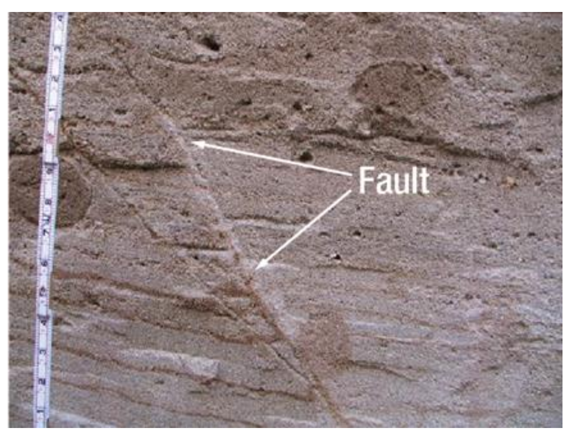
During excavation of the tunnel, water and gas are prevented from traveling along the sides of the tunnel by pressure grouting around the tunnel. Grout is pressure injected around the tunnel through the tail of the tunneling shield as it advances. This is done not only to minimize surface settlement but also to provide continuous support of the segmental tunnel lining and to reduce the flow of water and gas along the contact between the tunnel and the ground. Monitoring of grout pressures and volumes injected is conducted during each advance of the tunnel shield, and a continuous digital record is obtained for immediate viewing by the contractor’s engineers and operators and for review and evaluation. In addition, if necessary, a program of check grouting is carried out to test for grout placement around the lining after the grout is in place.

Are there preferential pathways such as faults or fissures for the movement of gases through the ground?

Assessment: The geologic materials above the planned depth of excavation along Section 2 of the Project have been evaluated through investigations utilizing trenches, borings, and geophysical testing procedures. There are two types of ground in a general sense: rock or soil. Faults/fractures in rock can provide a preferential pathway for fluids (liquids or gases) to flow through the rock, because those faults/fractures can be "open" to some extent. In soils, faults do not generally represent an "open" preferential pathway for fluid flow because most fractures in soil in a relatively stable earth environment, such as along Section 2 of the Project, are flush or have been infilled with soil eroding from above (instability resulting in open factures in soil could be present in locations with landsliding, which is not present along Section 2 of the Project. The investigations performed in the vicinity of the tunnel found some faults within soils, but found no open fissures/fractures present in the soil that would present a preferential flow path for gases; all existing faults and other contacts between dissimilar earth materials have been found to be flush and tight or filled with soil rather than open. For example, in fault trench F-2 by Leighton Consulting, Inc. (LCI, 2012a), "Several clay filled fractures or cracks were documented…" Similarly, in fault trench F-3, two zones of minor faulting were encountered, but the faults and fractures were found to be infilled with soil (and not open) (LCI, 2012a). Also, in fault trench FT-4, "several clay filled fractures were observed" rather than being open fractures. This is consistent with what would be anticipated for the types of alluvial materials that are present along the Section 2 Project alignment. An example of a fault encountered in a trench excavation at BHHS is shown below in Figure 6-2(a), and a photograph of the Newport-Inglewood Fault encountered at Los Angeles Southwest College is shown in Figure 6-2(b). These are examples of the closed, tight nature of faults encountered in similar geologic materials as to those along the entire Project Alignment at tunnel depths. In conclusion, these closed faults do not provide a preferential path for movement of soil gases in the subsurface because these closed faults do not represent an open vertical path along which gases could preferentially move.

Figure 6-2. Photographs of faults encountered in trench explorations (a) at BHHS (Leighton Consulting, 2012), and (b) Newport-Inglewood Fault at Los Angeles Southwest College (Mactec, 2009)





In addition, the stratigraphy along the BHHS campus consists of horizontal layers of fine-grained (such as clay) alluvial deposits and layers of coarse-grained (such as sand) alluvial deposits, as shown in Figure 2-17. The layers of fine-grained material prevent the rapid movement of gases vertically through the ground. Therefore, with a tunneling method horizontally through the ground,, no additional vertical pathways of gas travel are introduced.

Considering all of the above, even with no nearby tunneling activities, when sufficient concentrations of gases are present in the subsurface, the potential exists for those gases to accumulate at the surface and below, and possibly enter, buildings. The risk increases if the gas pressures are higher than atmospheric pressure.

Testing has been done to document the concentrations and pressures of subsurface gas along the Section 2 alignment. The data is presented in the Geotechnical Baseline Report (Metro 2014) and the Geotechnical Data Reports (Metro 2016a, 2016b, and 2016c). As summarized in the existing conditions above, the data indicates that elevated concentrations of methane and hydrogen sulfide gas are not present along Section 2 of the Project between Stanley Drive (west of the Wilshire/La Cienega Station) and the City of Los Angeles/City of Beverly Hills boundary (east of the Century City Constellation Station). Elevated levels of methane gas are present at the far eastern portion of the Section 2 alignment (east of Stanley Drive) and elevated levels of methane and hydrogen sulfide gas are present within the immediate area of the Century City Constellation Station (west of the City of Los Angeles/City of Beverly Hills boundary).

Given the non-elevated subsurface gas concentrations and pressures along most of the Section 2 alignment, the current level risk for additional subsurface gases to migrate to buildings or to emit from the ground surface, is low along most of the Section 2 alignment. Gas that enters the atmosphere dilutes rapidly. There is a higher risk of gas migrating to buildings or off-gassing (emitting) from the ground surface west of the City of Los Angeles/City of Beverly Hill boundary or east of Stanley Drive.

However, the incremental risk that the proposed tunneling activities could cause subsurface gas to migrate to buildings, or to off-gas from the ground surface, is negligible. This is due to the absence of elevated levels of methane and hydrogen sulfide gas along the majority of the alignment (measured both at tunnel depth and in shallower materials), coupled with the absence of a viable mechanism by which the proposed tunneling activities could cause pressurization and/or migration of subsurface gas the distance to the ground surface. In addition, there are no evident “preferential paths” for migration of gases to the surface in the soils at tunnel depth and above along the alignment. Because of the absence of a viable mechanism for tunneling activities to cause migration of subsurface gas to the surface, and because of the lack of preferential vertical paths of gas to the ground surface, even in areas with elevated soil gas levels at depth, the incremental risk of increased gases at the surface due to tunneling activities is negligible. Since the incremental risk is negligible, there is no adverse effect related to migration of subsurface gas during tunneling activities.

Although the existing risk of an explosion due to build-up of methane and hydrogen sulfide gas along most of the Section 2 alignment is low, the result of such an explosion, if it were to occur, would be severe. Since the incremental risk of the tunnel construction to cause subsurface gas to migrate to buildings or off-gas from the ground surface is negligible, so too is the incremental risk of an explosion. Since the incremental risk of an explosion is negligible, there is no adverse effect related to explosion risk during tunneling activities

Since this pre-existing risk to buildings is present in areas of the Los Angeles basin where methane levels are elevated, the City of Los Angeles has acknowledged the risk by implementing measures for permitting of design and construction of structures in City of Los Angeles Methane Zone or Methane Buffer Zones, and Metro has implemented measures during design, construction, and operation of their facilities throughout Los Angeles County where existing subsurface gases are encountered. Similarly, the City of Beverly Hills has implemented the provisions of the California Building Code (as part of the Beverly Hills Building Code) that require the geotechnical report for a project "specify whether methane exists on site" and includes "results of the testing procedure and the proposed mitigation measures."

How is gas monitored? And what happens if it is detected?

Assessment: Gas wells were installed along the alignment during the geotechnical investigations. Additional multi-stage (varying depths) soil gas wells (or probes) will be installed along the alignment in areas where elevated gas has been detected. The probes will be monitored for methane, hydrogen sulfide, oxygen, and carbon dioxide before, during and after tunneling. In addition, in areas where elevated gas levels have been detected, and in the vicinity of known oil wells, ambient air monitoring will also be performed at the ground surface to screen for indications of soil gas emissions. This may be done daily during the tunneling operation and less frequently before and after tunneling.

If gas probe or ambient air monitoring indicate significant deviations from the pre-construction levels, combustible gas monitoring will be conducted in the interior of the closest building(s). In the highly unlikely event that elevated gas levels are found- and persist- the affected building(s) will be ventilated to reduce the gas levels.

How are construction workers in the tunnel protected from gas exposure?

Assessment: Since the western end of Section 2 of the Project (west of the City of Los Angeles/City of Beverly Hills boundary) and the eastern end of Section 2 of the Project (east of Stanley Drive) are located in ground that is known to contain elevated methane and/or hydrogen sulfide, the potentially explosive or otherwise harmful gases could be encountered during the excavation of the tunnels and station boxes. This condition represents a potential exposure risk to workers in the tunnels and stations.

The combination of the proposed tunneling method, the proposed monitoring and ventilation, and the treatment of gases in the tunnel and station excavation, reduces the risk of exposure of workers to soil gases. These procedures are described below:

- Tunneling Equipment and Protocol: A pressure face tunnel mining system will be used. This technology is a considerable improvement over the methods used during construction of Metro's initial Red Line operating segments, and was used successfully for the Metro Gold Line Eastside Extension Project. It is currently being used for the Metro Crenshaw/LAX Line and the Metro Regional Connector Line tunnels, both under construction. New technologies developed over the course of the design phases also will be considered. Appendix E of the Final EIS/EIR presents additional information on tunneling technology, and the Westside Subway Extension Century City Area Tunneling Safety Report (Metro 2011b) contains additional information on tunneling in gassy conditions and areas with suspected oil well casings.

- Detection and monitoring: Detection and monitoring equipment will be required to warn of the presence of methane and/or hydrogen sulfide in the excavations. Once excavation has been completed, Metro will continue to monitor for gases within the completed tunnel and stations. Exposing new ground for construction of cross-passageways, shafts, and other structures could also expose workers to potentially hazardous gases, and monitoring will continue as these other types of structures are excavated. Monitoring will alert personnel working in the tunnel and station excavations to enhance ventilation, don personal protective equipment, suspend excavation activities, and if warranted, temporarily evacuate the excavation.
- Ventilation: Fans will provide air movement to dilute methane and hydrogen sulfide concentrations in the tunnels and stations. Toxic gases such as hydrogen sulfide emanating from a slurry treatment plant (if used), will be captured and treated (absorbed and/or neutralized). Once above ground, methane rises and dissipates rapidly in the atmosphere and will not be a public health hazard.
- Treatment of Exhaust Air: Air scrubbers will be specified to treat hydrogen sulfide to meet Air Quality Management District standards before release from the tunnel/station ventilation system.

Furthermore, for underground construction classified as "Gassy" by the State of California Division of Occupational Safety and Health (Cal/OSHA) (California Code of Regulations, Title 8, Tunnel Safety Orders), specific requirements will include compliance with the following Tunnel Safety Orders:

- All equipment used in the tunnel must be approved. For example, internal combustion engines and other equipment such as lighting must meet approval standards of the U.S. Mine Safety and Health Administration. These approvals require verification that equipment is safe with respect to not producing sparks or emitting gas into the tunnel.
- Smoking will not be allowed in the tunnel, nor is standard welding, cutting, or other spark-producing operations, in accordance with Cal/OSHA requirements. Special permits and additional air monitoring will be required if welding or cutting operations are essential for the work. In addition, welding will only be allowed in stable atmospheres containing less than 10 percent of the lower explosive limit and under the direct supervision of qualified personnel.
- A fixed system of continuous automatic monitoring equipment will be provided for the heading (working area of the tunnel), spoils handling transfer points, and return air sources. The monitors will be equipped with sensors situated so as to detect any anticipated gas to be encountered. Monitors will automatically signal the heading, give visual and audible warnings, and shut down electric power in the tunnel—except for acceptable ventilation, lighting, and pumping equipment necessary to evacuate personnel, when 20 percent or more of the lower explosive limit is encountered. In addition, a manual shut down control will be provided near the heading.
- Tests for flammable and hazardous gas and petroleum vapors will be conducted in the return air and measured a short distance from the working surfaces.
- Whenever gas levels in excess of 10 percent of the lower explosive limit are encountered, Cal/OSHA will be notified immediately. After the approval to proceed by Cal/OSHA, any work will then be conducted with required precautionary measures such as increased ventilation.
- The main ventilation systems must exhaust flammable gas or vapors from the tunnel, will be provided with explosion-relief mechanisms, and will be constructed of fire-resistant materials.

This exhaust requirement means that only rigid fan lines (as opposed to flexible) and two-way fan systems that operate in both directions by blowing exhaust out from the tunnel and blowing air in to the tunnel could be used in gassy tunnels. The tunnel (and stations) must have adequate ventilation to dilute gases to safe levels.

- A refuge chamber or alternate escape route must be maintained within 5,000 feet of the face of a tunnel classified as gassy or extra-hazardous. Workers must be provided with emergency rescue equipment and trained in its use. Refuge chambers (typically pre-fabricated) will be equipped with a compressed air supply, a telephone, and means of isolating the chamber from the tunnel atmosphere. The emergency equipment, air supply, and rescue chamber installation will be acceptable to Cal/OSHA.

Special health and safety training and procedures will be implemented due to the health and safety issues associated with tunneling through a zone known to have elevated methane, hydrogen sulfide, and oil seeps. These procedures may require basic Hazardous Waste and Emergency Response training (29 CFR 1926 Subpart M), as well as training for excavations in a hazardous atmosphere (29 CFR 1926 Subpart P).

Previous projects in the Methane Risk Zone, for example, Metro's Red Line tunnels, have been successfully and safely excavated using procedures similar to those proposed for the Project alignment.

Multiple underground parking garages, such as the Century City Theme Towers parking facility adjacent to the Century City Constellation Station, the Century Plaza Hotel parking basement, and the Westfield Shopping Center basement, have been constructed in the vicinity of Section 2 of the Project alignment.

Numerous basements and underground parking structures have also been constructed along Wilshire Boulevard in areas with elevated subsurface gas levels without incident. Most of those underground structures were constructed before 1986 with no mitigation measures specific to methane, or have basic measures consisting of ventilation. In contract, the Project will have extensive gas barriers and gas monitoring and ventilation measures. Some of the buildings along Wilshire Boulevard adjacent to the Project alignment, such as buildings at the Los Angeles County Museum of Art, are in close proximity to the La Brea Tar Pits.

In addition, in 2013-2014, Metro constructed a 75-foot-deep exploratory shaft in an area where high concentrations of subsurface gas were present, to evaluate construction procedures and potential rates of gas emission from the excavation. This exploratory shaft was advanced through tar-saturated gassy ground in the Wilshire/Fairfax area. The test excavation and the ongoing work along Section 1 of the Project have confirmed the suitability of the excavation, monitoring, and mitigation measures that were proposed for the Project in the Final EIS/EIR.

A number of other tunnels have been safely constructed in the Los Angeles Basin as described in the Century City Area Tunneling Safety Report (Metro 2011b). With implementation of similar monitoring, ventilation, and treatment construction measures along Section 2 of the Project as are currently being used in Section 1 of the Project (including the Wilshire/Fairfax Station) (discussed under mitigation), the impact on worker safety will be mitigated.

With the implementation of the proposed tunneling techniques, the risk to construction workers is low and presents no adverse effect.

What are the risks of encountering abandoned oil wells?

Assessment: The locations of abandoned wells, including the six identified abandoned oil wells on the BHHS property, have been evaluated based upon State Department of Oil, Gas and Geothermal Resources (DOGGR) records, historic aerial photographs, and geophysical (magnetometer) surveys to identify more precisely the location of metal casings. Based upon this information, the closest known abandoned oil well at the BHHS site is believed to be located approximately 35 feet from the proposed alignment. In addition, an abandoned well may be located near the tunnel alignment near Century Park East. Finally, several former wells have been identified near the Century City Constellation Station. Apart from these wells, the likelihood of encountering a well along Section 2 is low. Nevertheless, as discussed in Section 7.0 below, additional precautionary measures are proposed to screen for wells along the alignment before and during the proposed tunneling activities.

Such measures include supplemental geophysical survey to be performed along the proposed tunnel alignment prior to construction in the areas of known oil production and mapped wells. This survey will incorporate ground penetrating radar and/or electromagnetic testing procedures to screen for oil wells and other subsurface improvements along the tunnel. If any anomalies are detected, shallow excavations will be made to expose and observe such anomalies. Other planned techniques include horizontal directional drilling with magnetometers used to detect metal casings. Procedures for handling abandoned oil wells are further described in the *Century City Area Tunneling Safety Report* (Metro 2011b) and below.

What would happen if the TBM were to encounter an abandoned oil well? How is it removed?

Assessment: Oil wells typically have a larger diameter steel “surface” casing that extends from just below the ground surface to a depth of 100 feet or more, with one or more smaller-diameter steel casings located inside that surface casing. When the wells are abandoned, DOGGR requires that the casings be filled with a series of cement plugs along their lengths. The upper cement plug that is provided at the ground surface must be at least 25 feet in length but typically extends to depths of 100 to 200 feet. If the TBM were to encounter an oil well at the proposed tunnel depths, it would likely do so within the surface casing interval. The steel casings and associated cement plugs could damage the TBM cutting head, resulting in the need for repairs and associated project delays. The cutting head could also significantly damage the well casing(s). However, because the depth of the tunnel (on the order of tens of feet) would be relatively shallow compared to the depth of the wells and the production zone (on the order of thousands of feet), the presence of multiple largely redundant plugs within the well casings, and depth of soil cover over the top of the tunnels (on the order of tens of feet), it is highly unlikely the damage would result in the release of combustible gas from the damaged casing reaching the surface. This is because the path of least resistance for gas under pressure would be for the gas to enter the TBM chamber rather than move through the tens of feet of soil cover. If a casing were damaged by the TBM and that well contained gas under pressure, some amount of methane and/or hydrogen sulfide gas could be released into the tunnel working area as well as to the ground surface through the well casing as stated above. If gas enters the TBM pressure chamber and mucking system, it would be detected by the existing TBM instrumentation. If sufficient quantity were detected, tunneling operations would cease so that gas entering the tunnel could be controlled.

If an abandoned well is found, and access to the top of the well is available at the ground surface, then the well can be re-abandoned after removing the portion of steel casing at the tunnel depth. The work for the removal of the casings and re-abandonment would be performed by specialty contractors from the surface via a borehole or small diameter shaft drilled down to below the invert of the proposed tunnel. The re-abandonment of abandoned oil wells in tunnels is described in the *Century City Area Tunneling Safety Report* (Metro 2011b)

If an abandoned well is found that would obstruct tunnel excavation and access to the top of the well is not available at the ground surface (i.e. the well is located under a structure), several options exist. Depending on the well location with respect to the tunnel, it first be determined whether it is possible to adjust the tunnel alignment to avoid the abandoned well. This is feasible if the well is very near the side of the tunnel. Second, it would have to be determined if altering the alignment is feasible with respect to constructability issues and operation of the system. If this is not possible, then the steel casings would have to be removed.

To remove steel casings at depth without access from the surface, access would be required from underground at tunnel depth. Options for such access include from within the tunnel that encountered the abandoned well or from the parallel tunnel. The procedures for removal of the steel casings and abandonment of the well at depth are detailed in the *Century City Area Tunneling Safety Report* (Metro 2011b), and access procedures are described below:

- **Access from within the tunnel that is in the way of the casing**: To remove the casing from within the tunnel being excavated, access would be required in front of the TBM's face or cutterhead. Depending on ground and groundwater conditions, ground treatment such as grouting would be required in the area around the well to provide safe, stable ground conditions in front of the TBM free of excessive groundwater. The ground treatment could be performed from within the TBM, such that surface access is not required, or in some cases using angled grout holes from the surface to reach the area to be stabilized with grout. The Metro specifications for TBMs require that grouting of the ground can be done from the TBM.
- **Access from the parallel TBM**: To access the casing from the other tunnel drive, an adit (small tunnel) could be mined from the parallel tunnel to the location of the abandoned oil well before the tunnel that would encounter the oil well was driven. The construction of the adit would be similar to that of the construction of a standard cross passage between tunnels, and would likely be constructed using the Sequential Excavation Methods (SEM) with ground treatment performed from within the excavation to control ground and groundwater. Depending on ground conditions (i.e., sufficient ground water) ground freezing methods would also be considered to stabilize the ground.

7.0 PROPOSED MONITORING AND MITIGATION MEASURES

Existing soil gas conditions in Section 2 of the Project (with the exception of west of the City of Los Angeles/City of Beverly Hills boundary and east of Stanley Drive) are not considered "elevated," and therefore the risk of encountering substantial levels of methane or hydrogen sulfide with the proposed Section 2 tunneling is low and there is no adverse effect related to tunneling activities. In the areas with existing elevated levels of methane and/or hydrogen sulfide, there is negligible incremental risk for migration of these gases to the ground surface or into buildings due to tunneling activities. Nevertheless, monitoring and mitigation measures have been proposed in the Final EIS/EIR to further evaluate and reduce the risk of methane or hydrogen sulfide entering buildings, including on the BHHS campus due to the presence of unknown oil wells. As stated in Section 4.15 of the Final EIS/EIR, implementation of the mitigation measures will minimize the subsurface gas hazards associated with tunneling so that no adverse effect remains.

Based on the further analysis on the risk associated with the potential presence of subsurface gas during tunneling presented in this Draft SEIS, the construction period subsurface gas impacts would be minimized with implementation of the following mitigation measures, as specified in Section 4.15 of the Final EIS/EIR. CON-8, CON-51, and CON-54 will mitigate risk to workers in the tunnel, and CON-53 will mitigate risk to both structures at the surface and workers in the tunnel.

- **CON-8—Monitoring and Recording of Air Quality at Worksites**: Monitoring and recording of air quality at the worksites will be conducted. In areas of gassy soil conditions (Wilshire/La Brea and Wilshire/Fairfax work sites), air quality will be continuously monitored and recorded. Construction will be altered as required to maintain a safe working atmosphere. The working environment will be kept in compliance with Federal, State, and local regulations, including SCAQMD and Cal/OSHA standards.
- **CON 51—Techniques to Lower the Risk of Exposure to Hydrogen Sulfide**: The primary method for reducing exposure to subsurface gases is dilution through the ventilation system. In areas where hydrogen sulfide is encountered, several additional techniques could be used to lower the risk of exposure. The primary measures to prevent exposure to hydrogen sulfide gas are separation of materials from the tunnel environment through use of enclosed tunneling systems such as pressurized-face TBMs and increased ventilation capacity to dilute gases to safe levels as defined by Cal/OSHA. Secondary measures could include pre-treatment of groundwater containing hydrogen sulfide by displacing and oxidation of the hydrogen sulfide by injecting water (possibly containing dilute hydrogen peroxide) into the ground and groundwater in advance of the tunnel excavation. This "in-situ oxidation" method reduces hydrogen sulfide levels even before the ground is excavated. This pre-treatment method is unlikely to be necessary where a slurry-face TBM is used, but may be implemented at tunnel-to-station connections or at cross-passage excavation areas and where open excavation and limited dewatering may be conducted, such as for emergency exit shafts and low-point sump excavations.

  When needed to reduce hydrogen sulfide to safe levels for slurry treatment; additives could be mixed with the bentonite (clay) slurry during the tunneling and/or prior to discharge into the slurry separation plant. For example, zinc oxide could be added to the slurry as a "scavenger" to precipitate dissolved hydrogen sulfide when slurry hydrogen sulfide levels get too high. Gas levels will be maintained in accordance with Cal/OSHA requirements for a safe working environment.

- **CON-53—Oil Well Locations and Abandonment**: Pre-construction geophysical surveys will be conducted to detect oil wells should unknown wells be present along the tunnel alignment. Detection of oil wells will include use of magnetic devices to sense oil well casings within the tunnel alignment. It is anticipated that the geophysical survey will be performed along the proposed tunnel alignment prior to construction in the areas of known oil production and mapped wells. This survey will incorporate techniques such as ground-penetrating radar and electromagnetic testing procedures to screen for oil well casings and other subsurface obstructions along the tunnel. These methods could be initiated from the ground surface, in horizontal holes drilled using horizontal directional drilling techniques, or a combination of methods. Shallow excavations may be made to expose and observe anomalies that are detected.

  Where the tunnel alignment cannot be adjusted to avoid well casings, the California Department of Conservation (Department of Oil, Gas and Geothermal Resources) will be contacted to determine the appropriate method to re-abandon the well. Oil well abandonment must proceed in accordance with California Laws for Conservation of Petroleum and Gas (1997), Division 3. Oil and gas, Chapter 1. Oil and Gas Conservation, Article 4, Sections 3228, 3229, 3230, and 3232. The requirements include written notification to DOGGR, protection of adjacent property, and before commencing any work to abandon any well, obtaining approval by the DOGGR. Abandonment work, including sealing off oil/gas bearing units, pressure grouting, etc., must be performed by a state-licensed contractor under the regulatory oversight and approval of DOGGR. Similarly, during construction if an unknown well is encountered, the contractor will notify Metro, Cal/OSHA, and Oil, Gas and Geothermal Resources for well abandonment, and proceed in accordance with state requirements.

- **CON-54—Worker Safety for Gassy Tunnels:** Although not specifically required for gassy tunnels, workers will be supplied with oxygen-supply-type self-rescuers (a breathing apparatus required for safety during evacuation of fires).

- **CON-89 – Gas Monitoring - Assessment:** Gas wells have been installed along the alignment during the preliminary geotechnical investigations. Additional multi-stage (varying depths) soil gas wells (or probes) will be installed along the alignment in areas where elevated gas has been detected. The probes will be monitored for methane, hydrogen sulfide, oxygen, and carbon dioxide before, during and after tunneling. Ambient air monitoring will also be performed at the ground surface to screen for indication of soil gas emissions. While elevated gas levels have not been detected at BHHS, monitoring will be conducted in response to concerns from the school district. This will be done daily during the tunneling operation beneath Beverly Hills High School and less frequently before and after tunneling. Any instance where methane is detected at or above a concentration of 5,500 ppm (10% LEL) or hydrogen sulfide is detected at or above a concentration of 20 ppm (OSHA PEL) in a soil probe (5 feet below ground surface), will be investigated. Where these levels are exceeded, combustible gas monitoring will be performed in the interior of the closest building. In the unlikely event that elevated gas levels are found, and persist, the affected building(s) will be ventilated to reduce the gas levels.

8.0 SUMMARY

As described above, a considerable amount of subsurface data is available for the Section 2 alignment including the portion that extends across the BHHS property. That data indicates elevated levels of combustible gas are present along portions of the alignment. Elevated levels of methane gas have been identified along portions of Tunnel Reaches 4 and 5 (the far eastern end of Tunnel Reach 4, at well M-17, and the far western end of Tunnel Reach 5) and around the Century City Constellation Station. At BHHS, elevated levels of methane gas have not been identified at any locations outside of the upper field basketball court area and the southeast corner of the northern parking lot. Elevated concentrations of hydrogen sulfide gas have not been identified at any location along the alignment on the BHHS property, but do appear at the Century City Constellation Station. Given the ground conditions, low gas concentrations, and tunneling methods to be used, there is not a plausible mechanism by which the proposed tunneling could cause a significant amount of that gas to migrate to, or to be released from, the ground surface. Despite the low level of baseline risk associated with the proposed tunneling, additional monitoring and mitigation measures are proposed to further evaluate and reduce risk. With the documented site conditions and the additional precautionary measures that are contemplated, the risk associated with the potential presence of combustible soil gas along the Section 2 alignment is low. Although the risk is low, mitigation measures will be in place to monitor field conditions and respond accordingly to avoid and minimize potential effects.

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