

4.0 TUNNEL FEASIBILITY REVIEW

This chapter analyzes tunneling challenges in the portion of the Study Area which contain gassy ground. Tunneling in these areas, which are known to contain methane and, in some places, hydrogen sulfide, presents special challenges during construction and operation. After summarizing the geotechnical conditions in the area, this chapter evaluates appropriate tunneling technologies with a focus on tunnel boring machines (TBMs), muck handling (the technical term for dirt and rock excavated during tunneling), and station construction methods. The chapter closes with a discussion of environmental issues and costs associated with tunneling in this area.

4.1 Geotechnical Review

Findings and recommendations of the Geotechnical Evaluation and Tunneling Technology Recommendations Report and related reports are summarized below. Subsurface conditions studied include geology, ground water, gas conditions, man-made contaminants, and seismic issues.

4.1.1 Geologic Conditions

The alignments under study are located in the northern portion of the Los Angeles Basin, approximately 1/2 to 3 miles south of the Santa Monica Mountains. Regionally, the alignment is located at the northernmost end of the Peninsular Ranges geomorphic province, near the southern boundary of the Transverse Ranges geomorphic province. The Peninsular Ranges geomorphic province is characterized by elongate northwest-southeast trending geologic structures such as the nearby Newport-Inglewood fault zone. In contrast, the Transverse Ranges geomorphic province is characterized by east-west trending geologic structures such as the Santa Monica fault, the Hollywood fault, and the Santa Monica Mountains. The Santa Monica and Hollywood faults are considered the boundary between the two geomorphic provinces within the area of the alignments under study.

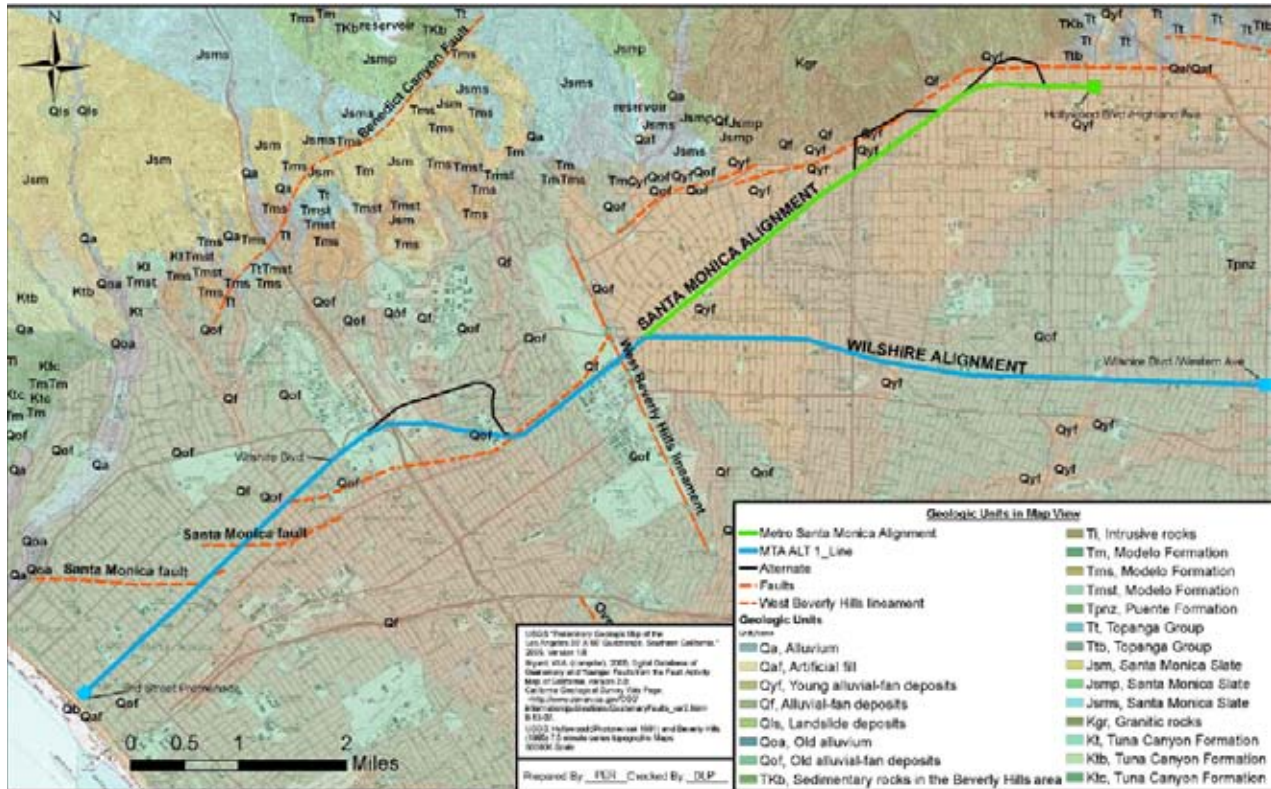
The geomorphology south of the mountain front in Santa Monica, Westwood, and West Los Angeles is characterized by deeply dissected, segmented old alluvial fans and two flights of marine terraces (Dolan et. al., 2000). The southern ends of these older fans appear to merge with the gently sloping Santa Monica Plain. The West Hollywood alignment from Hollywood Boulevard and La Brea Avenue to the west is geomorphologically distinct in that it traverses a relatively steep alluvial front characterized by numerous active alluvial fans that merge southward into a very gently sloping alluvial apron, referred to as the Hollywood Piedmont Slope (California Department of Water Resources [DWR], 1961).

Wilshire Boulevard Alignment (Alternatives 1 and 11)

The Wilshire Boulevard tunnel alignment will encounter several geologic units that range in age from Miocene to Holocene. The geologic units that would be encountered in a tunnel excavation along the Wilshire Boulevard alignment, from oldest to youngest in geologic age, are the Miocene-age sedimentary bedrock of the Puente Formation, Pliocene-age sedimentary strata of the Fernando Formation, Pleistocene-age San Pedro and Lakewood Formations, Pleistocene-age (older) alluvium, and Holocene-age (younger) alluvium. Pleistocene- and Holocene-age alluvial deposits comprise the surficial geologic units along the alignment. The San Pedro, Fernando, and Puente formations would be encountered at variable depths beneath the Holocene and late Pleistocene sediments in the subsurface along the Wilshire Boulevard alignment. The aerial distribution of geologic units and

major Quaternary faults crossing and in close proximity to the Wilshire Boulevard and West Hollywood tunnel alignments under study are shown in Figure 4-1, Regional Geologic Map.

Figure 4-1. Regional Geologic Map



Petroliferous sands (tar sand) was encountered in the several borings drilled for the Metro Rail alignment along Wilshire Boulevard from just west of La Brea Avenue to Fairfax Avenue (CWDD/ESA/GRC, 1981). The petroliferous oil sands appear to be present within the San Pedro Formation between Fairfax and Sweetzer Avenues. The South Salt Lake oil field crosses Wilshire Boulevard between these two streets. The San Pedro formation would likely be encountered in portions of the tunnel excavation between Western and Fairfax Avenues based on the preliminary alignment profile grades.

West Hollywood Alignment (Alternative 11)

The West Hollywood alignment would traverse the Hollywood Piedmont slope and adjacent alluvial fans westward to its intersection with the Wilshire Boulevard alignment. The Hollywood Piedmont slope is composed of a series of coalescing alluvial fans that were deposited by intermittent streams that shed sediments from south flowing canyons draining the Santa Monica Mountains, and emptied out into the northern portion of the Los Angeles Basin. The section below discusses the general lithologic composition of the geologic units in the West Hollywood area.

4.1.2 Groundwater

Wilshire Boulevard Alignment (Alternatives 1 and 11)

The Wilshire Boulevard 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).

Shallow groundwater, probably perched, lies between 10 to 35 feet below ground surface (bgs) (CWDD/ESA/GRC, 1981). Locally, groundwater as shallow as 5 to 10 feet bgs has been reported (LeRoy Crandall and Associates, 1983) in borings drilled along Wilshire Boulevard between Curson and Orange Grove Avenues.

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 the Wilshire Boulevard alignment. A review of historical groundwater contour maps indicate that a portion of the Wilshire Boulevard alignment is located near an historic artesian area delineated by Mendenhall (1905). The most recent groundwater measurements from multi-level monitoring well/vapor probes along the Wilshire Boulevard alignment between Crenshaw Boulevard and Burnside Avenue in September 2007 indicate groundwater levels ranged between approximately 12 to 40 feet bgs (TRC, 2007).

Existing groundwater level data information along the Wilshire alignment west of the I-405 freeway is sparse. Groundwater level measurements recorded in 1974 and 1975 from three wells located near Wilshire Boulevard between Bundy Drive and Sepulveda Boulevard in the Sawtelle area of West Los Angeles ranged from about 40 to 75 feet bgs (DWR, 1977). Depth to groundwater was found to be 38.5 feet bgs in a boring that was drilled in 1989 on Wilshire Boulevard, about 200 feet west of Barrington Avenue (LeRoy Crandall and Associates, 1989). Groundwater level measurements in core borings that were drilled in 2004 on the northern portion of University High School, located at Texas and Barrington Avenues in West Los Angeles (about 1000 feet south of Wilshire Boulevard), indicated groundwater depths at approximately 20 to 25 feet bgs with apparent localized zones of perched water as shallow as 5 to 10 feet bgs (Mactec, 2004).

West Hollywood Alignment (Alternative 11)

The West Hollywood alignment lies within the Hollywood Basin from its proposed eastern connection with the Metro Rail Red Line to near the intersection of Santa Monica and Wilshire Boulevards. The Hollywood Basin is bounded on the north by the Santa Monica Mountains and the Hollywood fault, on the east by the Elysian Hills, the west by the Newport-Inglewood uplift, and the south by the La Brea High, an area of relatively shallow bedrock (DWR, 2007). The depth of the groundwater basin (to the base of the Pleistocene water bearing units) is about 660 feet (DWR, 1961).

Groundwater in the Hollywood Basin occurs within several aquifers of the Lakewood and San Pedro Formations. The aquifers consist generally of permeable sands and gravels separated by semipermeable to impermeable sandy clay to clay. Relatively shallow groundwater is present locally within the recent and/or older alluvium and is reported as semi-perched (DWR, 1961 and DWR, 2007). Groundwater contour maps prepared by the DWR show a general northeast to southwestward groundwater flow in the shallow aquifers of the Hollywood Basin.

Along Camino Palmero from Hollywood Boulevard northward to the foot of the south flank of the Santa Monica Mountains 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. A groundwater level measurement of 27.8 feet was measured in March 1986 in soil vapor probe/monitoring well No. 61, located near the intersection of La Brea Avenue and Sunset Boulevard. This suggests groundwater levels may be shallower (with respect to ground surface) towards the south, away from Hollywood Boulevard. A groundwater level contour map of the Hollywood and Beverly Hills Quadrangle, showing the historically highest groundwater levels (CDMG, 1998), indicates groundwater depths ranged from historic highs of 10 to 150 feet below ground surface along the West Hollywood alignment.

4.1.3 Subsurface Gas Conditions

Wilshire Boulevard Alignment (Alternatives 1 and 11)

In the Mid-Wilshire area, methane and minor amounts of H₂S are encountered in the San Pedro and Lakewood Formations at 10 to 50 feet below ground surface. These gases migrate upward to the surface from deeper formations. Historically, there have been occasions when the gas has accumulated beneath or within structures. In 1985, methane accumulated in the basement of the Ross Store at Fairfax Avenue and Third Street caused an explosion. The City of Los Angeles has since implemented special building code provisions for “methane zones” and “methane buffer zones” within the city to address this natural occurrence and provide mitigation (see Figure 4-2).

Figure 4-2. Study Alignments with Methane Risk Zone and Methane Buffer Zone



Building measures in this area include proper investigation of gases, construction of methane barriers/liners and vent systems beneath building slabs, special heating, ventilating, and air conditioning (HVAC) requirements, and/or methane detection and eradication equipment/systems among other possibilities.

A panel of experts assembled by the American Public Transportation Association (APTA) has concluded that tunnels can be safely constructed and operated in the Wilshire Boulevard corridor given:

- Advances in TBM technologies such as use of Pressure Face TBMs,
- Increased local and international tunneling experience with Pressure Face tunneling,
- New knowledge about methods to mitigate risks,
- Local experience with subterranean construction along Wilshire Boulevard,
- Improvements in gas measurement instrumentation technology,
- Successful operation of the existing Metro System with its gas monitoring and mitigation measures, and
- Improved attitudes with regard to safety in the industry

Panel recommendations include:

- **Tunnel Liner and Gasket Design:** As the double gasketed system used for the Metro Gold Line Eastside Extension had not been tested in the field as of November 2005, the panel recommended staying with a “two-pass” system to provide redundancy in gas mitigation.
- **Alignment and Station Location:** Minimize construction in the gas and tar bearing formations as much as possible, particularly the San Pedro Formation’s unsaturated zones. These zones were found to have high methane and hydrogen sulfide (H₂S) concentrations during explorations for Metro’s Mid-City alignments in the mid 1990’s.
- **Locate Abandoned Oil Wells:** Develop procedures for responding should they be found.
- **Be Aware of Lessons Learned:** Periodically review other tunneling projects to make use of lessons learned. Two experiences, the Detroit River Outfall and the Spanish Fork Canyon projects, were provided for examples.
- **Use a trial pit constructed in Tar Sand areas** to measure earth and gas pressures
- **Cross passage construction will expose workers to gassy ground** and will require special treatment.
- **Investigate technologies for methane and H₂S degasification** such as in-ground remediation
- **Develop procedures for membrane repair** should seismic events or fires occur.

In addition to the Mid-Wilshire area, gases are also detected at other former oil field areas such as in the Century City area and near downtown Los Angeles. In some areas near the La Brea tar pits, methane can reach up to 90 to 100 percent by volume of the vapor phase (the explosive range is 7 to

24 percent). Additionally, H₂S, has been measured in the range of 10 to 600 parts per million (ppm) in the Wilshire/Fairfax area.

Metro Purple Line Wilshire/Western Station. Historical data along the Westside alignment is fairly voluminous from Western Avenue to San Vicente Boulevard. In the area of the existing Western Avenue station historical H₂S data show fairly low values in the immediate vicinity (12 ppm) of the station footprint and methane as high as 9 percent by volume. However, values of H₂S and methane increase two blocks to the west with readings of H₂S reaching 98 ppm and methane reaching 35 percent by volume between Saint Andrews Place and Gramercy Place.

Wilshire/Crenshaw Optional Station. Approximately six blocks west of the Metro Purple Line Wilshire/Western Station footprint is the planned Wilshire/Crenshaw Station at the intersection of Crenshaw and Wilshire Boulevards. In this vicinity, methane and H₂S appear to have generally reduced in concentration with readings from the Engineering Science probe P-35 and other probes and borings indicating methane in the range of 1 to 3 percent by volume and H₂S between non detected to 1 ppm (based upon available data). Readings within the deeper portion of the San Pedro Formation are rare in this area however.

Wilshire/La Brea Station. Westward from the Crenshaw Avenue Station, methane and H₂S levels remain low for about six blocks along Wilshire Boulevard. At Rimpau Boulevard, there is a fairly significant increase in methane with a reading of 60 percent from P-39 (Engineering Science probe) in the San Pedro Formation. However, H₂S remains low at this location. With the exception of a reading of 33 percent methane at Tremaine Avenue and Wilshire Boulevard, the readings of both methane and H₂S remain low through the planned La Brea Station at La Brea Avenue and Wilshire Boulevard. Increased methane and H₂S concentrations can be seen at Sunsmur Avenue and Ridgeley Drive three blocks east of the La Brea Tar Pits (methane reaching 19 percent and H₂S at 157 ppm).

Rancho La Brea (Tar Pits). At the intersection of Masselin Avenue and Wilshire Boulevard, the highest recorded reading of H₂S (from available historical data along the Westside extension) was noted with a reading of 600 ppm from Enviro-Rail's RC-2 probe installed in 1994. Methane concentrations were low at this location, however. At Curson Avenue and Wilshire Boulevard (adjacent to the La Brea Tar Pits Park), methane was detected at 78 percent in the lower San Pedro Formation and H₂S was detected at 160 ppm.

Wilshire/Fairfax Station. Similar readings to those detected at the La Brea Tar Pits area were detected at Fairfax Avenue and Wilshire Boulevard. A probe from the Enviro-Rail projects of 1995 detected H₂S in the range of 17 to 33 ppm while methane was detected at 100 percent by volume in GW-2 (sample taken from headspace in groundwater well located approximately 400 feet north of Wilshire Boulevard). The high methane reading may be skewed due to it being from off-gassing of ground water within a well. A nearby probe (P-48) located approximately 150 feet north of Wilshire Boulevard (and the planned Fairfax Station) had methane readings of 58-65 percent.

As one approaches McCarthy Street two blocks west of Fairfax Avenue, a probe reading indicates lower methane (less than 1 percent) and some H₂S at the top of the San Pedro Formation (50 ppm). Further west, at San Vincente Boulevard, the methane readings and H₂S drop down to zero or none detected for both. Additional data to the west of La Cienega Boulevard is sparse, though some institutional knowledge has indicated that significant methane has been detected in the Century City area and the Sawtelle neighborhood near the I-405 Freeway intersection with Wilshire Boulevard.

Century City Area. Along Santa Monica Boulevard, between Wilshire Boulevard and Beverly Glen Boulevard, the West Area of the Beverly Hills Oil Field intersects the alignment. In this area, several oil wells are located both northwest and southeast of the alignment within a few hundred feet. In this area, there not only is a high likelihood of the presence of gases associated with oil field wells, but there have been measured levels of methane at a few documented locations ranging from 13 to 99.9 percent.

West of the I-405 Freeway. The alignment intersects the Sawtelle Oil Field beginning approximately 300 feet west of I-405 Freeway (going westward) to approximately where Wilshire Boulevard crosses San Vicente Boulevard (west of I-405 Freeway). Mapped wells in the Sawtelle Oil Field are fairly distant to the alignment (approximately 1/4-1/2 mile northwest), with the exception of three dry-hole plugged wells located approximately 1-2 blocks northwest of Wilshire Boulevard between San Vicente Boulevard and 26th Street (DOG Wildcat Map, 117, City of Santa Monica).

West Hollywood Alignment (Alternative 11)

The available gas data for much of the West Hollywood alignment is fairly sparse. A review of the California Department of Conservation Division of Oil and Gas Wildcat Maps (#117, June of 2006) indicated that from the Hollywood Boulevard/North Highland Avenue intersection to La Cienega Boulevard (along the West Hollywood alignment), no mapped oilfields are indicated. However, between La Cienega Boulevard and San Vicente Boulevard (going southwestward down Santa Monica Boulevard) an abandoned oil field is indicated - the Sherman Oil Field. Seven wells installed a few hundred feet southeast of Santa Monica Boulevard have since been abandoned.

4.1.4 Man Made Contaminants

Wilshire Boulevard Alignment (Alternatives 1 and 11)

The Wilshire Boulevard alignment will encounter the types of contaminant release sites typical in a large city. These findings are associated with normal contaminant releases related to gasoline stations and dry cleaner facilities. The contamination, in most cases, has been cleaned to site closure, but for those cases that are yet open the contamination is often confined to the upper 100 feet (below ground surface). One Superfund-listed site was noted due to releases of methyl tert-butyl ether (MTBE) and this site is currently being remediated. MTBE contamination is often associated with releases of gasoline. Contamination plumes associated with this site are likely in the process of being controlled from further spreading due to the pumping that is underway.

West Hollywood Alignment (Alternative 11)

Contaminant release and hazardous materials findings are generally similar to those along the Wilshire Boulevard alignment. The contamination associated with gas stations and dry cleaning facilities along the West Hollywood alignment is generally typical for this type of commercial area (heavy in gas stations, food establishments, and other service businesses). In most cases, such contamination is limited in depth and area and is generally confined to the upper 50 to 100 feet below ground surface. If a site is open, there may be Volatile Organic Compound (VOC)-contaminated groundwater with concentrations above Department of Health Services Drinking Water Maximum Contaminant Levels; or contaminants in soil (in the zone above first groundwater) at levels exceeding site screening goals. If a site is closed, there may be remnant low levels of VOC contaminant in soil and groundwater.

4.1.5 Seismic Conditions - Liquefaction

Wilshire Boulevard Alignment (Alternatives 1 and 11)

The California Geological Survey (CGS) has rated the liquefaction susceptibility for the Holocene age sediments in the alignment area as high if saturated and, if not saturated, the susceptibility is rated as low (CGS, 1998). 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 ground-water levels. The young (Holocene) age deposits along the alignment, where present, are on the order of 5 to 35 feet thick. Preliminary alignment profiles show the tunnel crown elevations appear to be below the young alluvial deposits that are rated as highly susceptible to liquefaction.

For station locations with shallow ground water 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 more likely to occur at the proposed Westwood, Bundy, and La Cienega Station locations. Settlement beneath the aforementioned planned stations due to liquefaction is considered remote due to the dense character of the older alluvium at preliminary station depths.

West Hollywood Alignment (Alternative 11)

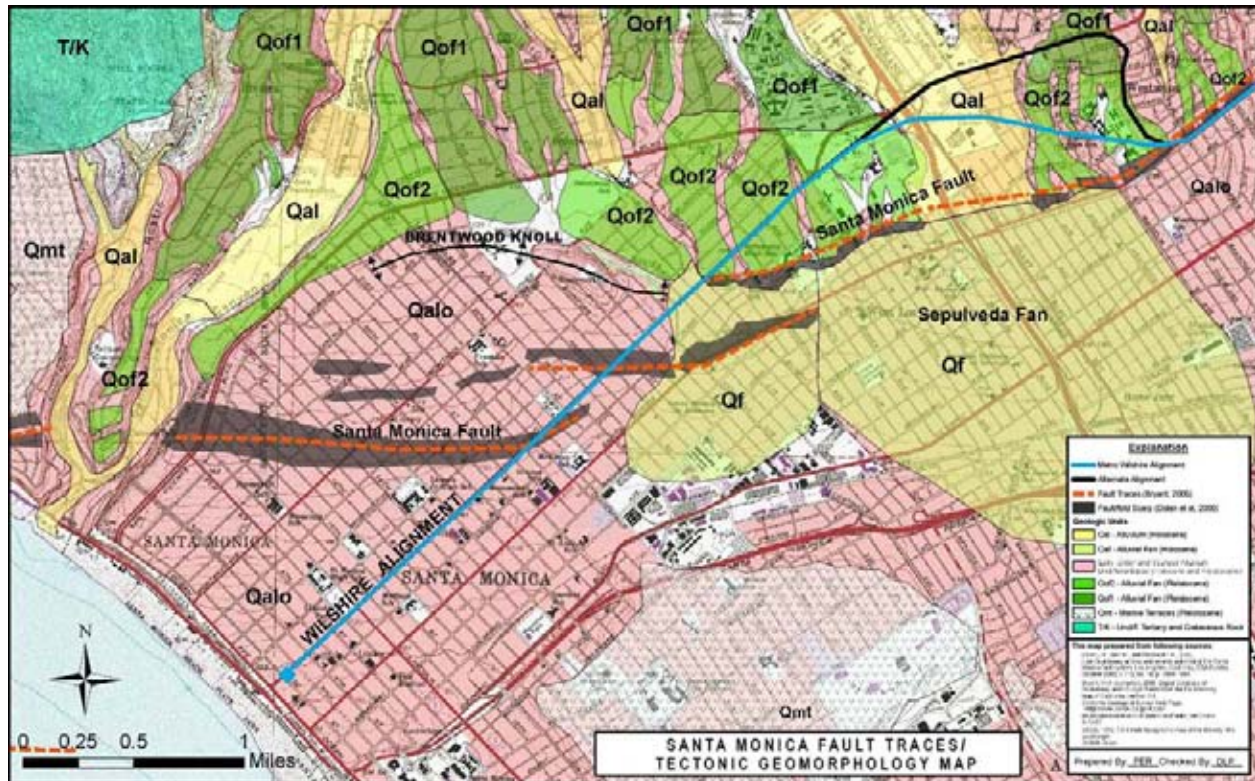
The eastern portion of the West Hollywood alignment would appear to traverse a portion of the late Holocene alluvial fans that are shown as susceptible to liquefaction. However, based on the relatively thin cover of Holocene-age sediments in this fan complex and the depth to groundwater identified in borings drilled along Camino Palmero (Earth Technology, 1992), it appears that at preliminary tunnel excavation invert grades, the tunnel will be driven below the Holocene section and above groundwater levels (north of Hollywood Boulevard). The portion of the alignment along Santa Monica Boulevard between La Cienega and Beverly Boulevards lies within a liquefaction susceptible zone. Likewise, it appears that based on preliminary tunnel excavation invert grades, the tunnel will be driven below the Holocene alluvial section and above groundwater levels along this reach of the West Hollywood alignment.

4.1.6 Seismic Conditions - Faults

Wilshire Boulevard Alignment (Alternatives 1 and 11)

The numerous faults in Southern California include active, potentially active, and inactive faults. 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 five miles of the alignment are discussed below with respect to their known recency of displacement and location relative to the alignments under study.

Active Fault - Santa Monica Fault. The Santa Monica fault zone (SMFZ) is the western segment of the Santa Monica-Hollywood fault zone. The Wilshire tunnel alignment will traverse the SMFZ at several locations, as shown on Figure 4-3.

Figure 4-3. Santa Monica Fault Zone


The easterly portion of the northerly of the three scarps west of the I-405 freeway appears to cross Wilshire Boulevard near Bundy Drive in the Sawtelle District of Los Angeles. In the City of Santa Monica, the central scarp appears to cross Wilshire Boulevard between Stanford and Harvard Streets, whereas, the eastern scarp crosses Wilshire Boulevard between about 22nd and 24th Streets. The trend of the three scarps in the Sawtelle District and Santa Monica appear to intersect the Wilshire Boulevard alignment at a relatively small angle (i.e., the acute angle of intersection between the scarp crossing and Wilshire Boulevard is about 10 to 40 degrees).

Active Fault - Newport-Inglewood Fault Zone. The active Inglewood fault of the Newport-Inglewood fault zone is approximately 2.9 miles south-southeast of the 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).

Active Fault - Hollywood Fault. The active Hollywood fault, located approximately 1.1 miles north-northwest of the Wilshire alignment, 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. The fault may act as a ground-water barrier within Holocene sediments (Converse et. al., 1981).

4.2 Evaluation of Tunneling Technology

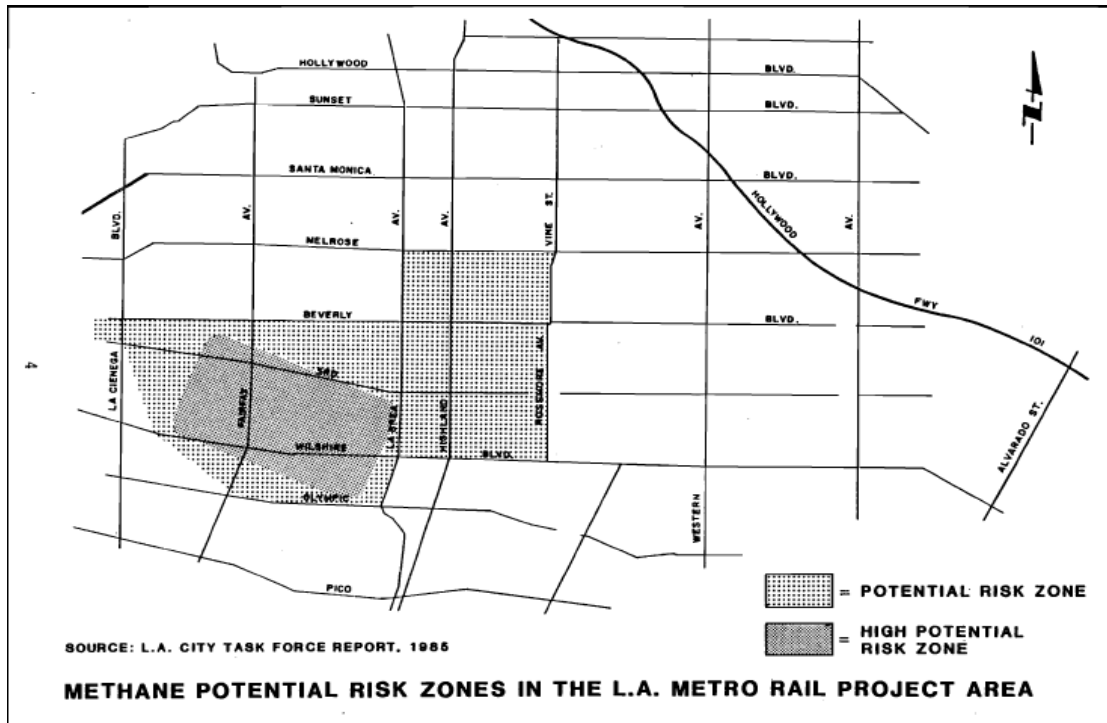
The feasibility of tunneling for the Westside Extension Transit Corridor begins with comparison to past and present experience in Los Angeles, other cities around the U.S., and worldwide. That experience has shown that the proper combination of design, modern tunneling equipment and methods, and the use of sufficient ventilation will lead to successful tunnel construction. Evidence of this is found in the now completed Metro Gold Line Eastside LRT tunnels and in similar successes of other tunnel projects in the U.S.

Of these success stories, that from the Metro Gold Line Eastside Extension is most applicable because it is local and demonstrates that tunnels can be constructed and operated in local conditions. Experience from Metro Red Line tunneling and other projects is also applicable to Westside alignments. The most recent completed Metro Red Line tunnel was the North Hollywood line completed in 2000. More modern tunneling practice, i.e., the use of earth pressure balance machines, has demonstrated even better success in the gassy ground of the Boyle Heights area of Los Angeles. The latter tunnels are not yet in service but were designed and constructed successfully and are judged ready and safe to go into service. Studies conducted for the Mid-City Extension and Red Line Eastside Extension (suspended) also provided testing results and recommendations for safe tunneling in gassy areas. Much of this experience can be applied to the evaluation of tunnel feasibility and development of design criteria for the Westside Extension area. The following sections expand on previous Metro experience and approaches to be taken for the next phases of the Westside studies given the known data and APTA panel recommendation.

4.2.1 Metro Red Line – Existing System Design and Construction

In 1985, after the Ross Dress-For-Less Fire and the subsequent creation of the Methane Risk Zone, Metro commissioned the Congressionally Ordered Re-Engineering Study (CORE) to evaluate alternative alignments with respect to gas conditions. Ultimately, the existing Metro Red Line alignment from the Wilshire/Vermont Station to Hollywood Boulevard was selected, and the final conclusions of the CORE study were:

1. No part of the study area (see Figure 4-5) can be considered to be free of gas.
2. Gas is more likely to be found over or near old oil fields.
3. The highest concentrations of gas were measured in the southern area (Wilshire and San Vicente Boulevards between La Brea and Fairfax Avenues). Less gas was found along Sunset Boulevard.
4. There is no discernible difference in the likelihood of the presence of gas between the portions of the alignment on Western Avenue and on Vermont Avenue.
5. Given that no part of the study area can be considered free of gas, subsurface facilities should be constructed using standard precautions and gas migration measures to ensure the safety of the system.

Figure 4-5. Methane Potential Risk Zones (1985)


In order to minimize gas (and water) inflow, all Metro Red Line segments were designed with a “two-pass” tunnel lining system that included a high-density polyethylene (HDPE) water and gas barrier. Early contracts used ribs and boards for initial support, and subsequent contracts used precast, expanded (non-gasketed) segments for initial support. Open face shields were used for all soft-ground tunnels, as this was the traditional tunneling method used in Los Angeles until about 1995, and most of the tunnel reaches were above groundwater. The Metro Red Line tunnel driven through the Santa Monica Mountains used a hard rock type (Closed Face) TBM. For construction, Metro Red Line tunnels excavated in the Los Angeles basin (south of the Santa Monica Mountains), have been classified Gassy by Cal/Occupational Safety and Health Administration (OSHA). This classification requires continuous air monitoring for hazardous and explosive gasses, “spark proof” equipment, and other special requirements for tunneling operations.

Several occurrences of gas alarms were reported during construction of the Metro Red Line. One of the most notable experiences was an encounter with tar seams in the tunnel reach of Red Line Contract B-201, 1,000 feet west of MacArthur Park. Initially, ventilation rates were increased, to dilute the gas. However, reduced air flow rates and slower mining proved to be the ultimate solution to mining safely through this zone. At the higher rates, volatiles were found to be more readily released.

4.2.2 Mid-City Studies

Although the Mid-City (Red Line) Extension was not constructed, much was learned from tunneling studies conducted in this area south of Wilshire Boulevard between Crenshaw and San Vicente

Boulevards (north of Pico Boulevard). Within this geographic area, gas measurements (H_2S in particular) were found to be higher than those measured at Wilshire Boulevard and Fairfax Avenue.

During the Mid-City Re-Assessment Study in 1994, soil-gas monitoring and testing programs were undertaken to locate the gas-bearing formations, determine the extent of the gas reservoir, examine methods of treatment - both pre-tunneling and during tunneling, and recommend tunnel and station configurations to avoid the gassiest ground. Conclusions pointed to safe tunneling if pressure face TBMs (in particular, slurry face TBMs) were used for worker protection. In-situ testing included soil-gas extraction and injection methods. By injecting air and extracting gases exposed to air, exposure to H_2S during tunneling could be reduced. These techniques are commonly used in the soil remediation work to reduce ground contamination. Other conclusions of this study were that:

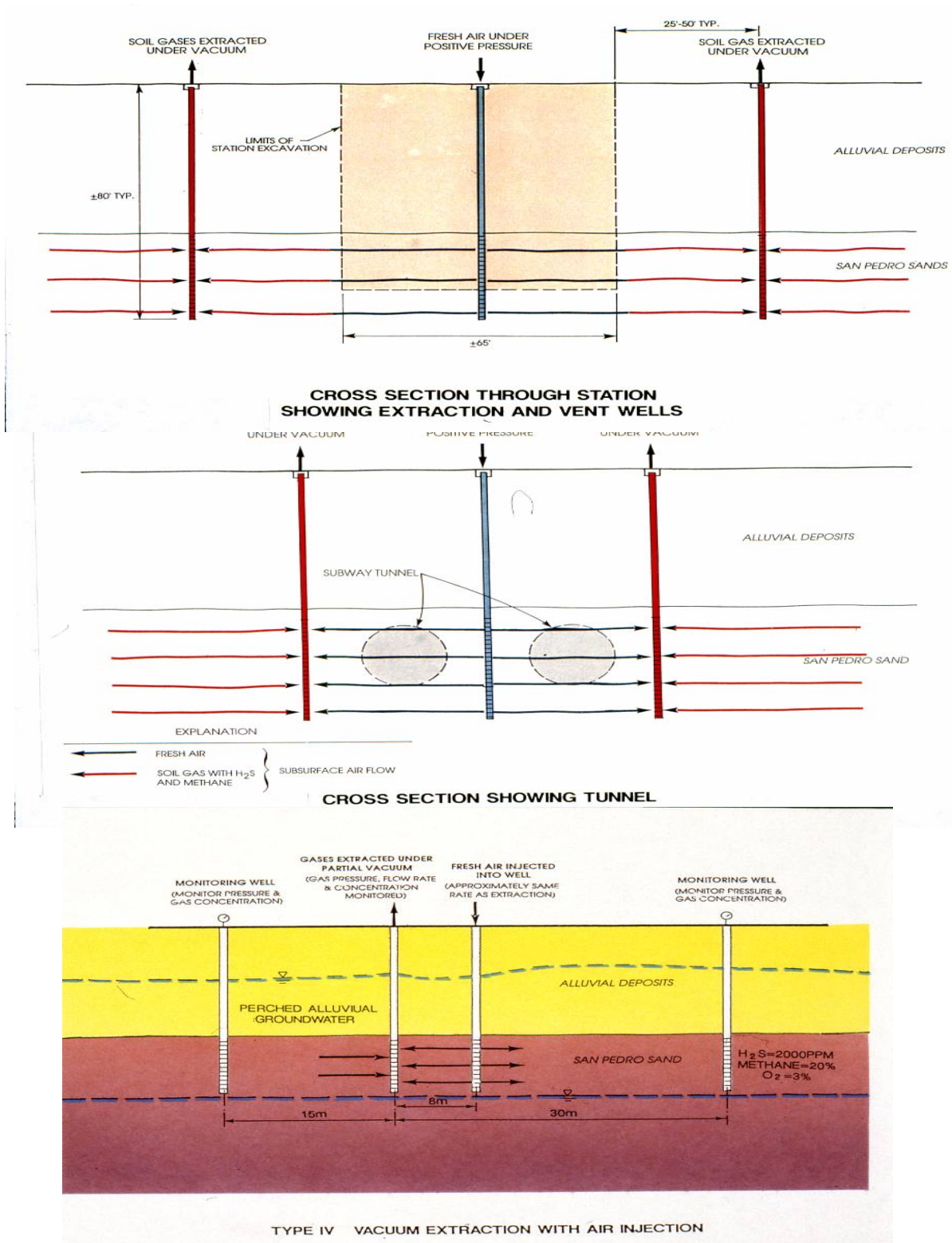
- Several alignments were feasible in Mid-City that involved raising the alignment above the gassiest ground, including one alternative with an aerial station.
- All structures were to be raised above the San Pedro Formation to the extent possible – especially if it were un-saturated.
- While Health and Safety thresholds are on the order of 10 ppm for H_2S , odor thresholds are much lower (about 0.002 ppm). The study concluded that while H_2S levels that the general public could tolerate in the subway were unknown, very low levels (safe yet above the odor threshold) might be objectionable.

Red Line Eastside Extension (Suspended Project)

Technology developed for the Eastside Suspended Project is directly applicable to the Wilshire Boulevard alignment in the Methane Risk Zone. During final design of the Suspended Project, high levels of H_2S (up to 21,000 ppm) were measured in head space of groundwater monitoring wells. These conditions occurred in the tunnel reach south of Union Station between the 101 Freeway and the Little Tokyo Station. Methane levels were also high, over the lower explosive limit of five percent. Other contaminants included man-made VOCs. In this reach, the water table was mostly above the proposed tunnel crown, conditions similar to those in the Wilshire Boulevard Alternatives' gassy areas.

As with the Mid-City Segment (refer to Section 4.2.2), slurry face TBMs were to be specified for the tunnel segment in H_2S bearing ground. Metro developed final specifications for slurry treatment and monitoring at the treatment plant, as well as pre-treatment of the ground prior to exit shaft excavation. Due to the configuration of the existing yard-lead tunnels, the Eastside tunnel separation required exit shafts to the surface in some locations, as opposed to cross-passages between tunnels. A number of environmental studies were undertaken to develop specifications to control H_2S . Studies included supplemental gas investigations and small scale “bench testing” to develop in-situ methods for reducing risks of mining in H_2S bearing environments.

Figure 4-6. Possible In-Situ Mitigation Measures – Mid-City Extension

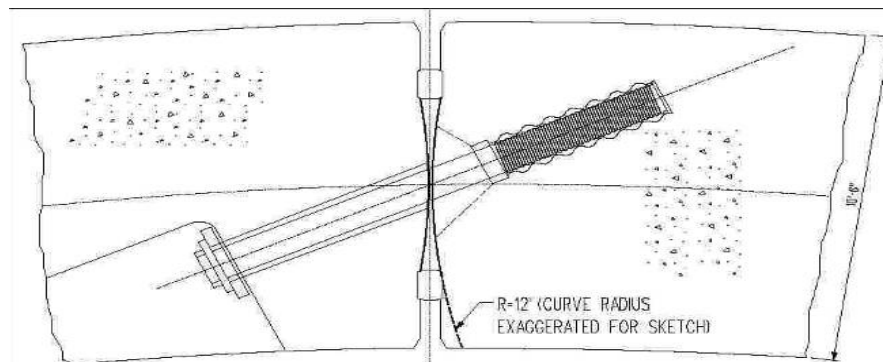


Three methods were identified for reducing H₂S:

1. Reduce concentration in groundwater ahead of the TBM or excavation. Injecting large quantities of H₂S -free water, treated with dilute hydrogen peroxide, appeared to be the most efficient means to accomplish in-situ mitigation. Injection from TBM probe holes could also be considered (but would delay tunneling). Injection well spacing requirements were close, less than 15 feet on centers.
2. Maintain high pH in the TBM slurry. Bench testing found that a pH of 10 would be sufficient to keep H₂S in a dissolved state. With the high pH, off-gassing at the slurry treatment plant was predicted to be less than 1 ppm. Additives to increase pH were checked against oil-field drilling experience, as some additives would adversely affect slurry properties. Sodium hydroxide (NaOH) was stated to be the most feasible additive. The most efficient approach would be to add the NaOH at the slurry treatment plant.
3. Use a zinc “scavenger” to precipitate dissolved sulfide out of the slurry.

Given the risks of H₂S and methane leakage in to the tunnel, designers and Metro’s Tunnel Review Board recommended use of a double-gasketed tunnel liner (“one-pass” system) for use with the pressure face TBMs. Seismic conditions led to design of a convex to convex shape on radial joints principally to “flex” during earthquakes so that the tunnel remained sealed from gas. Figure 4-7 illustrates the double gasket system recommended. This sealing system was believed to be the first of its kind, and thus Metro undertook a six-month, nearly full scale, laboratory testing program, conducted at the University of Illinois. While the Red Line suspended project was not constructed, the double-gasket system was ultimately used on the Metro Gold Line Eastside Extension. These tunnels are not yet in service but have been constructed. No gas has been detected to date in the completed tunnels.

Figure 4-7. Schematic of Convex to Convex Double Gasketed Radial Joint



Metro Gold Line Eastside Extension

The Metro Gold Line Eastside Extension (MGLEE) project tunnels pass through the abandoned Boyle Heights oil field, and methane and H₂S were anticipated during construction. No H₂S gas was measured in soil borings but H₂S odor was reported on boring logs. Methane was measured with a maximum reading of 1,700 ppm. Cal/OSHA ultimately issued a “Gassy” tunneling classification. As with the suspended project, Metro specified pressure face TBMs (also refer to Section 4.3.3 for

additional discussion of this technology) and a pre-cast concrete, bolted, gasketed lining for the MGLLE. This would provide additional safety with respect to gassy conditions.

Similar to the Suspended Project, specifications required PFMs for face control in the alluvial ground above and below the groundwater. Selection of an earth pressure balance (EPB) or slurry face TBM was left to the contractor. The primary objectives of the PFM specification were to minimize ground loss and related disturbance to the community and to increase tunneling safety. Thus, the specification called for tunneling under positive pressure (minimum of 0.7 bar or 10 pounds per square inch [psi] above groundwater pressure), as well as immediate backfilling of the tail void by grouting through the tail shield. Other requirements for the TBM tunneling included:

- Compressed air locks to access face
- Provisions for adding disc cutters, should they be needed in cobbly or bouldery ground
- Provisions for probe hole drilling and grouting through/ahead of the tunnel face
- Automatic Data Acquisition Systems to provide TBM data in “real-time”
- “Gassy” tunnel classification - compliance with Tunnel Safety Orders, Title 8, of the State of California for use in Class 1, Division 2, hazardous locations

The MGLLE project has proven that the tunneling specifications for that project were realistic and the construction was successful. Inflows of water have been well below specifications and no gas leakage through the tunnel lining has been measured. That the tunnel lining segments are operating as planned is apparent from observation and from all available measurements. It is noted that low levels of H₂S were encountered (smelled) in some construction areas (e.g., cross passages), but these were readily, safely, and successfully handled with an increase in local ventilation, which was no longer needed after completion of the tunnel lining.

4.3 Evaluation of TBM technology

4.3.1 Slurry Shield Tunneling

For this project, a pressure-face, slurry-shield tunneling boring machine (SF TBM) is expected to be used for tunneling in Methane Risk Zones. Tunneling using an SF TBM minimizes exposure of workers to elevated gas concentrations underground, since the excavated soil is removed in a fully enclosed slurry pipeline to an enclosed treatment plant. Based on the previous Metro and other project experience with pressure-face tunneling machines, it is anticipated that the SF TBM will travel approximately 50 feet per day on the average, and tunneling may utilize two or more SF TBMs simultaneously from one mining shaft, typically the station box excavation. The SF TBM will create a tunnel with a 19-foot inside diameter and a 21-foot outside diameter.

In a SF TBM, the excavated ground in front of the bulkhead is mixed with slurry (usually bentonite). The bulkhead allows for a positive pressure to be applied to the tunnel face, while allowing tunnel workers to be in free air (atmospheric pressure). Maintaining a positive pressure at the tunnel face decreases the potential for ground loss and soil instability (sloughing or caving), as well as preventing infiltration of groundwater. As a result, the spoil has the consistency of a viscous fluid. Pressure in this fluid is controlled by pressure gauges and pressure relief valves. A separate air pressure may be applied to provide even closer control of the pressure. The bentonite is introduced to the face by pipe

to the chamber and the bentonite and ground mix is removed through piping and pumped to the surface. At the surface, the solids are removed in a special treatment plant and the bentonite is reconditioned and recirculated to the heading.

An advantage of the SF TBMs is improved face control, as the hydraulic pressure can be finely adjusted using the added air pressure. For coarse grained soils, separation of slurry from the excavated material is less complex – than when clay materials are present. Bentonite provides some lubrication of the TBM cutting wheel, and wear may be reduced. Tunnel construction using SF TBMs is a cyclic process which begins with advancing of the TBM by excavating and removing soil from the tunnel face while the tunnel lining is erected within the end portion (tail) of the shield. After the lining is bolted into place, the machine is propelled forward by jacks that react against the installed lining. As the TBM advances, the annular space between the lining and the excavated perimeter is injected with grout from the tail shield of the TBM shield. Seals between the shield and the lining ring inside the TBM tail shield prevent the grout from flowing back to the inside of the shield. The segments themselves have gaskets to provide watertight joints while the lining as a whole is required to structurally maintain the safety and stability of the opening.

The SF TBM maintains a positive pressure on the tunnel face using a cake of bentonite that forms from impregnating (injecting) slurry at the tunnel face through the cutter head. The cake then acts as a membrane or penetrates the pore spaces at the face. Some SF TBMs use a compressed air buffer to help regulate chamber pressure. The buffer allows pressure applied at the tunnel face to be quickly adjusted based on varying earth (soil and groundwater) pressures encountered as the tunnel advances. Typically, pressure equal to or slightly greater than the prevailing earth pressure is applied. The effectiveness depends upon the extent of penetration of the slurry into the soil at the tunnel face, forming a membrane cake. Slurry penetration generally results in two types of caking:

- Membrane Cake (Figure 4-8) - Formed in ground of low permeability with use of relatively stiff slurry. The fine-grained soils do not allow slurry to penetrate into the ground and the slurry cake is formed at the tunnel face.
- Impregnation Cake (Figure 4-9) – Formed in moderate to high permeability ground. Due to the open nature of the ground, the slurry penetrates as much as several meters into the ground before it loses velocity and sets.

In addition to providing an impermeable membrane and assisting confinement pressure to develop within the excavation chamber, secondary functions of the slurry include:

- Spoils encapsulation and transport
- Lubrication for abrasion reduction
- Environmental acceptability (e.g., reduced impacts on adjacent structures)

Soil conditions in which a SF TBM would be best suited have been outlined by Maidl et. al., (1996). Sandy soils are considered best for efficient soil separation from the slurry. Clay soils will require additional processing at the treatment plant, and if not separated from the slurry can be difficult to dispose of due to the wet consistency.

Figure 4-8. Membrane Cake

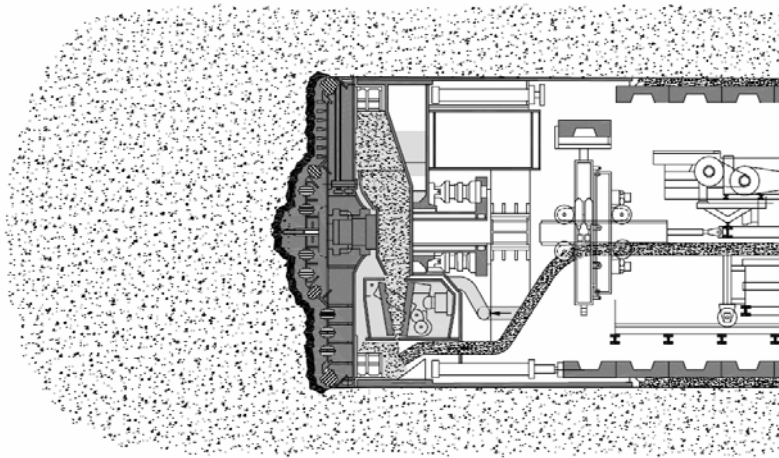
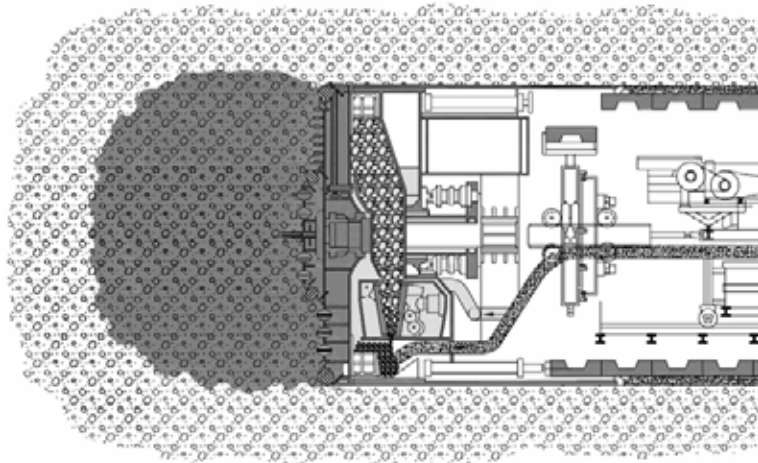


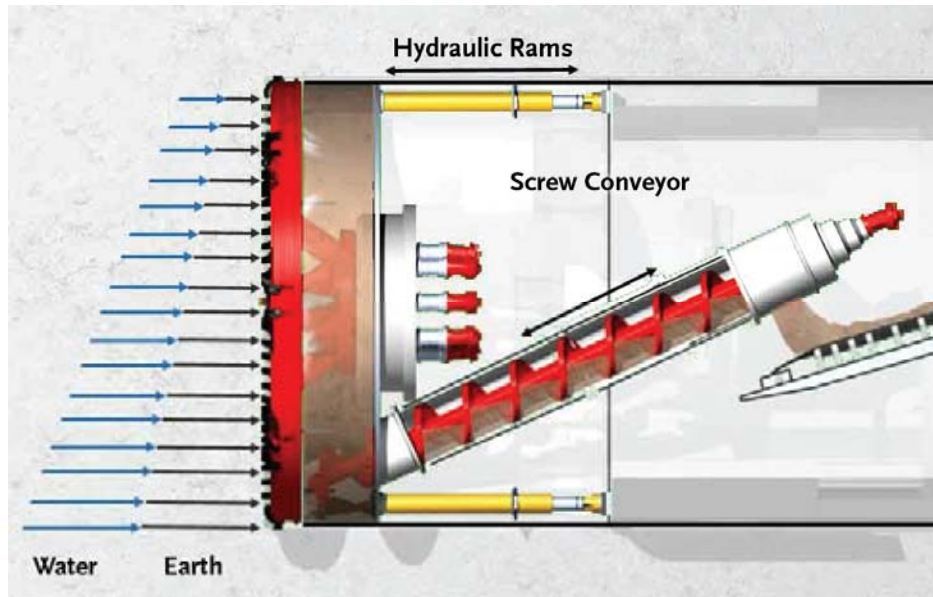
Figure 4-9. Impregnation Cake Formation (High-Permeability Ground)



4.3.2 Earth Pressure Balance Machine

EPBs are similar to SF TBMs in that the soil is excavated by a wheel and trapped at the face by a bulkhead in the machine (Figure 4-10). Removal of the soil is by means of a screw conveyor which also provides the pressure reduction (by friction) from the pressure at the face to ambient at the screw discharge point. As with the SF TBM, conditioners are typically added to the material to produce the optimum material properties for operation of the machine. For the EPB, that optimum is a greater stiffness than that for a SF TBM. Control of the pressure at the face is usually more difficult because it relies on mechanical or friction rather than hydraulic properties.

Figure 4-10. Schematic of EPB TBM



EPB TBMs were used very successfully for the MGL EE project. For that project, the contractor designed a special long screw conveyor to discharge soil well away from the tunnel working face, where most of the workers are located. At the end of the long conveyor, additional ventilation capacity was provided, should gas be detected.

Selection of the construction means, methods, sequences, and systems will require a full consideration of the ground conditions to be encountered, and the adoption of systems that offer flexibility to adapt to those conditions quickly without major re-tooling or costly delays.

4.3.3 Pressure Face Tunnel Boring Machines

For the original construction of the Metro Red Line, open face TBMs were used. These machines were modern adaptations of the Brunel tunnel shields first used in the late 1800s. They were called open face machines because the ground at the face of the machine was exposed to the tunnel atmosphere and relied upon installation of timbers, plates, jacks or mechanical doors to attempt to stabilize the face. Given the availability and success of pressure face tunneling methods, open face methods are not likely to be permitted for long tunnel drives in soft ground.

4.3.4 Recommended Boring Machine

At the present, it is tentatively recommended that SF TBMs are most appropriate tunnel boring machines for the Westside Extension gassy areas based on the following:

- Removal of contamination occurs at the surface where it can be handled more safely
- No release of contaminants within the tunnel

4.4 Spoils Handling and Disposal

Tunneling operations will require worksite space for accessing the tunnel, slurry and grout plants, electrical equipment, muck storage, dump truck access, segment storage, and other equipment storage. For Slurry TBMs, a slurry separation plant requires space for slurry handling and separation. Slurry processing is more difficult in clay and silty soils. Additional steps are required for separation of soil from the slurry, and sufficient plant capacity must be available to keep up with the tunnel progress. Wet materials (not fully processed) may be hauled away, but this also means additional cost. Treatment plants for slurry processing would also require air monitoring for hazardous gases and appropriate ventilation systems.

The size of these slurry treatment facilities can be reduced somewhat by stacking some of the equipment. Noise and protection of the equipment generally requires an enclosed building. For planning purposes, an area of two acres for a two TBM tunneling site can be used. This would not include parking or offices. It may be feasible to pipe slurry for treatment some distance from the tunneling work shaft. Feasibility of this approach depends on the mining sites selected.

With the SF TBM method of tunneling, a bentonite slurry is used to apply fluid (hydraulic) pressure to the tunnel face and to transport soil cuttings from the tunneling machine's pressure chamber to the surface. The slurry mixed with soil cuttings is processed to separate the soil from the slurry. Soil is disposed of off site and the cleaned bentonite slurry is returned to the machine's cutting chamber. The slurry mixed at a surface plant is pumped in and out of the tunnel and the machine's pressure chamber through a series of pipes. The result is that excavated material is kept enclosed and fluid until it reaches the slurry separation plant on the surface.

The SF TBM technology involves the setup of a temporary slurry treatment plant(s) at surface. The slurry treatment plant provides two basic functions: (1) to prepare the bentonite slurry by mixing the slurry for use in the tunneling process; and (2) to treat the used slurry, i.e. the slurry discharge. The slurry discharge will be pumped out via pipeline to the ground surface where it will undergo a separation process for soil (clay, sand, and gravel) removal. The removal process involves settling and the use of sieves for separation of large particles and centrifuges for small particles. Once the excavated material is separated from the slurry, the resulting soil can typically be stockpiled at the plant grounds or at offsite locations for approximately two to three days to dry before being hauled to a landfill or other disposal facility.

General assumptions for slurry treatments plants at this conceptual level of study are as follows:

- The slurry plant is anticipated to require an approximately one-acre site for the building enclosure
- The building is anticipated to be approximately 40 feet tall and the ventilation structures 50 feet tall
- The tunneling would require approximately 150 pounds of bentonite per one linear foot of the tunnel. Based on two tunneling machines, approximately 100 feet per day would be tunneled, using approximately 15,000 pounds of bentonite each day.
- Diesel locomotives will be used in the tunnel to transport workers, pre-cast concrete tunnel liner segments, and other materials to the tunnel working face.

- Water removed from the discharge slurry would be recycled for further use in preparing the bentonite slurry.

A schematic diagram of the slurry treatment process is shown in Figure 4-11. Examples of slurry treatment plants are shown in Figure 4-12 and Figure 4-13. When space and noise restrictions are of concern, treatment plants may be containerized for size reduction and sound proofing.

Figure 4-11. Slurry Treatment Process

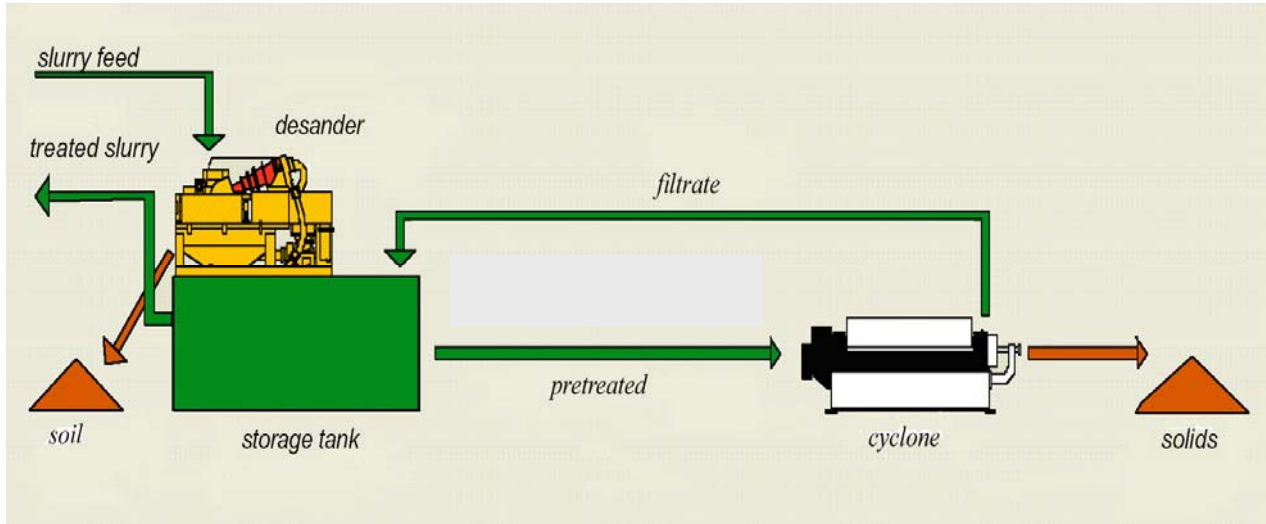


Figure 4-12. Slurry Treatment Plant, Westside CSO Project, Portland, OR



Figure 4-13. Enclosure with Materials Storage Silos, Eastside CSO Project, Portland, OR



4.5 Station Construction Methods

Existing Metro stations generally have been excavated and supported using conventional methods. Typically, initial ground support has been provided by soldier piles and lagging (timber or shotcrete) followed by a cast-in-place concrete final lining. Exceptions to this have been at Union Station, where slurry walls were used to reduce ground water treatment, at the Hollywood/Vine Station, where a deep soil mixing technique was used for initial support, and at the Barnsdall (construction) Shaft, where secant piles were used with tie-backs. For final walls, all stations were wrapped with HDPE to exclude gas and have used a modular approach to allow for local variations in the station layouts. This construction has occurred successfully in ground containing methane and/or H_2S . Figure 4-14 shows examples of these various methods.

4.5.1 Underground Construction in Methane Zone

In addition to Metro stations and other Metro structures, there is now an extensive history of construction in the Westside geology. This includes parking garages successfully excavated and completed in ground containing methane and H_2S and extending to depths similar to those anticipated for the Westside Project. The APTA panel (described previously in Section 4.1.3) noted “no problems with deep basements along Wilshire Boulevard,” referring to new construction in the Methane Risk Zone since 1985. Several other projects constructed in the Methane Risk Zone were reviewed to check if problems with gas or tar occurrences have been reported during operations, and if any construction issues could be verified. Figure 4-15 shows the concentration of high-rise buildings in the Methane Risk Zone around the Tar Pit Area.

Figure 4-14. Station Wall Initial Support Methods



SECANT PILE WALLS, BARNSDALL SHAFT,
HOLLYWOOD



DEEP SOIL MIX WALL EQUIPMENT, HOLLYWOOD AND
VINE STATION



SOLDIER PILES AND LAGGING WITH CROSS
BRACING, MARIACHI PLAZA, MGLEE



SLURRY WALL EXCAVATION, PORTLAND, OR

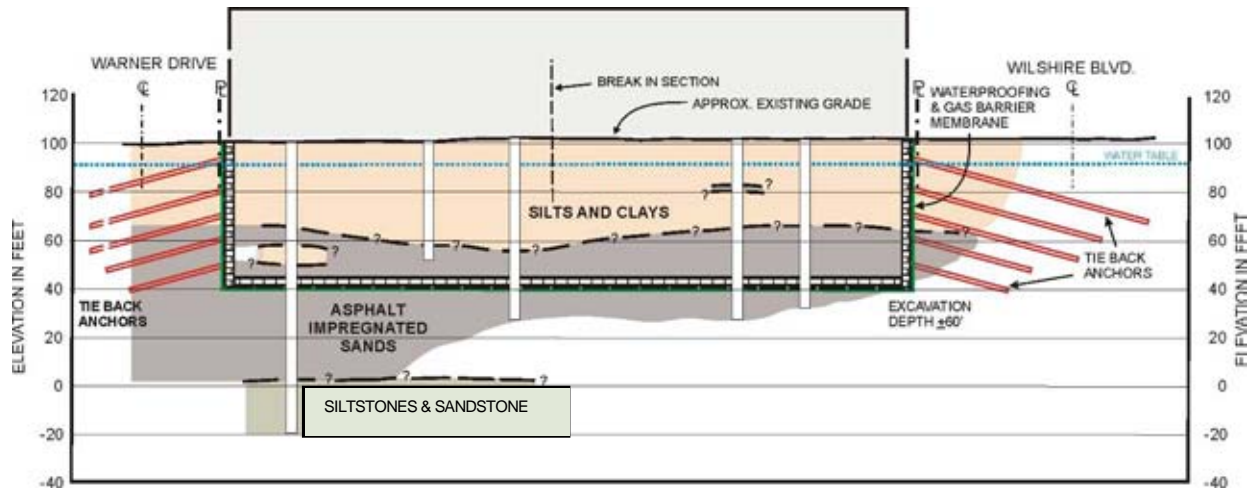
Figure 4-15. Building Concentration Wilshire Boulevard/Fairfax Avenue Area

Subterranean construction (parking garages) can extend 80 feet below street level. Many of these structures are located within the Methane Risk Zone. Typically, deep excavations use tied-back soldier pile and lagging methods. Some deep excavations use slurry wall construction. These excavations addressed the challenges of shallow ground water and of protecting adjacent buildings and streets against settlement (subsidence). Of these numerous deep excavations, two that have particular similarities and application to the planned stations are discussed below.

6100 Wilshire Building

This building, at the southwest corner of Wilshire Boulevard and Fairfax Avenue was constructed in the early 1980s. It has a subterranean garage approximately 60 feet deep. The lower 20 to 30 feet of the excavation extended into asphaltic sands (tar sands), which are a well recognized source of methane and H₂S. Groundwater was encountered at depths as shallow as 15 feet. Similar to most deep excavations along Wilshire Boulevard, the subterranean excavation was achieved by the use of tied-back soldier piles and lagging.

The excavation was achieved successfully and the building was supported on the asphaltic sands by a quasi mat-type foundation. To protect the building against water and gas intrusion, an 80-mill HDPE membrane was used to encapsulate the entire subterranean portion of the building. During a recent visit to the subterranean garage in the company of the building maintenance engineer, it was confirmed that during the past 20+ years no incidence of gas or water intrusion has occurred. Figure 4-16 illustrates the Foundation System and Geology.

Figure 4-16. Foundation System used at 6100 Wilshire Boulevard


LACMA

New construction (2007) has been underway at the Los Angeles County Museum of Art (LACMA) for a new museum building and a large two level underground parking structure. Figure 4-17 shows the location of the new underground parking area in the northwest portion of the site. The parking garage was constructed to be a sealed system with heavy (reported to be five feet thick) concrete walls to resist uplift pressures from high groundwater. Groundwater at the site was reported to be about 10 feet below the ground surface in some locations and dewatering was specified for garage construction. Less water than anticipated was pumped, and this was believed to be due to the presence of tar, less permeable soil and/or smaller volumes of perched water.

During excavation through alluvial soils, gas encounters occurred on several occasions, and workers donned Personal Protective Equipment (PPE) to protect against exposure to H₂S. Water and gas-proofing of the underground structure was provided by bentonite and an HDPE gas proofing membrane. At this writing, the foundation sealing system is not complete, and the effectiveness is not known. Other buildings investigated in the area were found to have minor tar leakage into sumps or through walls in underground parking garages. These were typically dealt with as a maintenance issue, and no gas detection or alarms were reported.

As with the existing Metro tunnels, construction of structures in the methane zone has followed the provisions of the Los Angeles City Code Division 71 and guidance from Cal/OSHA. Ventilation is the principle means for such construction and specifications have typically provided for it in abundance. Once the excavation is completed, the structures are completely wrapped with HDPE to passively prevent the ingress of any gas. The final concrete walls and interior structures are placed inside of, and fully protected by, the HDPE lining. In addition, sensing devices and alarms are also used in the final structure, with the alarms set to go off at low levels, i.e., before the concentration begins to approach a dangerous level. This construction approach has been proven by operation of the final structures to be efficient and successful.

Figure 4-17. New Construction at LACMA


4.5.2 Potential Construction Methods – Metro Stations

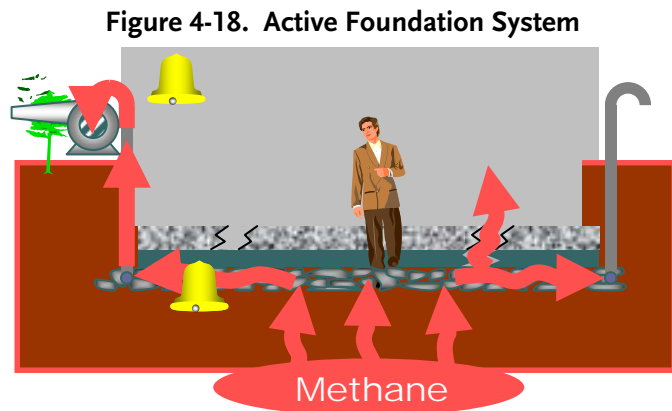
It is assumed that, given the success of existing Metro stations and other structures in gassy grounds, these methods can be used again for the Westside project along with provisions for additional redundancy where conditions are more severe such as the Wilshire/Fairfax area (Area of Methane Zone in 1986). Station construction methods will be selected based on the ground conditions (soil, water and gas) and the requirements for the final structure. In areas of high gas levels, final design of the structure will include provisions for water and gas-proofing in the form of barrier systems, and operational systems for station ventilation and gas detection. The final design could also incorporate provisions to repair leakage, should it occur. Additional discussion of these methods to be used in final design is presented in the Final Geotechnical Evaluation and Tunneling Technology Recommendations Report (22c).

Table 4-1 compares various station construction methods. Additional techniques may include Deep Soil Mixing, Pre-Construction Grouting (such as by Jet-Grouting to reduce soil permeability), or combinations of these. Post treatment methods should also be investigated such that the work is done on an as-needed basis. For example, the Vermont/Santa Monica Station has experienced water leakage, and de-watering wells outside the station have recently been installed to reduce leaks and facilitate repairs. In the Wilshire/Fairfax area, some gas wells have been installed to reduce methane and Tar leakage at the surface.

Table 4-1. Station Design Construction Methods

Station Construction Method	Advantages	Disadvantages
Soldier Piles and Lagging	<ul style="list-style-type: none"> ■ Traditional station construction method, usually least cost. ■ Placement of HDPE, Inspection and cast-in-place concrete used on previous Metro Stations, methods have been improved over time. ■ Minimum street/traffic impacts – single lane closures during pile drilling, several weekends needed for deck beam placement. ■ Some cross-excavation utility relocation may be avoided and/or some utilities may be suspended from deck beams. 	<ul style="list-style-type: none"> ■ Dewatering required if groundwater present ■ Initial support not “gas-tight.” ■ Gas could be encountered in piles drilled without drilling mud. ■ This “flexible wall system” requires added stiffness when construction is close to adjacent buildings and facilities. ■ May require slurry or casing to install soldier piles in sand. ■ Requires concerted effort to obtain tight lagging to reduce raveling of sand and related wall movement.
Slurry Walls	<ul style="list-style-type: none"> ■ Minimal Dewatering required. ■ Best gas barrier for initial and final support. ■ Initial support can be incorporated as final, balancing some of the additional cost. ■ Greater wall stiffness and potential for increased bracing spacing. ■ Minimal deformation – least impacts to adjacent structures/utilities. ■ Reduces worker exposure to gas during excavation support installation. 	<ul style="list-style-type: none"> ■ Requires “specialty” contractors and equipment. ■ Generally requires more utility re-locations to avoid conflicts during wall excavation. ■ Impacts to surface have longer duration for wall installation. ■ At least one, possibly two, dedicated traffic lane(s) needed for heavy excavation equipment. ■ If tiebacks have been installed for adjacent structures these could interfere with wall excavation. ■ Requires mixing slurry on site and disposing of wet materials with some adhered slurry residual. ■ Generally more expensive. ■ Secondary gas barrier and cast in place wall (resists hydrostatic pressure only) may be required for gas barrier and finished appearance. ■ System used with secondary barrier and wall could facilitate leak repair using flexible repair products (e.g., Turbo-seal).
Secant Pile Walls	<ul style="list-style-type: none"> ■ No specialized equipment/contractors. ■ Minimal dewatering required. ■ Depending on geology and ground water conditions, piles may be drilled “dry” (No slurry). 	<ul style="list-style-type: none"> ■ Higher potential for leakage due to number of joints between piles. ■ Similar to slurry walls with respect to existing utilities and tie-backs.

Conceivably, in-situ mitigation measures, or “active barriers” could be used for long term control of gas. An example of this approach is a double walled foundation with a pressurized or vented void between sections (Figure 4-18). Such active systems have been reviewed previously and rejected in favor of the passive systems of HDPE envelopment used on all Metro projects to date. Active foundation systems involve the use of permanent air injection and air/gas extraction to keep a station or other element “flushed” of gas at all times, and would require more rigorous maintenance than the existing Metro system.



Metro has used a passive HDPE envelope on other designs. Such an envelope continues to function for the life of the systems without additional attention. Laboratory testing has verified our confidence in the veracity of this assumption. At this time, it is our professional opinion that reliance on HDPE (and/or other barrier materials) is the appropriate way to proceed. However, Metro should study other possible in-situ solutions during Preliminary Engineering. These are likely to include supplementing HDPE with other products such as non-curing methane-resistant materials and repair methods. Subsequent studies during preliminary and final design should be undertaken to evaluate the best alternative for leak prevention, detection and repair. Design and construction methods will need to be developed to assure system safety and reliability in the “challenging” environmental conditions. In addition to the hazardous subsurface gasses, design must also address effects resulting from seismic shaking.

4.5.3 Potential Construction Methods – Cross Passages

Cross passages perform two basic functions: they allow passengers to move from one tunnel to the other any time that it becomes necessary, such as egress in the event of an emergency on a train, and similarly they allow emergency personnel to pass from one tunnel to the other any time that becomes necessary. In addition, they provide space for train operations equipment and sump structures.

Excavation of cross passages is typically a “hand” operation because they are too short for the use of large construction equipment or tunneling shields. Thus, some pre-treatment of the ground is usually necessary to allow safe construction of the cross passages. Such pre-treatment is determined on a case by case situation depending upon the local geology and geometry, and thus there is no single design that suits all situations. Pretreatment may include any of the following, either singly or in combination:

- Permeation grouting (single or multiple stages), jet grouting, or soil mixing with a variety of materials: cement (including micro fine and ultra fine), colloidal silica, and others, depending on soil properties
- Pre-treatment of ground and/or ground water by such techniques as dewatering, local draining, or freezing

Relocating cross passages for improved ground should be evaluated; however, Fire/Life Safety requirements must also be strictly adhered to. Sealing cross passages against tunnel liners will also require special details, to be developed during later design phases. Similar to tunnel segment design, the following features may include: swelling materials to seal joint; adding gaskets and plates at connections; and post-construction grouting to maintain seals at cross passage to tunnel connections.

Cross passage linings have traditionally been “two-pass” systems, where initial ground support may consist of ribs and lagging or shotcrete and lattice girders. Installation of the final cast-in-place lining must take into account protection of the HDPE (or other methane-resistant barrier) during installation and placement of concrete. Waterproofing products continue to improve, and composite materials with felt or other protective backings are now common. Final design details will include the investigation of new products for ease of installation and reduced leakage.

4.6 Preliminary Environmental Analysis

4.6.1 Tunnel Safety

4.6.1.1 Construction

Prior to tunnel construction, designs will have been developed to minimize gas intrusion into the tunnel or station under construction and for the final structure. Potential methods are discussed in Task 4.2, Geotechnical Evaluation and Tunneling Technology Recommendations Report, including using pressure-face tunneling boring machines (specifically slurry face machines in highly gassy ground), and gasketed tunnel liners. Additional precautions involve a strict adherence to tunnel safety standards including use of tunnel ventilation systems during construction, monitoring for gas, and use of specialized mechanical and electrical equipment.

In California, tunnel construction safety is governed by the California Occupational Safety and Health Administration (Cal/OSHA) Tunnel Safety Orders and worker safety training. The Safety Orders are contained in California’s Code of Regulations, Title 8, Tunnel Safety Orders Division 1, Department of Industrial Relations, Chapter 4, Division of Industrial Safety, Subchapter 20, Tunnel Safety Orders. California Electrical Safety Orders also will apply for use of electric equipment. California Tunnel Safety Orders are considered to be among the most comprehensive, structured, and most stringent in the world, and have been cited for use in other states.

The Tunnel Safety Orders regulation “establishes minimum safety standards in places of employment at tunnels, shafts, raises, inclines, underground chambers, and premises appurtenant thereto during excavation, construction, alteration, repairing, renovating or demolishing.” These apply to not only bored tunnels but also to cut and cover operations, such as subway stations, that are both physically connected to ongoing underground construction operations and are covered in such a manner as to create conditions characteristic of underground construction.

This regulation focuses on tunnel safety in all tunnels where methane and H₂S gases are expected to be encountered. For these conditions, the regulations are very specific, and begin with the tunnel classification, as determined by Cal/OSHA. The classifications range from “non-Gassy” where there is little likelihood of encountering gas during the construction of the tunnel, to “Gassy” which is applied when gas in the tunnel is likely to be encountered at a concentration greater than five percent of the Lower Explosive Limit (LEL) of the gas. “Extra hazardous” classifications have been assigned

upon discovery of serious danger to the safety of employees. Classifications are assigned by Cal/OSHA based on the geotechnical investigations, experience in the area, existence of oil fields, gas measurements, and other data that may be available.

More specific safety requirements of the Tunnel Safety Orders include:

- The tunnel must have adequate ventilation to dilute gasses to safe levels.
- All equipment used in the tunnel must be approved.
- Smoking is not allowed in the tunnel.
- A fixed system of continual automatic monitoring equipment must be provided.
- Tests for flammable and hazardous gas must be conducted.
- Whenever gas levels in excess of 10 percent of the LEL are encountered, Cal/OSHA is to be notified immediately.
- The main ventilation systems must exhaust flammable gas or vapors from the tunnel.
- A refuge chamber or alternate escape route must be maintained.
- Health and safety training and procedures will be implemented.

These training and safety procedures need to be reflected in the cost projections and schedules for this segment of the tunnel. A process that involves training, auditing, and monitoring will ensure that procedures are followed and that health and safety can be maintained during construction in these areas.

Environmental controls will also be required to dilute and control elevated methane and/or H₂S to protect workers underground, workers above ground, and the areas surrounding tunnel excavation and ventilation sites. Issues associated with gaseous release during construction will be minimized since a slurry-face tunnel boring machine (SF TBM) will be used in the affected reaches. The tunneling with a SF TBM in the methane zone minimizes exposure of workers to elevated gas concentrations underground, since the excavated soil is removed in a fully enclosed slurry pipeline to the surface. Vapor controls and monitoring, and possibly other safety design features, will be employed at the surface if gaseous contaminants are released as the slurry is desanded and circulated for reuse by the SF TBM.

4.6.2 Operations

Operational safety and procedures will be developed that depend on the alternative selected, subsurface conditions encountered, and advances in equipment and technology in the years prior to construction. Basic operations are likely to be similar to those of existing Metro systems that are designed for locations where gas is known to be present, which include:

- Design to exclude gasses, through use of barriers such as HDPE barriers and reinforced concrete wall systems
- Inspection and testing during construction to ensure quality for the concrete placements and barrier construction and to minimize leakage into the structure



- Installation of ventilation systems capable of purging gas to safe levels. These systems are also used for exhaust smoke in case of fire.
- Installation of gas detection and monitoring equipment to warn if gas levels approach pre-set alarm levels, and to automatically activate additional ventilation.
- Provisions for minimal air-flow during non-revenue service to prevent gas accumulation.
- Inspection and maintenance programs for all of the above.

4.6.3 Seismic Considerations

The Westside study area could be subjected to ground shaking as a result of earthquakes on any of the documented or undocumented nearby active or potentially active faults. The interactive probabilistic seismic hazard map of California on the California Geological Survey website (accessed March 2008) is based on the 2002 National Earthquake Hazards Reduction Program data, including adjustments for alluvium site conditions. For the study area, this map indicates that the peak ground accelerations (which are measures of the how hard the earth is shaking during an earthquake in a given area) with a 10 percent probability of being equaled or exceeded in 50 years range from about 0.47 g to 0.53 g, with “g” representing the ground acceleration due to gravity. Along the Wilshire Alternatives, between Western Avenue and La Cienega Boulevard, no known active faults are mapped. Metro seismic criteria currently uses two ground shaking levels for design and is described below.

Station walls may have to be designed for greater than usual lateral earth pressures to account for liquefaction potential. This condition is only indicated to occur at La Cienega Station location in the Study Area, but would be evaluated in more detail in the preliminary geotechnical investigations.

Metro began developing special seismic design criteria for its underground structures in the early 1980s¹ and has continued to update ground motion parameters for design of new structures as the California Division of Mines and Geology (CDMG) publishes new data, or based on findings of site-specific geotechnical investigations. Metro’s design ground motion criteria have been based on two levels of earthquake:

- **Operating Design Earthquake (ODE):** Defines, for any point on the subway system, the level of ground shaking at which critical items maintain function so that the overall system will continue to operate normally. In other words, after an ODE, the system shall be inspected and go back into service immediately. This earthquake has a return period of about 100 years and has a reasonable expectation of occurring during the life of the facility.
- **Maximum Design Earthquake (MDE):** The level of ground shaking at which critical items continue to function as required to maintain public safety, preventing catastrophic failure and loss of life. This earthquake level has a small probability of occurrence – a return period of several thousand years – or less than five percent probability of occurring.

¹ Converse Consultants, for SCRTD, Seismological Investigation and Design Criteria.

During design, the ground motions expected to occur for the ODE and MDE are evaluated based on CDMG publications and site specific conditions. Stations and tunnels are designed to structural standards for reinforced concrete structures under the various loading scenarios that include ground and groundwater loads, earthquake loads, and the dead loads of the structure and adjacent structures as applicable. All design for seismic conditions would be further developed during subsequent project phases.

LACMTA's ODE criterion was tested during the Northridge earthquake, when ground motion reached ODE levels. The system was quickly inspected and was back in service within hours of the earthquake. No damage to Metro structures was reported.

4.6.4 Hazardous Waste/Disposal of Soils during Construction

The issue of disposal of soils and other waste from construction in the Methane Risk Zone that also contains tar and other potential contaminants is preliminarily addressed through records-database searches and other available information. The focus is on identifying any special handling and/or safety issues associated with such waste and identifying existing disposal facilities with capacity to receive the waste. In addition, a database search of federal, state, and local listed hazardous waste sites was conducted for both the Wilshire Boulevard and West Hollywood alignments.

The Wilshire alignment alternatives will likely encounter sites impacted by numerous listed underground storage tanks, dry cleaners, and other small- and large-quantity generators of hazardous waste. The West Hollywood alignment alternatives will also encounter similar sites, with more small-quantity generators, due to the large number of small businesses along the alignment.

The Wilshire alignment alternatives, particularly the segment between Western Avenue and La Cienega Boulevard, will encounter soils impacted with petroleum hydrocarbons, VOCs, and H₂S from natural sources.

4.6.5 Potentially Impacted Soils

Potentially impacted soils may be encountered during construction of the selected alignment near existing and historic underground storage tank sites (UST) including gasoline stations, dry cleaners, and industrial facilities. Soils may be impacted with petroleum hydrocarbons, VOCs, and H₂S. Many soils along the Wilshire Boulevard Corridor are impacted with tar and crude oil due to presence of oil producing formations, evidenced by existing and abandoned oil fields.

A review of the Environmental Data Resources (EDR) database for listed properties was conducted as an initial screening for identifying properties of potential environmental concern to the proposed alignments. Table 4-2 shows that there are several large-quantity generators (LQG), as defined by the Resource Conservation and Recovery Act (RCRA), along both the West Hollywood and Wilshire alignments. More small-quantity generators (SQG) are found along the West Hollywood alignment, since there are more small businesses along this alignment. Underground storage tanks (UST), including those on databases for leaking (LUST), hazardous substances (HISTUST), and the State Water Resources Control Board (SWEEPSUST), are distributed equally along the corridors, as are drycleaners.

Table 4-2. Sites Containing Hazardous Materials: West Hollywood and Wilshire Alignments

Hazardous Site Type	West Hollywood	Wilshire
Resource Conservation and Recovery Act - Large-Quantity Generators (RCRA-LQG)	4	3
Resource Conservation and Recovery Act - Small-Quantity Generators (RCRA-SQG)	122	85
Leaking Underground Storage Tank (LUST)	33	33
Underground Storage Tank (UST)	41	41
Hazardous Substance Storage Container Database (HISTUST)	46	46
State Water Resources Control Board, Underground Storage Tank Listing (SWEEPSUST)	79	79
Drycleaners	37	37
California Environmental Protection Agency Hazardous Waste Information System for Annual Manifest (HAZNET)	521	521

Source: EDR, 2008

4.6.6 Soil Management/Soil Disposal

During construction, soils containing contaminants that are encountered along the corridor will be sampled, characterized, excavated from the site, loaded onto trucks, and transported offsite to a treatment and disposal facility. Waste disposal profiles will be generated from soil sampling and site characterization data. Based on the site characterization data, soils excavated at the site will be classified as non-hazardous or hazardous depending on the concentration of the impacted soil.

Soils characterized as non-hazardous would be transported to one of the following local non-hazardous Class III landfills or recycling facility:

- Waste Management, Palmdale Landfill, Palmdale, California
- Waste Management, McKittrick Waste Disposal Facility, McKittrick, California
- Thermal Remediation Solutions, Azusa, California,
- Other disposal facilities licensed or permitted by the State of California to accept this type of material

In the event that soils excavated from the site are determined to be a RCRA or non-RCRA hazardous waste, the hazardous soils would be transported to the following Class I landfill facility for disposal:

- Waste Management, Class I Kettleman Hills Facility, Kettleman Hills, California
- Other sites as determined / become available during subsequent phases.

These sites are licensed to accept these materials and, therefore, the feasibility of constructing the tunnel through the petroleum-contaminated sites along the Wilshire alignment would not be compromised.

Tunneling using SF TBM may generate wet soils (muck), particularly if clay soils are predominant. Therefore, either a disposal facility that accepts wet soils would need to be identified, or these wet soils would need to be dried prior to disposal. For the soils that are mostly sandy, drying can be accomplished on site through the soil separation system. For soils with higher water content (clays), in the event that the volume of such clay soils is substantial, additional temporary offsite storage location may be needed, unless a disposal facility that accepts wet soils can be identified. Additional separation processes may also be an option.

4.6.7 Storm Water Quality

Tunnel construction activities may affect storm water quality where excavated materials come in contact with storm water or are discharged into storm water drainage facilities. The processed water used in the slurry is also a potential source of concern if not properly contained and disposed but allowed to discharge from the construction site and into nearby drainage facilities.

The construction will require a National Pollutant Discharge Elimination System (NPDES) permit coverage under the NPDES General Permit, Waste Discharge Requirements for Discharges of Storm Water Runoff Associated with Construction Activity (General Permit). This Construction General Permit issued by the State Water Resources Control Board will require a Construction Storm Water Pollution Prevention Plan (SWPPP) to be developed and implemented. In the Construction SWPPP, a detailed site plan and descriptions of all best management practices (BMPs) selected for implementation to reduce or eliminate the potential for pollutants (sediment, tar sand, etc.) generated from all construction activities from contacting storm water runoff will be provided.

It is likely that the following minimum BMPs will need to be implemented. After more detailed definition of project activities, additional specific BMPs may be identified.

- Slurry treatment plant operation areas (mining sites) will require BMPs to divert potential storm water runoff from entering the construction area. Containment around the site may include use of temporary measures such as fiber rolls to surround the construction areas to prevent any potential spills of slurry discharge or spoils recovered during the separation process. Downstream drainage inlets should also be temporarily covered to prevent potential discharge from entering the storm drainage system.
- Construction entrance/exits should be properly set up so as to reduce or eliminate the tracking of sediment and debris offsite. Appropriate measures may include measures such as grading to prevent runoff from leaving the site, and establishing rumble racks at the exit to remove sediment from construction vehicles.
- Overhead covering for the soil separation plant and debris loading areas should be considered to prevent contact with rainfall.
- Onsite rinsing or cleaning of any equipment should be performed in contained areas and rinse water collected for appropriate disposal.
- TBM motors require cooling. Typically, cooling water is recycled and cooled using cooling towers near the access shafts. Thus, cooling water will have little impact on water use or discharge into the sanitary or storm drain system.

- Depending on the amount of wastewater generated from the slurry discharge, a tank may be required onsite to collect the waters for periodic offsite disposal. Since the slurry production is a closed loop system in which the water separated off from the discharge slurry is continually recycled, minimal and infrequent water discharges are anticipated. These discharges can be accommodated in a tank on site to collect the waters and dispose offsite periodically.
- If any soil is planned for storage on-site, it must be contained and covered to prevent contact with storm water and potential offsite discharge.

Implementation of the above BMPs (and any additional BMPs identified in project-specific construction SWPPPs) minimizes the potential for storm water impacts due to tunneling activities in the gas zones and supports project feasibility.

4.6.8 Noise

The types and levels of noise associated with tunneling and construction activities in the Methane Risk Zones would be generally the same as those associated with tunneling in a non-gas zone. In any zone, construction activities that generate noise include demolition, station erection, workers travel, hauling of soils and debris for disposal, deliveries of materials, and other. Since a SF TBM will likely be used for tunneling in the Methane Risk Zones, the slurry plant would be an additional component of the construction activities and associated noise. Noise from the treatment plant may be mitigated partially by enclosing the plant within a building. The noise associated with this single component would not result in significantly higher noise levels from overall construction activities.

Noise at street level from underground train operations would be transmitted through vent shafts at station locations. The vent shafts would transmit both train passby and ventilation fan noise to street level. An underground station located in the Methane Risk Zones would have the same train passby noise at street level as any other station. The level of passby noise would be dependent on the depth of the station and any acoustical treatment in the shaft. In most cases the train passby would be barely audible at street level.

Tunnel ventilation in a non-gas zone would require routine testing of the fans, usually on a monthly basis. These tests are conducted during non-revenue hours which are typically between 1 a.m. and 5 a.m. The fans would require noise control in the form of sound attenuators and/or the addition of sound absorptive treatment to the vent shafts to meet the requirements of both the Metro Systemwide Noise and Vibration and the Los Angeles Noise Ordinances. If the ventilation fans are operated under emergency conditions then they would be exempt from any noise limits. The level of noise control required for fan testing would be dependent on the fan speed and system load.

In the Methane Risk Zones, ventilation fans would be operated during non-revenue hours (as they are now for existing systems). Noise control would be required for both daytime and nighttime operations. The fan noise control measures for continuous operation versus periodic nighttime testing would be similar. Therefore, there may be no difference in either the expected noise levels at street level for a vent shaft located in a gas zone or the cost of noise control required. However, federal and state noise attenuation requirements increase as average exposure time increases.

4.6.9 Air Quality

4.6.9.1 Odors

Hydrogen sulfide gas has a distinctive “rotten egg” odor. The typical odor recognition threshold for hydrogen sulfide is 0.0005 ppm by volume. Hydrogen sulfide concentrations in the tunnel may be controlled utilizing a combination of techniques. These techniques include dilution through additional ventilation, and potentially, pre- and post-treatment using compounds such as hydrogen peroxide, as well as use of Personal Protective Equipment (PPE). Above-ground hydrogen sulfide concentrations may be controlled by methods such as maintaining high pH levels in the slurry or using a zinc “scavenger” to precipitate dissolved sulfide out of the slurry prior to its reaching the treatment plant. These methods will be further evaluated during design phases of the project.

Given the potential for “pockets” of high concentration hydrogen sulfide in the segment between the Wilshire/Western and Wilshire/La Cienega stations, it is likely that the odor of hydrogen sulfide would occasionally be detectable by workers (above the typical odor recognition threshold of 0.005 ppm) even after implementation of control techniques. However, because of the tar pits in this area, odors are commonly perceived at the ground surface. It is therefore unlikely that the additional hydrogen sulfide would be noticeable.

4.6.9.2 Construction Emissions

Table 4-3 shows estimated emissions that would be associated with tunnel construction. Short-term emissions would occur from operation of the slurry treatment plant, tunneling, soil transport, station construction, and worker travel. Volatile organic compound (VOC) carbon monoxide (CO), sulfur oxide (SO_x), particulate matter 2.5 microns or less in diameter (PM_{2.5}), and particulate matter 10 microns or less in diameter (PM₁₀) emissions would not exceed the South Coast Air Quality Management District (SCAQMD) regional construction significance thresholds. Nitrogen oxide (NO_x) emissions would exceed the SCAQMD the regional construction significance threshold of 100 pounds per day during the soil transport phase, and would result in a significant impact. The exceedance would primarily result from emissions generated by haul trucks. In addition, PM_{2.5} and PM₁₀ emissions would likely exceed the SCAQMD localized significance thresholds during soil transport and station construction phases. Although emissions would be significant, the emissions are short-term and would not affect long-term operational air emissions.

Table 4-3. Construction Emissions Associated with Tunneling Activity

Emission Source	Pounds Per Day					
	VOC	NO _x	CO	SO _x	PM _{2.5}	PM ₁₀
Slurry Treatment Plant	--	--	--	--	<1	<1
Tunneling	2	12	16	<1	<1	<1
Soil Transport	11	109	45	<1	5	5
Station Construction						
Demolition	5	44	19	<1	2	4
Excavation	8	69	33	<1	4	7
Station Construction	9	75	36	<1	4	4
Worker Travel	<1	<1	1	<1	<1	<1

Source: Terry A Hayes Associates LLC, 2008

Slurry Treatment Plant. Particulate matter emissions for the slurry treatment plant were calculated based on US Environmental Protection Agency (USEPA) AP-42 calculation formulas for materials handling. The slurry treatment plant would include a bag house to collect dust during the mixing process. Bag houses typically filter at least 99 percent of fine particulate matter. As a result, the slurry treatment plant generates minimal dust emissions.

Tunneling. The SF TBMs use electric power, which would be connected to the electric grid, would not generate air emissions. Diesel locomotives would be used in the tunnel to transport workers, pre-cast concrete tunnel liner segments, and other materials to the SF TBM. For the emissions estimates, it was assumed that tunneling activity would utilize two 185-horsepower diesel locomotives typically operating six hours per day. Locomotive emission rates were obtained from the USEPA *Emission Factors for Locomotives (December 1997)* document. Construction activity was assumed to occur in 2012.

Removal and Transport of Soils for Disposal. The majority of construction emissions would occur as a result of removal and transport of soils for disposal from tunneling activity. The tunneling could simultaneously utilize two tunneling machines, each with the capability of tunneling a 21-foot outside diameter for an assumed distance of 50 feet per day. Each tunneling machine would generate approximately 641 cubic yards of excavated soil per day resulting in a total of 1,282 cubic yards per day. Excavated soil would be separated from the slurry and stockpiled on the surface for two to three days. The soil would be hauled to a landfill or other disposal area using trucks that would average approximately 9.5 cubic yards per load. Thus, approximately 135 haul truck trips would be generated to remove the excavated material each day. Haul truck emission rates were obtained from the California Air Resources Board's (CARB) EMFAC2007 Motor Vehicle Emissions Inventory Model. Note that if more than two SF TBMs are used, the amounts of emissions would increase accordingly.

Station Construction. Station construction activities would include demolition (as required at station entrances or other locations), excavation, and station construction. It was assumed that demolition would require two front-end loaders and 25 debris haul truck trips per day. Based on the CARB URBEMIS2007 Transportation and Land Use Program Model, demolition debris haul trucks were assumed to travel 30 miles per round trip.

Sources of air emissions during station construction would include heavy-duty equipment and heavy-duty truck trips associated with materials delivery. It was assumed that station construction equipment would include simultaneous operation of two front-end loaders, two forklifts, one crane, two pumps, and two miscellaneous pieces of equipment. It was further assumed that daily materials delivery activity would include ten trucks traveling 20 miles per round trip. Heavy-duty equipment emission rates were obtained from OFFROAD2007 and truck emission rates were obtained from EMFAC2007. It was assumed that heavy-duty equipment would operate for 12 hours per day.

Worker Travel. Emissions from construction workers' travel to and from the site would be a function of vehicle emission rates and commute distances. Vehicle emission rates were obtained from EMFAC2007. It was assumed that worker vehicles would be split equally between light-duty automobiles and light-duty trucks. The worker commute distance of 13.3 miles per one-way trip was obtained from URBEMIS2007.

4.6.10 Sensitive Land Uses

With the conclusions of these preliminary assessments indicating that potential impacts can be mitigated, including the consideration of the advanced gas monitoring and ventilation systems that can manage the presence of gas in a safe manner, tunneling along Wilshire Boulevard would be expected not to have an adverse effect on sensitive land uses located near the stations and the alignment.

This section presents a description of land uses within the vicinity of the existing Metro Purple Line station at Wilshire/Western, and at four preliminary station locations between Western Avenue and La Cienega Boulevard on Wilshire Boulevard, at Crenshaw Avenue, La Brea Avenue, Fairfax Avenue, and La Cienega Boulevard. These five locations are located within the Methane Risk Zone.

A land use survey was conducted within an approximate three-block radius for each of the station locations to identify the types of land uses that exist in the vicinity of each station, as shown in Figure 4-19 through Figure 4-23. Generally, Wilshire Boulevard is lined with commercial uses, with residential uses (either single-family or multi-family or both) predominantly occupying the parcels behind the commercial frontage, north and south of Wilshire Boulevard.

Some land uses are considered more sensitive to changes in air quality (including gaseous, fugitive dust, and particulate emissions) than others, depending on the population groups and the activities involved. People most likely affected by air pollution include children under 14 years old, the elderly over 65 years old, athletes, and people with cardiovascular and chronic respiratory diseases. According to the South Coast Air Quality Management District (SCAQMD), sensitive land uses include residences, schools, playgrounds, childcare centers, athletic facilities, long-term health care facilities, rehabilitation centers, convalescent centers, and retirement homes. For the purpose of this analysis, these uses have been identified as sensitive to potential exposure to emissions and odors associated with gas releases and the slurry treatment plant near the existing and preliminary station locations.

The following provides a more detailed description of the sensitive uses near each of the five proposed station locations.

Wilshire/Western Station

This station is part of the Wilshire Center, which is a dense regional commercial center that includes high-rise office buildings, large hotels, regional shopping complexes, churches, entertainment centers (e.g., the Wiltern Theater), and high-rise and low-rise apartment buildings. Sensitive land uses in the immediate vicinity of the station (within one block) consist primarily of multi-family residences and high-density mixed-use development, as shown in Figure 4-19.

Figure 4-19. Sensitive Land Uses – Wilshire/Western Station

LEGEND:

-  = Automotive-Related Use
-  = Church/Place of Worship
-  = Commercial
-  = Health Facility
-  = Hotel/Motel
-  = Mixed-Use
-  = Multi-Family Residence
-  = Public Facility
-  = School
-  = Single-Family Residence
-  = Vacant
-  Existing Station Location

Wilshire/Crenshaw Station

This station would be located in the mid-Wilshire area near Windsor Square. Sensitive land uses in the vicinity consist primarily of low-density single-family residences north of Wilshire Boulevard, and a mix of single-family and multi-family residences south of Wilshire Boulevard, as shown in Figure 4-20.

Figure 4-20. Sensitive Land Uses – Proposed Wilshire/Crenshaw Station

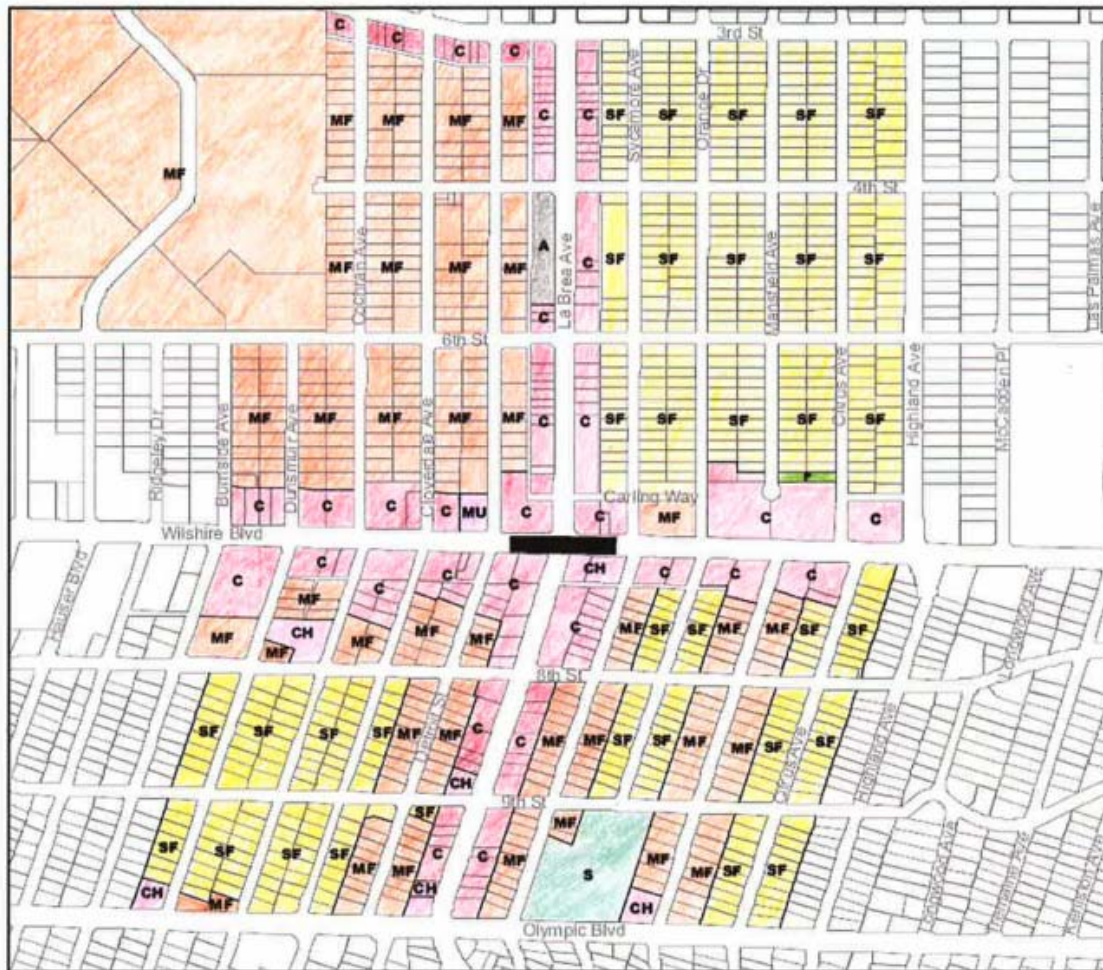
LEGEND:

- CH = Church/Place of Worship
- C = Commercial
- HF = Health Facility
- MF = Multi-Family Residence
- P = Park
- PL = Parking Lot
- PF = Public Facility
- S = School
- SF = Single-Family Residence

■ Preliminary Station Location

Wilshire/La Brea Station

This station would be located in the eastern end of the Miracle Mile District, which is one of the city of Los Angeles' more densely populated areas. Sensitive land uses in the vicinity consist primarily of residential uses, including single-family and multi-family uses north and south of Wilshire Boulevard. A mixed-use development is located at Wilshire Boulevard and Detroit Street, as shown in Figure 4-21.

Figure 4-21. Sensitive Land Uses – Proposed Wilshire/La Brea Station

LEGEND:

-  = Automotive-Related Use
-  CH = Church/Place of Worship
-  C = Commercial
-  MU = Mixed-Use
-  MF = Multi-Family Residence
-  P = Park
-  S = School
-  SF = Single-Family Residence

 Preliminary Station Location

Wilshire/Fairfax Station

This station would be located in the western end of the Miracle Mile District, immediately adjacent to the Los Angeles County Museum of Art, Hancock Park, and the La Brea Tar Pits. Sensitive land uses in the vicinity consist of multi-family residences north and south of Wilshire Boulevard, and single-family residences south of Wilshire Boulevard. Park La Brea, a large residential complex with over 4,000 apartments, is located one block north of the station, as shown in Figure 4-22.

Figure 4-22. Sensitive Land Uses – Proposed Wilshire/Fairfax Station

LEGEND:

- CH = Church/Place of Worship
- C = Commercial
- HF = Health Facility
- M = Museum
- MF = Multi-Family Residence
- P = Park
- PL = Parking Lot
- S = School
- SF = Single-Family Residence
- Preliminary Station Location

Wilshire/La Cienega Station

This station would be located adjacent to the eastern boundary of Beverly Hills. Sensitive land uses in the vicinity of the station include single-family residences north and south of Wilshire Boulevard and west of La Cienega Boulevard, and multi-family residences north and south of Wilshire Boulevard and east of La Cienega Boulevard, as shown in Figure 4-23.

Figure 4-23. Sensitive Land Uses – Proposed Wilshire/La Cienega Station



LEGEND:

-  = Commercial
-  = Health Facility
-  = Multi-Family Residence
-  = Park
-  = School
-  = Single-Family Residence

 Preliminary Station Location

Table 4-4 presents a matrix indicating the type of sensitive land uses located within approximately three-block radius of each of the five station locations.

Table 4-4. Sensitive Uses near Proposed Station Locations

Station Location	Single-Family	Multi-Family	Mixed-Use	Health Facility	School	Park
Wilshire/Western *	Y	Y	Y	Y	Y	
Wilshire/Crenshaw	Y	Y			Y	Y
Wilshire/La Brea	Y	Y	Y		Y	Y
Wilshire/Fairfax	Y	Y	Y	Y	Y	Y
Wilshire/La Cienega	Y	Y		Y	Y	Y

* Existing Metro Purple Line Station

4.6.11 Cultural Resources

This section identifies existing paleontological, archaeological, and historic resources that could potentially be impacted by tunneling and construction activities in the areas along the Wilshire/Western to Wilshire/La Cienega segment located in the Methane Risk Zone.

The analysis is based on available existing information such as past studies in and around the study area, as well as national, State, and City historic resource registers and inventories available online.

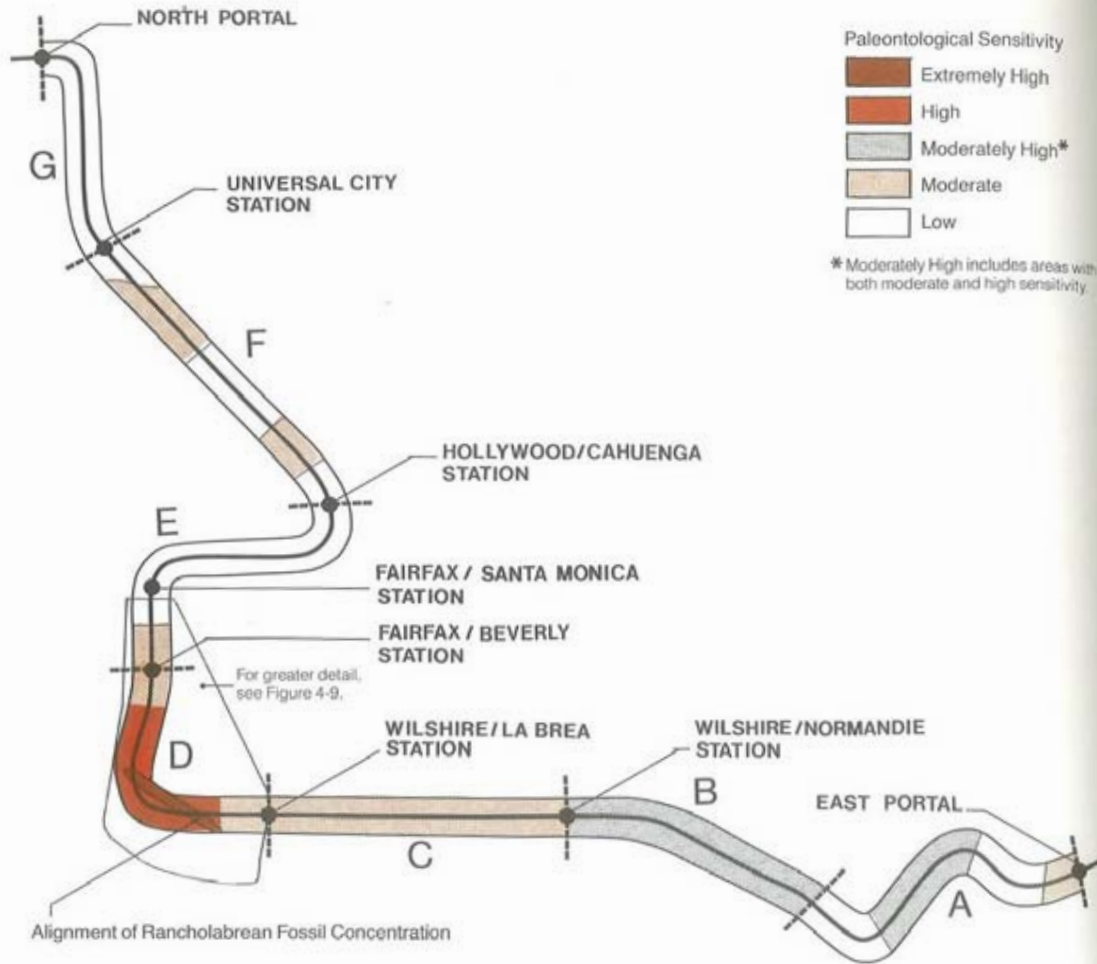
4.6.12 Paleontological Resources

The potential for encountering paleontological resources (sites of fossils or ancient life forms) is related in part to the depth of the tunnel in relation to the type of subsurface soil/rock strata (stratigraphy) present at that depth. While a surface or aerial alignment would disturb those strata closest to the surface, tunnel alignments would affect deeper strata. The largest paleontological impact and recovery opportunity would be at station sites, especially those near the La Brea Tar Pits.

The Los Angeles County Metropolitan Transportation Authority, *Los Angeles Rail Rapid Transit Project Final EIS*, December 1983, is of particular relevance since it considers the alignment that parallels the alternatives presently considered. Also, it is the only previous study found that both covers the study area and considers the impacts of a tunnel configuration on paleontological resources. The study identified one very important recorded paleontological resource along the alignment, the La Brea Tar Pits area (see Figure 4-24). The study also noted, however, that “the route would pass through and disturb a variety of marine and nonmarine sedimentary deposits ranging in age from Medial Miocene to Holocene.” All stratigraphic units except the Holocene alluvium (young Quaternary alluvium) and the intrusive basalts and andesites in the Topanga Formation are considered to have at least moderate potential for paleontological resources.”

Three of the segments analyzed in the study parallel or cross some of the alternatives being presently considered. The analysis of each of those segments is provided below. Note that this is a preliminary study and further evaluation will need to be performed during future phases of the project.

Figure 4-24. Paleontological Sensitivity, 1983



Source: Westec Services

<p>Southern California Rapid Transit District Metro Rail Project PRELIMINARY ENGINEERING PROGRAM</p>	<p>Figure 4-8 Paleontological Sensitivity Along Alignment</p> <p>SEDWAY/COOKE Urban and Environmental Planners and Designers</p>
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1983 Alignment: Wilshire/Normandie Station to Wilshire/La Brea Station. According to the 1983 study, “this segment would encounter old Quaternary alluvium from the surface down to depths of 50 to 60 feet. Deeper tunneling would also reach the San Pedro, Puente, and Fernando Formations. There are no known paleontological resources along this segment of the Metro Rail route, but there is a moderate potential for finding nonmarine vertebrates, as well as mixed nonmarine and marine invertebrates, in the old alluvium (Palos Verdes Sand).”

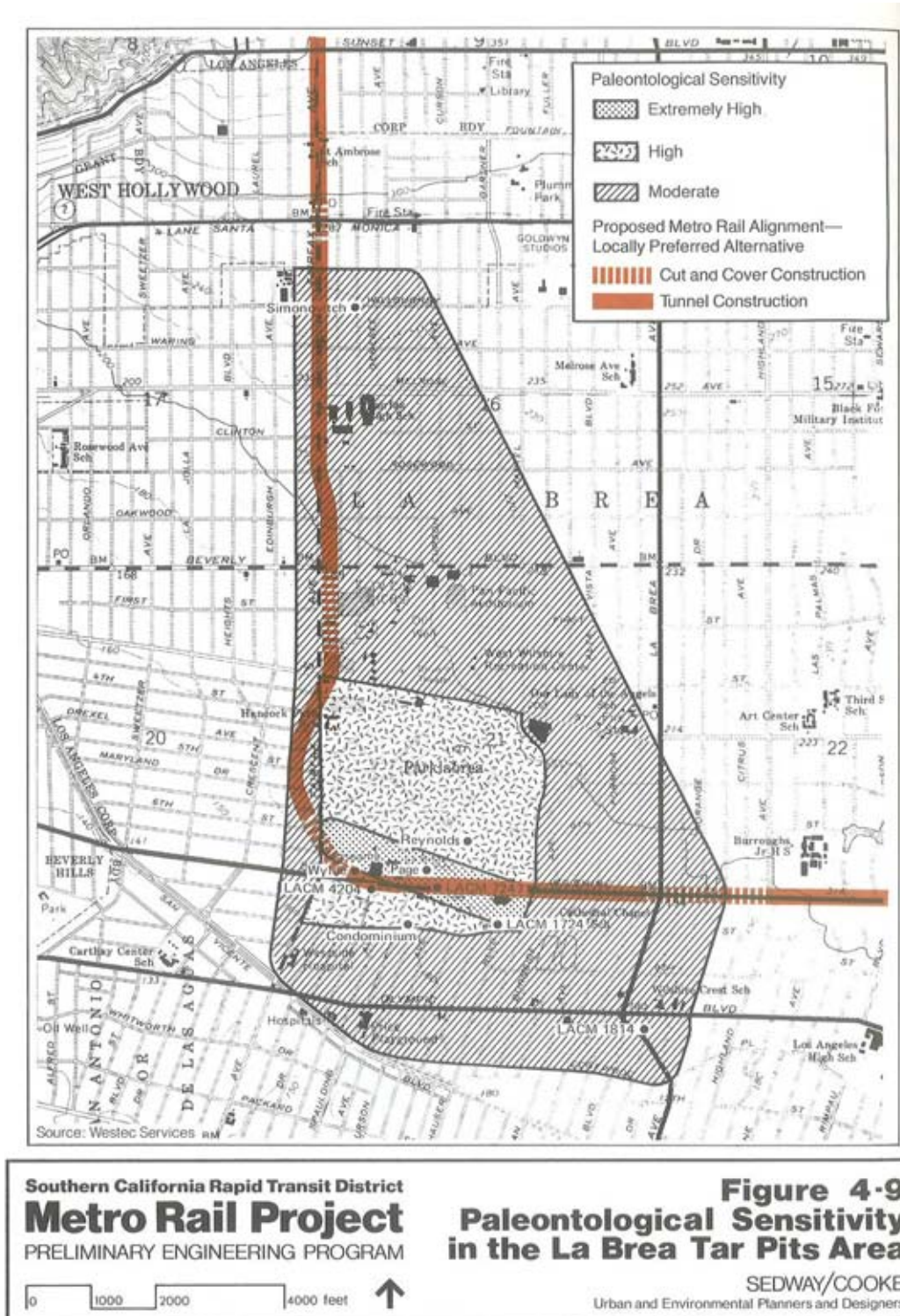
1983 Alignment: Wilshire/La Brea Station to Fairfax/Beverly Station. According to the 1983 study, “this segment includes old Quaternary alluvium (Palos Verdes Sand) from the surface down to depths between 30 and about 60 feet. The San Pedro Formation would be reached in some areas below about 30 feet. This segment includes the La Brea Tar Pits area, which has produced abundant marine and nonmarine invertebrates, plants, and world-famous ice-age land animals. Because of the abundance and extraordinary preservation, the Rancho La Brea area has provided the most prolific record of Late Pleistocene vertebrate animal life discovered anywhere in the world. Rancholabrean fossils are abundant in the upper 11 to 26 feet (under recent fill) of the area studied.” Figure 4-25 “shows the area with the heaviest concentration of known fossil deposits and, therefore, an area with extremely high paleontological sensitivity.”

The sensitivity area starts at approximately Hauser Boulevard and ends at Fairfax Avenue. It is rectangular in shape with a width of 700 feet, running from east-south-east to west-north-west. The area, described as high in sensitivity, is roughly bounded by Third Street on the north, Eighth Street on the south, Fairfax Avenue on the west, and Burnside Avenue on the east. Deposits in this area tend to occur in large cone-shaped pockets, oriented vertically and tapering downward. More than one million fossil bones, as well as specimens of insects, shelled invertebrates, and plant remains, have been recovered from about 35 excavations of various size (from approximately 100 that have been dug) since excavations began in 1906 in the La Brea Tar Pits area. Additional excavations outside the park area also have produced fossils, indicating that fossils are not concentrated in the La Brea Tar Pits area alone. The fossiliferous deposits at Rancho La Brea appear to be confined to the uppermost 55 feet below the present surface and particularly within the uppermost 25 to 30 feet.”

1983 Alignment: Fairfax/Beverly Station to Hollywood/Cahuenga Station. According to the 1983 study, “along this segment, young Quaternary alluvium would be encountered from about 30 to 85 feet beneath the surface, with increasing alluvium thickness from south to north along Fairfax Avenue. Below this level, old Quaternary alluvium extends for 100 feet or more. No fossils are expected in young alluvium, but there may be some terrestrial vertebrates in old alluvium. This segment is of low sensitivity because excavations are not likely to reach below the base of young alluvium. The young alluvium at the Fairfax/Santa Monica, La Brea/Sunset, and Hollywood/Cahuenga Stations is between 75 and 100 feet thick.”

Conclusions. The relevant data from previous studies, discussed above, indicate that since the La Brea Tar Pits area lies within the known Methane Risk Zone, there is an increased probability of encountering pockets of presently unknown resources while tunneling through tar soils in this general area. For other portions of the entire Methane Risk Zone area, there is no relevant data indicating that the likelihood of encountering paleontological resources would be significantly greater in tunneling in those portions of the gas zone when compared with tunneling in areas outside the gas zone. At this time, the exact extents of the Methane Risk Zone are not precisely known (although an estimate has been mapped by the City of Los Angeles within the City area), and it is unknown whether there are paleontological resources along much of the candidate alignments.

Figure 4-25. La Brea Tar Pits Area



Overall, with an increased likelihood of encountering scientifically significant paleontological resources in tar soils, it is likely that mitigation measures would need to be implemented to recover and preserve such potentially encountered resources. The mitigation measures would most likely be similar to those identified in the 1983 Final EIR as follows:

“If important or potentially important fossils are discovered during the excavation phase, excavation would be temporarily halted or diverted until the findings can be appraised and, if necessary, the fossils removed by a qualified paleontologist.” Also, since “the proper repository for significant specimens is one of the most important elements in the mitigation of adverse impacts on paleontological resources, invertebrate fossils and fossil plant material would be donated to an appropriate educational/research institution as dictated by the significance of the materials.”

In addition, a “Recovery and Salvage Plan”, similar to the plan prepared by the Page Museum for the 1983 study, will also be appropriate for the project. Such a plan would include the identification of the most feasible mitigation measures for minimizing impacts, as well as time and cost estimates for excavation monitoring by paleontologists, recovery, management, storage, treatment, archiving/repository, and other associated activities. Depending on the magnitude of potential discoveries and availability of qualified paleontologists, these activities may also include freezing and preserving all fossil-bearing soils excavated from a Wilshire/Fairfax station site for a period of up to 20 years until qualified paleontologists can examine the materials. As appropriate, the provisions for protection of these resources may also be included in the memorandum of agreement with an appropriate educational/research institution as identified and determined by Metro.

It is possible that the duration and cost of paleontological recovery efforts would be greater in the Methane Risk Zones since additional safety measures and procedures for the monitoring and recovery personnel may be necessary in these areas.

4.6.13 Archaeological Resources

Several previous studies, as noted, in and around the study area were reviewed to assess the potential for encountering archaeological resources during tunneling.

The 1983 and 2001 studies are of particular relevance since they consider alignments within the study area. The 2001 study identifies three known archaeological sites along its alignment, one in the Mid-City area and two in West Los Angeles. Of the several archaeological sites identified in the 1983 study, one site, the Hancock Park/La Brea Tar Pits, is located in the study area. The 1983 study provides the following description of this site.

“A site (labeled LAN-159) in Hancock Park is represented by artifacts recovered from the La Brea Tar Pits. Artifacts recovered indicate the La Brea Tar Pits may have been visited for hunting purposes and for acquiring pitch and tar rather than for settlement. The first non-Indian visitors to the La Brea Tar Pits were scouts of the Portola expedition on August 3, 1769. No mention of Native American settlement at that location was made in diaries kept by these explorers. The La Brea Tar Pits, containing Pleistocene to Early Recent fossil deposits, are considered one of the most significant paleontological sites in the world and have been designated California State Historic Landmark No. 170.”

The study further summarizes the potential for discovering archaeological resources during construction as follows:

“The Metro Rail Project route follows existing right-of-way through extensively urbanized areas. Very little undisturbed original ground surface is visible, and little is known of archaeological sites in the Regional Core. Few archaeological sites have been recorded with the California State Clearinghouse in the vicinity of the proposed Metro Rail Project. The potential for affecting subsurface archaeological resources in the remaining areas is unknown because no archaeological sites or artifacts have been recorded in the vicinity.”

Any disturbance of the ground surface has the potential to impact archaeological resources, whether this results from permanent change such as excavation for a station or tunnel entrance, or only temporary use such as parking or storage. Significant impacts to archaeological resources would require implementation of mitigation measures similar to the following measures identified in the 2001 study:

“Monitoring and Scientific Recovery of Archaeological Resources: In the event that archaeological and buried historic sites are encountered, evaluation of the site is often accomplished through test level excavation designed to determine the horizontal and vertical extent of the site, and to characterize the content of the site. If the site is determined to be potentially eligible for listing on the National Register, and project plans cannot be altered to avoid impacting the site, then an adverse effect would result pursuant to 36 CFR 800.5(d)(2). To resolve an adverse effect it would be necessary to implement a Memorandum of Agreement (MOA) per 36 CFR 800.6(c) to resolve the adverse effect. Under CEQA, impact to archaeological sites can be mitigated to a less than significant level through the preparation and implementation of a data recovery plan.”

Based on the data from previous studies summarized above, there is no indication as to whether there is a higher probability of encountering archaeological resources in the Methane Risk Zone when compared to other areas. At this time, it is unknown whether there are archaeological resources along much of the candidate alignments, and the exact extents of the Methane Risk Zone are also not precisely known. However, since the La Brea Tar Pits site is located within the Methane Risk Zone, it is possible that other archaeological resources may be uncovered nearby because a larger area may have been visited by ancient people “for hunting purposes and for acquiring pitch and tar”. If an archeological resource is encountered, it is not expected that the duration or cost of recovering archaeological resources encountered in the Methane Risk Zone would be greater than that of recovering resources in other areas. Archaeological recovery efforts typically involve shallow excavation efforts which are not significantly affected by elevated gas levels.

4.6.14 Historic Properties

An initial database of historic properties in or near the study area was assembled and is on file. The database is based on the following listings:

- National Historic Landmarks
- National Register of Historic Places
- California Register of Historical Resources
- California Registered Historical Landmarks
- Local landmarks and districts for cities within the study area: Los Angeles, West Hollywood, Beverly Hills, and Santa Monica.

In addition to the structures and districts listed in the database, many of the street fixtures (such as streetlamps) along Wilshire Boulevard may have been installed prior to 1950 and may therefore be considered potentially historic (Mid-City Westside Transit Corridor Draft Environmental Impact Statement/Environmental Impact Report (EIS/EIR), April 6, 2001).

As the study progresses and additional and more precise information becomes available, the database will be both updated and refined to correspond to specific properties located within the Area of Potential Effects (APE) that will be identified in the later stages of the project development. The APE typically includes all parcels located above off-street tunnel configurations, and all structures within the first tier of structures adjacent to the project alignment, stations, subway, or open cut construction areas, or areas proposed for acquisition.

The preliminary database includes more than 900 listings within the study area, including 188 in the National Register. Of the 188 properties or sites listed in the National Register, nine are located on Wilshire Boulevard, two on Santa Monica Boulevard, six on Hollywood Boulevard, one on Beverly Boulevard, and six on Sunset Boulevard. There is also one property located on Rodeo Drive north of Wilshire Boulevard and one on Westwood Boulevard about a block north of Wilshire Boulevard.

Thus, there are numerous existing historic resources adjacent to the proposed alternative alignments. By itself, there is no discernable difference with respect to historic resources from tunneling in the Methane Risk Zone versus tunneling in other zones. The ancillary ventilation and other facilities used in the elevated gas zones are not substantially different from such ancillary facilities used for tunnels outside the gas zones, and are unlikely to result in a greater potential to affect historic properties.

4.7 Cost Methodology Differential

This section summarizes the findings of the Final Initial Tunnel and Station Cost Methodology Report (27c), which evaluated differential costs for tunneling in areas having elevated methane levels. Elevated areas are defined for this study as those areas having a potential for tunnel construction to encounter methane levels that are significantly higher than other areas to be tunneled under this project and areas previously tunneled for the Metro Red Line and Gold Line Eastside Extension. The differential cost consists of additional parts and labor required to address the higher expected levels of methane exposure. Note that these costs do not constitute a bottom up cost analysis.

The elevated methane area is expected to be found between the existing Wilshire/Western Station and La Cienega Boulevard, including tunneling and station excavation through asphalt impregnated (tar) areas. The elevated zone is generally considered to be the area surrounding the La Brea Tar Pits, within about a one-mile radius of the Wilshire/Fairfax intersection, and portions of the area defined previously by the City of Los Angeles as a high Potential Risk.

Table 4-5 below summarizes the additional costs to construct tunnels and stations where gas concentrations are well above the concentrations found in other areas where Metro has previously constructed. The costs in the table account for twin (two) tunnels. For the overall estimate, these costs may be added to the unit costs developed for the AA study cost estimates. Where ranges are shown for the tunnel costs, some interpretation by geotechnical engineers must first be made as to the percent of high-level gassy ground to be covered, and then more definitive costs can be applied as appropriate.

Table 4-5. Summary of Estimated Cost Differentials – Methane Zone

Item	Differential Cost
I – TUNNELS (SCC 10)	\$ / LF (twin tunnels)
1. Slurry TBM	\$ 360
2. Worksite Required for Slurry Processing	\$ 70
3. Tunnel Lining Additional Seal:	
a. Grout Between Double Gaskets (as required)	\$ 18
b. HDPE – Invert (as required)*	\$ 100
c. HDPE – Arch (as required)*	\$ 300
4. Additional Liner (Second Pass) (as required)*	\$ 450
5. Additional Contaminated Soil Disposal	\$ 40
6. Silica Fume Concrete	\$ 100
Total - Tunnels	\$ 870 - 1,738
II - CROSS PASSAGES (SSC 10)	Each
1. Additional Ventilation, monitoring and Soil Grouting	\$ 30,000
Total – Cross Passages	\$ 30,000
III –STATIONS (SSC 20)	Per Station
1. Ventilation and Gas Monitoring	\$ 90,000
2. Reduced Exc. Production	\$ 1,300,000
3. Slurry Wall system	\$ 1,500,000
4. Contaminated Soil Disposal	\$ 4,000,000
5. Cost of Double Wall Concrete (range \$1.7 to \$2.1 million, say \$2M)	\$ 2,000,000
Total – Stations	\$ 8,890,000

Range dependent on approach to tunnel lining enhancements for gas control.

General Note: Tunnel unit costs are based on total phase (27,840 lf) of tunnel and are therefore tempered to the lower side of unit cost for the affected portion of the tunnel within the phase.