CENTURY CITY AREA TUNNELING SAFETY AND FAULT INVESTIGATIONS

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1.0 INTRODUCTION

On October 28, 2010, the Metro Board approved the Draft Environmental Impact Statement/ Environmental Impact Report (EIS/EIR) for the Westside Subway Extension Project (the Project), which included two alternate tunnel alignments through the Century City area with station locations on either Constellation Boulevard or Santa Monica Boulevard both centered on Avenue of the Stars. During the meeting, Metro staff expressed concerns related to the potential impact of the Santa Monica Fault on the station location on Santa Monica Blvd., albeit investigations were still ongoing to determine the location of the fault zone in the vicinity of the station. Concerns were also expressed at the meeting regarding the safety of tunneling under Beverly Hills High School (BHHS), as required for the Constellation Station option.

To address the BHHS tunneling safety concerns, in approving the Draft EIS/EIR for the Westside Subway Extension, the Metro Board approved a motion from Supervisor Yaroslavsky to be undertaken during preparation of the Final EIS/EIR. Specific items in the Board motion included the following:

“that in the West Beverly Hills to Westwood area:

- Staff fully explore the risks associated with tunneling under the [Beverly Hills] High School, including but not limited to the following: risk of settlement, noise, vibration, risks from oil wells on the property, impact to use of the school as an emergency evacuation center, and overall risk to student faculty and community;”
- “Staff analyze the possibility of moving the subway tunnel in order to avoid all school buildings and avoid any future plans to remodel BHHS.”

In addition, Metro staff was directed to fully investigate the nature and location of faults in the Century City area and their potential impact on station locations. The investigations have been completed and are presented in two separate reports: the *Century City Area Fault Investigation Report,* which presents the results of an investigation of faulting in Century City, and the *Century City Area Tunneling Safety Report*, which addresses the issues surrounding the safety of tunneling under and in the vicinity of Beverly Hills High School, West Beverly Hills, Century City, and Westwood. The results from both the tunnel safety and fault studies provide a basis for the Board to make a decision on which station option to adopt.

The Metro Tunnel Advisory Panel (TAP) is providing this summary report based on its own evaluations and its review of the investigations conducted by the Project Preliminary Engineering Team and their consultants, with nationally recognized expertise in areas that include tunneling, seismic hazards, earthquake engineering, gas hazards and mitigation and oil field development and well abandonment.

2.0 FAULTING IN THE CENTURY CITY AREA

2.1 Fault Investigations

The original Alternative Analysis (AA) studies for the Westside Subway Extension Project (Project) considered two alignment options, one with a station located along Santa Monica Boulevard and one with a station located along Constellation Boulevard, both centered on Avenue of the Stars.

Existing geologic structures in the Century City area include the West Beverly Hills Lineament, a possible extension of the Newport-Inglewood Fault Zone and the Santa Monica Fault Zone.

The West Beverly Hills Lineament (WBHL) is a NNW-trending geomorphic lineament that was previously mapped as crossing Santa Monica Boulevard in the vicinity of Moreno Drive. It is delineated by discontinuous east-facing scarps (steps in the topography) that mark the boundary between two distinct geomorphic provinces.

The active Santa Monica Fault is part of the Transverse Ranges Southern Boundary Fault System, an east-west-trending system of high-angle, near-surface left-lateral strike-slip faults; deeper reverse faults; and low-angle, near-surface thrust faults. The system extends for more than 124 miles along the southern edge of the Transverse Ranges. Existing fault maps and geomorphic evidence showed that the Santa Monica Fault was just to the north of the proposed location of the station on Santa Monica Boulevard. Although the prominent topographic scarp parallel to and just north of Santa Monica Boulevard provided an approximate location of the Santa Monica fault zone, the precise location of the currently active fault strands had not been identified at the proposed station location.

Consequently, a geophysical and geological study was initiated to more precisely determine the locations of active faults in the Century City area with respect to the options for locating the two stations. The results are reported in the *Century City Area Fault Investigation Report*, and summarized below.

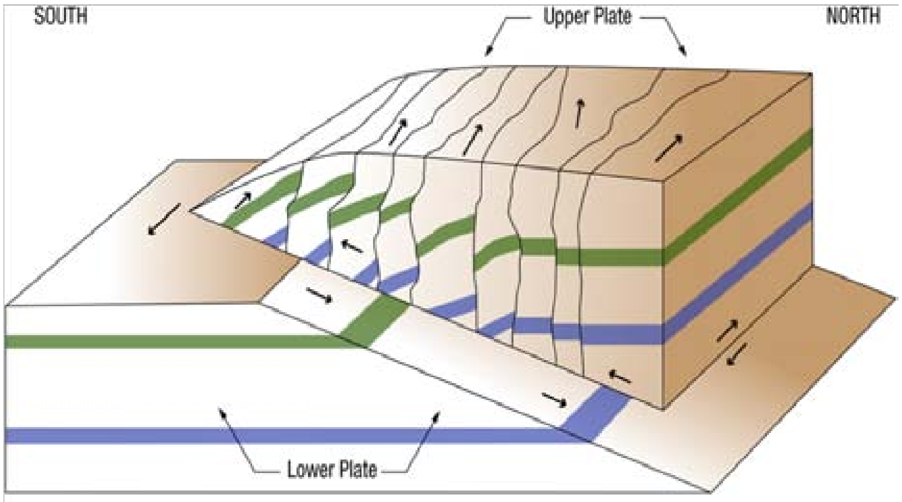
Two fault transects (exploration study lines) conducted in 2010 to the west of the originally proposed Santa Monica station showed that the width of the Santa Monica Fault Zone extends across and to the south of Santa Monica Boulevard at Century Park West with the likelihood that, toward the east, the zone would intersect the proposed Santa Monica station.

Additional transects were performed in 2011. The studies consisted of 56 core boreholes and 192 Cone Penetration Test (CPT) soundings along transect lines, and 5 seismic reflection profiles throughout the Century City area. Results confirmed that the Santa Monica Fault zone intersected the proposed station on Santa Monica Boulevard

The deformation characteristics of the fault are schematically illustrated by Figure 1, which shows the horizontal displacement and heave and disturbance at and behind the front of such a thrust fault and the displacements on the strike-slip faults.

In order to maintain a Century City station alternative on Santa Monica Boulevard, the originally proposed station location was shifted to the east, roughly centered on Century Park East, in an effort to clear the Santa Monica Fault Zone.

Figure 1: Schematic Cross Section of Santa Monica Fault Zone (from Figure 5, *Century City Area Fault Investigation Report*)



Schematic block diagram of the Santa Monica Fault Zone, an oblique left-lateral reverse fault zone.

The shift to the east placed the station location in the vicinity of the West Beverly Hills Lineament (WBHL). Although it had been inferred to be an extension of the Newport-Inglewood fault system it had not been investigated in the subsurface and therefore the location of the zone and the individual fault strands within the zone were unknown.

The additional fault investigations over the past nine months have shown that the WBHL is an active fault zone, inferred to be a northern extension of the active Newport-Inglewood Fault Zone and that it consists predominantly of a zone of multiple strands of right-lateral strike-slip faults. It intersects the Santa Monica Fault Zone, which extends along and to the north of Santa Monica Boulevard in the vicinity of S. Moreno Drive. The proposed eastern location of the Santa Monica Boulevard station is intersected by the WBHL Fault Zone and is within a complex area of faulting at the intersection of the two fault zones. Figure 2 shows the location of the fault zones determined from the fault investigation.

In summary, the fault investigation has shown that both the Santa Monica Fault Zone and WBHL (i.e., northern extension of the Newport-Inglewood Fault Zone) are active fault zones, and both of the proposed locations for the Santa Monica Boulevard station are within active fault zones. There is no clear evidence for a fault-free section along Santa Monica Boulevard in the vicinity of Century City that is large enough to accommodate a station. Thus it is recommended that proposed station locations along Santa Monica Boulevard no longer be considered acceptable options.

Figure 2: Fault Zones (from Figure 1, Century City Area Fault Investigation Report)

The fault studies have also included a series of borings and a transect across the proposed Constellation Station location. The results show that the proposed Constellation Station site is located outside zones of active faulting and can be considered an acceptable option for a station location.

2.2 Stations and Tunnels Subjected to Ground Shaking or to Active Fault Displacement

Metro design criteria use two levels of ground shaking hazard and fault offset: the Operating Design Earthquake (ODE), having a 50-percent probability of exceedance in 100 years, and the Maximum Design Earthquake (MDE), having a 4-percent probability of exceedance in 100 years. The guiding philosophy of earthquake design for the Project is to provide a high level of assurance that the overall system will continue operating safely during and after an ODE and that public safety will be maintained during and after an MDE and that damage will be repairable.

Earthquakes have two types of impacts on the ground and structures within or on the ground. The first is the shaking due to the ground motions that occur throughout the area affected by the earthquake. The second is rupture and displacement along the fault zone on which the earthquake is occurring. For the MDE on both the Santa Monica Fault and the Newport-Inglewood Fault, displacements are estimated to be on the order of 3 to 6 feet. During detailed design, probabilistic methods will be used to determine the displacements that would be used for design of tunnels crossing the active faults.

In the case of ground shaking, experience in California and worldwide shows that well-designed tunnels perform well and do not suffer significant damage. Since they are embedded in the ground, they move with the ground and thus, their motion is not magnified by the pendulum effect that occurs when an above ground structure is shaken by an earthquake. As an example, during the Northridge Earthquake (M6.7) in 1994, Metro's first phase Red Line tunnels and stations, which were in operation, received ground motions at the level of the ODE without damage. Inspection was performed and the system was reopened for service the following day, with greatly increased ridership because highways were closed due to earthquake damage to bridge structures. Another example is the 1989 Loma Prieta earthquake (M6.9) which shook San Francisco, collapsing key elevated highways but leaving the Bay Area Rapid Transit (BART) tunnel system unaffected. Following an inspection of the tunnels and trackwork, the system was reopened within a few hours.

In the case of rupture during an earthquake on an active fault, large concentrated fault offsets are imposed on structures located directly on the fault. Metro underground stations are sited so that they are not on active faults. Designing Metro's underground stations to withstand active faulting without collapsing or endangering the public is without precedent. The task would be extremely difficult and cost- prohibitive due to the extent of the distortions and the potential damage that would be imposed on these complex, multi-story, up to 1000-foot-long underground structures and their associated systems, services, and entrances. Even with a complex and sophisticated design, unacceptable risks would remain in the ability to limit damage and protect the public if faulting were to intersect a station.

Tunnels crossing active faults are designed to accommodate the fault displacement without collapse and with the capability of being repaired. Several tunnels have been designed and constructed through active faults in Los Angeles, including a tunnel on the Red Line, and design requirements are documented in Metro's Seismic Design Criteria. Alignments should be selected so that the tunnel is not running along the fault zone but crosses at a relatively sharp angle to the zone to minimize the length of tunnel that must be designed to accommodate fault displacements and would have to be repaired if faulting did occur. The presence of tunnels will not adversely affect the severity of the shaking of or the fault displacements imposed on overlying structures during an earthquake.

Several methods can be employed to allow a tunnel to withstand several feet of fault displacement. In the case of the Metro Red Line alignment through the Hollywood Fault zone in rock formations beneath the Hollywood Hills, the tunnels were excavated to a larger dimension at the crossing to facilitate realignment in the event of a fault offset. Other tunnels through active faults have been provided with a strong but flexible lining, such as ductile steel segments or segments with articulated joints. In addition, tunnels can be protected from fault displacement by placing a crushable backpacking material around the outside of the structural lining.

To construct the Project in the Century City area, it will be necessary to pass through two active fault zones, located in soil formations, typically stiff to hard clays and dense sands. There are numerous proven tools, designs, and construction methods that can be used to safely tunnel through fault zones. Procedures will be in place for monitoring and controlling ground movements and protecting overlying structures as the tunnels are advanced through the fault zones. Tunneling methods using pressurized, closed face tunnel boring machines (TBMs) have the capability to advance through the soil without causing damaging settlements. In addition, procedures for improving the ground, such as grouting, freezing, drainage and soil reinforcement, can be employed prior to or during tunneling in order to limit settlements.

The pressurized, closed-face TBMs proposed for the Project not only have the capability of controlling ground movements as they are advanced through a fault zone but also have the capability for installing a lining system that can accommodate fault displacement during an earthquake. Lining systems that are being considered include ductile steel segments surrounded by crushable materials, such as cellular concrete, that are capable of yielding and accommodating large fault displacements without rupture. The cellular concrete can be injected around the lining as the tunnel is advanced and can be installed as a composite with the steel segments. The linings will be designed specifically to accommodate fault displacements at the crossings of the Santa Monica Fault Zone and the Newport-Inglewood Fault Zone. The location and length of required lining at the fault crossings will be further defined during detailed design.

For the Constellation Station option, the tunnels to the east of the station will be driven through stiff to hard clays and very dense sands of the Older Alluvium, Lakewood, and San Pedro Formations. Results of the fault study show that the WBHL is a wide fault zone, inferred to be the northern extension of the Newport-Inglewood Fault Zone. It is located to the east of Century Park East and extends beneath the Beverly Hills High School property (Figure 2). Evidence for faulting along the tunnel alignment is also provided by soil borings along the alignment which show vertical offset of marker beds and formation boundaries between adjacent borings. In other areas, such as to the west of the fault zone, marker beds between borings line up, indicating the absence of faulting. Even within the faulted zones, the geotechnical data indicate that the soils will be dense and conditions will not be unfavorable for tunneling. The pressurized, closed-face tunnel boring machine system can accommodate any variability in soil and groundwater conditions that may exist. Further investigation is required to define the boundaries and characteristics of the fault zones in the vicinity of the tunnel crossings.

3.0 POSSIBILITY OF AVOIDING SCHOOL BUILDINGS AND AVOIDING IMPACTING FUTURE PLANS FOR DEVELOPMENT AT BEVERLY HILLS HIGH SCHOOL.

Subway alignments to the east of the proposed Century City Constellation Station were investigated in order to avoid or minimize impacts on the Beverly Hills High School (BHHS) property and buildings. None of the several horizontal alignments were capable of avoiding the BHHS property or avoiding all school buildings. The recommended horizontal alignment passes beneath the south end of BHHS Building B but avoids the central portion of the building and the gym/pool structure, so that they are outside of the zone of influence of the tunnels.

The proposed vertical alignment sets the tunnel crown at a depth of 55 to 70 feet below the ground surface which allows space for future development of Beverly Hills High School, both above- and below-ground. For example, multiple levels of underground parking can be safely placed over the tunnels. Foundations can be set above the tunnel, and, if necessary, deep foundations can be placed adjacent to and between the tunnels. Building foundation plans must be coordinated with existing or future tunnels, but major bridge structures spanning the tunnel are not required to support the buildings. The floor spans would be within typical building practice, on the order of that required to extend across the 21-ft-width of a single tunnel. Clearances between foundation mats and the Metro tunnels can be small. For example, one of the Metro tunnels is currently being designed to pass less than 10 feet below an existing Metro Red Line tunnel.

The tunnels would not reduce the availability of the high school for use as an emergency shelter or impact the operations of its use as an emergency shelter. As described in the previous section, the presence of tunnels will not adversely affect the severity of the shaking or the fault displacements imposed on overlying structures during an earthquake. The following sections describe the procedures that will be used to tunnel safely without impacting the use of the high school facilities.

4.0 INVESTIGATION OF RISKS ASSOCIATED WITH TUNNELING UNDER THE BEVERLY HILLS HIGH SCHOOL, WESTWOOD, AND WEST BEVERLY HILLS

4.1 Control of Settlement

Experience on LA Metro tunnels and on tunnels world-wide shows that ground movements can be controlled and the risk of damaging settlements minimized with current tunneling technology. On most transit tunnel projects, portions of the alignment are constructed beneath buildings. The capability to tunnel beneath structures without damage has resulted in large part from the use of pressurized, closed -face TBMs, with systems and protocols to monitor and control their operation.

In 1994, Metro responded to problems with settlement during Red Line tunnel construction, including a sinkhole on Hollywood Boulevard, by commissioning a three member Technical Advisory Panel (TAP) to evaluate the feasibility of tunneling in Los Angeles. Their November, 1995 report included the following:

"The geological and geotechnical environment along the existing and proposed corridors of Los Angeles Metro is clearly compatible with safe and economical underground construction. Dozens of cities in various countries have successfully developed underground transportation systems in similar or even more difficult ground conditions."

The TAP recommended that:

"…ground control be established as the governing design and construction criterion on the existing and future tunnel contracts, with firmly set rules about monitoring and interpreting ground deformation data as well as practical steps to be taken immediately when deformations exceed the permissible limits. MTA should consider the cost and benefits of specifying less risky construction methods which minimize construction impacts to the public, even if their initial cost may be more expensive."

4.1.1 Metro Gold Line Eastside Extension (MGLEE)

The above recommendations were followed in the design and construction of tunnels for the Metro Gold Line Eastside Extension (MGLEE). In the 1990's, tunneling technology in the United States was in transition from the open face tunnel shields, such as those that had been used in tunneling of the Red Line, to pressurized, closed-face tunnel shields that provided a continuous pressure against the ground being excavated ahead of the tunnel face thereby preventing ground movements and inflow of soil and water. This tunneling technology was specified for the MGLEE, and, in 2006, 1.7 miles of twin tunnel were excavated using two earth pressure balance machines (EPBMs), the most widely used type of pressurized, closed-face TBM. The tunnels were advanced through the Old Alluvium formation, consisting predominantly of layers of dense silty sand and stiff to hard clay (a formation also to be encountered along the Century City area alignment.).

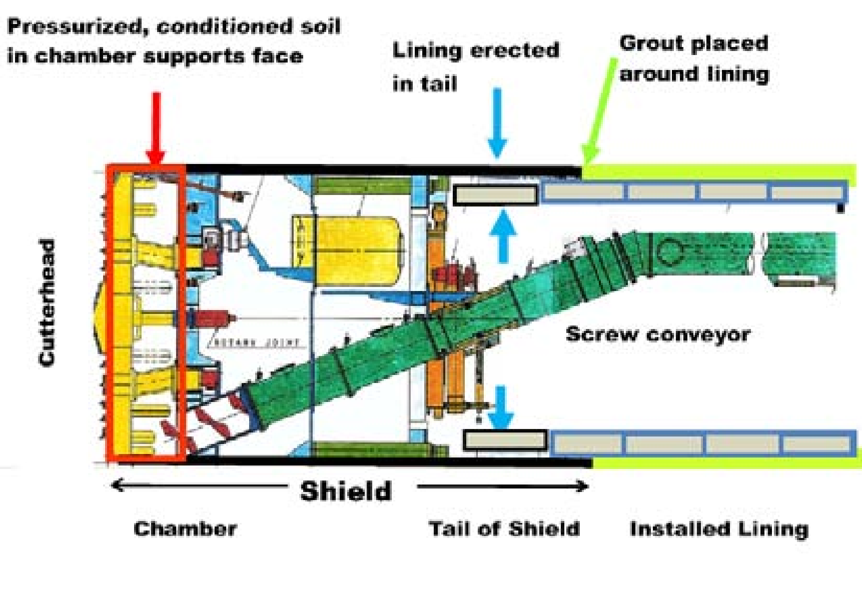
Throughout the two tunnel drives, procedures were in place to closely control the tunneling operation and limit settlement. A comprehensive program of instrumentation and surveying was conducted to monitor ground movement around and above the tunnels. Seventy-five extensometers were installed in vertical borings along the two tunnel centerlines to measure ground movement near the crown of the advancing tunnels and at mid-depth between the tunnel and the ground surface. Displacements immediately above the tunnel crown were typically less than 0.1 inch and an order of magnitude less than the specified Action and Maximum allowable settlement levels, confirming that the EPBM operation was effective in minimizing ground movement.

Survey points established along cross sections at the location of the extensometers and at 25-foot intervals along both tunnel centerlines showed that surface settlements were typically in the range of 0 to 0.3 inches, averaging a tenth of an inch. In many cases, there was no settlement or the measurements were below the level of the accuracy of survey equipment. The surface settlements were well below the design values that had been used prior to construction to assess the effect of ground movements on buildings along Metro alignments. Settlement points placed on the sides of buildings located above and adjacent to the tunnels also recorded little or no displacement and there were no substantiated claims for building damage.

4.1.2 Current Project Tunnel Design.

Tunnels on the Project will consist of two parallel bored tunnels, each with an 18-foot 10-inch inside diameter. Pressurized, closed-face tunnel boring machines will be specified and used. The machine is contained within a cylindrical shield with a closed chamber behind the cutting wheel that is pressurized with a viscous mixture of excavated soil and conditioners or bentonite to support the ground ahead of the tunnel face and prevent inflows of water and soil. Figure 3 shows an earth pressure balance machine, the type of pressurized, closed-face TBM used on the MGLEE.

Figure 3: Earth Pressure Balance Tunnel Boring Machine



The tunnel will be lined with precast concrete segments assembled within the protection of the shield, bolted together to form a ring and connected to the previously installed ring. Each ring will be installed after the TBM has advanced the width of the ring (usually 5 feet). The installed concrete segment lining will serve as the initial support during tunneling and the permanent support over the life of the project. The segments will be gasketed to make the joints between segments water- and gas-tight. A double-gasket system will be used that provides a robust seal against water and gas and a means for isolating and sealing any leaks. Metro developed and tested this system and proved its capabilities on the Metro Gold Line Eastside Extension (MGLEE).

As the tunnel is advanced, all spaces around the shield will be filled and grout will be continuously injected through the tail of the shield to fill the gap between the lining and the ground, thus minimizing loss of ground. No shield advance will be permitted without continuous injection of the grout. This capability, in addition to pressurization of the tunnel face, is the reason that settlements can be held to such small values.

4.1.3 Effects on Buildings

Geotechnical investigations have been performed along proposed tunnel alignments in Century City, Beverly Hills High School, and in adjoining residential areas (Westwood and West Beverly Hills). At the Beverly Hills High School site, the soils at the tunnel level are predominantly very dense sands of the San Pedro and Lakewood Formation overlain by very stiff to hard clays of Old Alluvium. In the Westwood area, the soils will be in the Old Alluvium, predominantly very stiff to hard clays and dense to very dense sands and silty sands.

The current alignment at Beverly Hills High School passes beneath the south portion of Building B, built in the late 1920's, with masonry walls and concrete floor beams and columns. Further definition of the building geometry and characteristics should be obtained during final design surveys. Damage criteria based on observations and analyses of masonry buildings throughout the U.S, many built in the late $19^{th}$and early 20^{th} centuries, indicate that maximum anticipated settlements will produce distortions well below the levels that cause structural or functional damage and in the range of negligible to very slight damage where cracking of finishes does not occur or is very minor.

These are conservative estimates, and the Tunnel Advisory Panel's experience in tunneling with earth pressure balance TBMs on the Metro Gold Line Eastside Extension and on other transit tunnels recently and currently under construction show that surface settlement can be small, within the range of accuracy of survey measurements, producing no damage to surface structures.

Design criteria and construction procedures will be in place to ensure that the ground movements are controlled to required levels. Action and Maximum levels for settlement will be specified and monitoring sections will be established to measure ground movements prior to and during tunneling beneath the high school and other structures along the alignment. The monitoring will be used to confirm that ground movements are being controlled to required levels or to make any required adjustments in tunneling procedures.

4.2 Control of Gas and Water Inflow

Experience in Los Angeles, and in other cities in the United States and world-wide has shown that the proper combination of design, modern tunneling equipment and methods, and a supply of sufficient ventilation lead to successful tunnel construction and operations in gassy ground. Proof of this is found in the operating Metro Red Line and Metro Gold Line Eastside Extension tunnels constructed through the Salt Lake and Boyle Heights oil fields. In fact, since 1990, more than 30 miles of tunnel, many through known oil fields, have been safely constructed in Los Angeles with no adverse incidents from either hazardous gas or encounters with oil well casings.

Federal funding for extending the Red (now Purple) line along Wilshire Boulevard and through the methane zone in the vicinity of La Brea and Fairfax Avenues was prohibited until 2007. An American Public Transportation Association (APTA) peer review was formed "to conduct an independent evaluation and report on gas related safety issues associated with the proposed extension of the Metro Red (now Purple) Line Subway along Wilshire Boulevard, taking into account currently available technologies." The panel determined that current tunneling technology, including the use of pressurized closed- face TBMs, was capable of safely tunneling through the zone.

In planning the Westside Subway Extension, Metro has followed up and built on recommendations of the APTA panel and its Tunnel Advisory Panel (TAP) as well as the experience gained in Metro construction since the study—in particular, successful completion of the MGLEE tunnels. On that project, designers and Metro's TAP recommended a double-gasketed tunnel liner ("one-pass" system) for use with the pressurized closed-face TBMs. The sealing system was believed to be the first of its kind, and, thus a six-month, full-scale laboratory testing program was conducted to verify the design. The testing program evaluated the structural capacity of the concrete segments under both static loads and seismic ground motions and the capability of the gaskets to prevent leakage of methane during and after seismic ground motions.

Methane levels measured in borings in the Century City area are in the range of the levels tunneled through on previous Metro tunnel projects, and they are substantially below the levels measured in downtown Los Angeles where tunneling was accomplished safely using open shields and initial linings that did not have capability of sealing against inflows during tunneling.

The gas hazard or risk during tunneling is related to the volume, concentration and pressure of the gas in the surrounding soil. Gas concentrations are not the same in the tunnel as they are in the soil because the soil permeability and the presence of the tunnel lining limits the flow of gas into the tunnel and because ventilation is provided to dilute and remove gases that enter the tunnel. On the MGLEE project, and on the proposed Westside project, tunneling has been and will be accomplished with closed, pressurized-face tunneling boring machines that limit inflow of gas and water into the tunnel face. Additionally, the tunnels are immediately supported with gasketed concrete linings that not only serve as both initial and final support but prevent inflow of gas and water into the tunnel during the construction period as well as over the life of the project.

The Westside Subway Extension will have gas mitigation measures for sealing and ventilating the tunnels that are similar to those employed for the MGLEE tunnels. Tunneling safety is ensured by such procedures. In addition, buildings above the tunnels are protected and isolated from conditions within the tunnel by the ground which surrounds the tunnels.

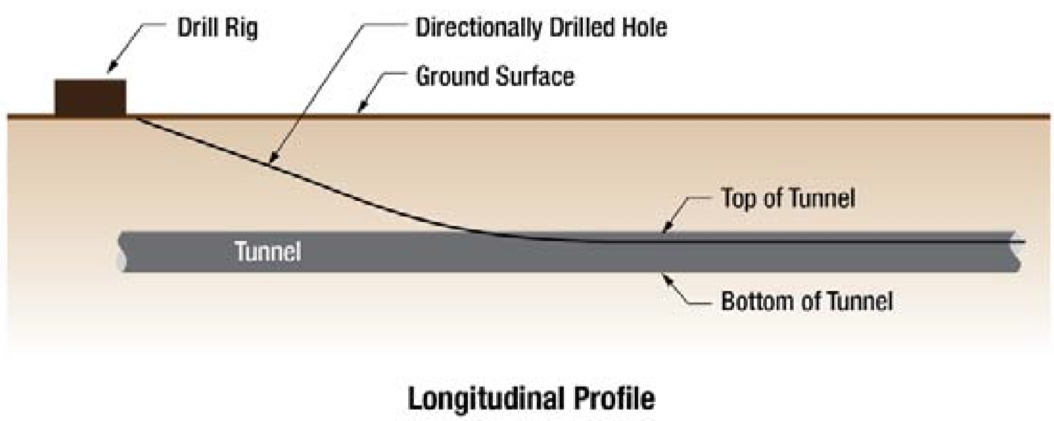
4.3 Oil Wells

Oil fields have been identified in Century City and on the Beverly Hills High School property, as shown by historic and current maps and California Division of Oil, Gas and Geothermal Resources (DOGGR) records. A comprehensive study of available information identified one abandoned oil well within the proposed tunnel zone. According to State records, the well is located beneath a parking structure on Century Park East and does not lie within the BHHS campus. Procedures for detecting this well will be employed prior to tunneling as described below.

As part of the investigation of Beverly Hills High School property, and other areas of suspected oil wells in the Century City area, a surface magnetometer survey was conducted in open areas along the proposed tunnel alignment to detect metal and possible well casings near the ground surface. The survey identified one anomaly on the west edge of the Lacrosse field on the BHHS campus that is within 5 to 10 feet laterally from the proposed tunnel alignment. This anomaly may or may not be a well casing so it will be further investigated, as described below. A series of anomalies indicative of well casings were found on Constellation Boulevard, in a known well field near the Constellation Station Site but not within the station footprint.

In areas of suspected abandoned wells, probing at the tunnel level is recommended to locate potential well casings before intercepting them in the tunnel. Magnetometer probe holes have been performed on past tunneling projects in Los Angeles. Magnetometer probe holes were extended in front of advancing tunneling machines in selected locations where abandoned wells were suspected to be present. Alternatively, the magnetometer probing can be accomplished prior to tunneling by using horizontal directional drilling (HDD) to extend a boring along the tunnel line into which a probe can be inserted in order to detect any steel casings in the path of the tunnels, as shown in Figure 4. If a well is encountered, procedures for removing the well casing and abandoning the well would be carried out, either prior to tunneling, or ahead of the tunnel face.

` Figure 4: Directionally Drilled Borehole along Tunnel Alignment



4.4 Noise and Vibration:

The Metro Red and Purple Line tunnels extend 18 miles through downtown Los Angeles, Hollywood and North Hollywood and run directly under a number of buildings. Metro reports that, to date, no complaints about noise or vibration during service operations have required mitigation. Monitoring of noise and vibration above operating segments of the LA Metro has shown that noise and vibration levels are within acceptable limits.

Testing of the transmission of vibration and noise through soil was recently performed in boreholes during the environmental studies on the Project alignment. On the campus of BHHS, study results predict that ground-borne vibration from the trains will be no greater than 64 decibels, which is lower than the vibration criteria of 72 to 75 decibels established by the Federal Transportation Administration (FTA) for residences and institutions, respectively. The ground-borne noise level is predicted to be no greater than 33 decibels which is lower than the FTA criteria of 35 to 40 decibels for residences and institutions, respectively. The measurements made above operating segments of the LA Metro show that the prediction techniques are valid and that noise and vibration levels are within acceptable limits.

During construction, low levels of ground-borne noise and vibration may be generated for a day or two as each of the two tunnel boring machines pass by a given location. In addition, as the tunnels are driven, construction trains bringing supplies to the front of the tunnel will generate vibrations, whose levels will be monitored and controlled. Control measures exist for construction-induced vibrations that were implemented in previous Metro tunnels including the MGLEE tunnels. For construction, Metro required that maximum ground-borne noise levels be limited to 40 to 45 decibels for residences and schools, respectively. The MGLEE specifications required the tunneling contractor to provide vibration isolation of the construction train rails system to mute noise levels should they exceed specified levels. There were no substantiated noise level complaints during MGLEE tunneling.

Previous studies by Metro of tunneling-induced vibration for the Red Line construction showed that vibrations affecting overlying buildings were unlikely to be perceivable and would be well below the most conservative damage thresholds. The findings were substantiated during actual construction.

Tunneling in the Century City area will be undertaken with the same noise and vibration level limits and mitigation measures that were in operation during MGLEE construction. During both construction and operations any substantiated complaints will be addressed and mitigation provided.

4.5 Overall Risk to Beverly Hills High School Students, Faculty, and Community

The Project is not expected to pose new risks to the students, faculty, or community as a result of its construction and operation. On most transit tunnel projects, throughout the U.S. and the world, portions of the alignment are constructed beneath buildings, and transit tunnels have been constructed beneath or adjacent to schools and public buildings. The capability to tunnel beneath structures safely has resulted in large part from the use of pressurized, closed-face TBMs, with systems and protocols to monitor and control their operation.

5.0 CONCLUSIONS

1. The proposed station locations on Santa Monica Boulevard are within active fault zones and are not acceptable sites for Metro stations.

2. The proposed station location on Constellation Boulevard is not on an active fault zone and is an acceptable site for a Metro station.

3. The tunnel alignment through Century City will cross two fault zones: the Santa Monica Fault Zone and the West Beverly Hills Lineament (i.e. the northern extension of the Newport-Inglewood Fault Zone).

4. Current information on the location and character of the fault zones is sufficient to provide the general location of the fault zones at the tunnel crossings. Tunneling can be safely accomplished and the tunnel lining at these crossings can be designed to accept fault offsets without collapse.

5. It is safe to tunnel under Westwood, Century City, West Beverly Hills and Beverly Hills High School using design and tunneling procedures outlined in this report.

6. The presence of a tunnel will not prevent Beverly Hills High School from being used as an Emergency Center or from developing their site by placing new facilities over the tunnel.

7. Noise and vibration will be monitored, controlled, and, if necessary, mitigated during both construction and operations.

6.0 RECOMMENDATIONS

The following recommendations are provided by the TAP:

1. During Project design and construction, provide criteria, specifications, and construction control procedures that meet the objectives and requirements for controlling tunneling operations.

2. During the design phase, conduct further investigations in the vicinity of the proposed tunnel crossings of the faults to further define locations of the fault zones. Design effort should include additional transects with geophysical surveys, cone penetrometer (CPT) probing, and borings. Investigate ground conditions and the fault zone characteristics and limits along the tunnel alignment at Beverly Hills High School working in cooperation with the High School.

3. During the design phase, assess the magnitude and distribution of fault displacements that the tunnel lining will be required to accommodate at each of the fault crossings.

4. During the design phase, analyze and test lining components and systems for supporting tunnels crossing the active fault zones.

5. Monitor noise and vibration during construction to confirm that noise and vibration levels are within acceptable limits and control levels that do not meet requirements.

6. Conduct magnetometer surveys in probe holes drilled along the tunnel alignment in oil fields where there is the possibility of intersecting well casings, either ahead of the advancing tunnels or prior to tunneling, using horizontal directional drilling. It is recommended that, to the east of the Constellation Station and on the Beverly Hills High School property, the surveys be conducted during the design phase using horizontal directional drill holes.