4.5 GEOTECHNICAL, SUBSURFACE, AND SEISMIC HAZARDS

This section discusses the geology, soils, seismicity, hazardous materials, and subsurface obstructions along Flower Street, and evaluates their potential impacts on the construction and operation of Alternatives A and B. The information presented in this section is based on the following documents that provided the basis for the Final EIS:

1. Geotechnical-Subsurface-Seismic-Hazardous Materials Technical Memorandum (Appendix U) in the Metro Regional Connector Transit Corridor Final EIS.
2. Final Geotechnical Data Report, Rev. 1 (GDR), Regional Connector Transit Corridor Project, March 30, 2013.
3. Geotechnical Baseline Report, Rev. 1a (GBR), Regional Connector Transit Corridor Project, August 1, 2013.

4.5.1 Affected Environment

Generally, conditions related to geologic, subsurface, seismicity, and hazardous materials along the Flower Street portion of the Project and two tunneling method alternatives have remained unchanged from those discussed in the Final EIS Chapter 4.09 Geotechnical/Subsurface/Seismic/Hazardous Materials and in Appendix U in the Final EIS. This section provides a more focused discussion on the Flower Street conditions, and the construction techniques considered for the two tunneling method alternatives and evaluation of potential impacts. There are no construction changes to the Little Tokyo portion of the project due to the two tunneling method alternatives.

4.5.1.1 Geology

Along the Flower Street segment of the alignment, alluvium and fill materials overlie the Fernando Formation consisting primarily of weak to very weak clayey siltstone. The alluvial deposit consists of interlayered silty clays, sandy silts, clayey sands, and silty sands with some sand layers containing variable gravel and few cobbles. The fill materials consist of a mixture of gravel, sand, silt, and clay mixed with construction debris. The depth of fill material varies along Flower Street with the maximum fill depth estimated to be about 40 feet below ground surface. Occasional boulders are also present in the alluvium. The principal geologic conditions on Flower Street that control tunneling risk are: groundwater, geologic interface of different soil or weak rock strata, and hazardous gases.

Groundwater seepage at relatively shallow depths (ranging from approximately 15 to 35 feet below ground surface) was encountered in geotechnical borings drilled for the many building sites lining Flower Street between 5th and 7th Streets. Within the lower portion of the alluvial deposits adjacent to Flower Street between 2nd and 5th Streets, groundwater (most probably perched above the Fernando Formation) has been reported at depths from approximately 18 to 27 feet below ground surface, which is close to or within the tunnel vertical alignment horizon. Groundwater problems would be magnified at the alluvium-Fernando interface.

Along Flower Street, the geologic interface of alluvial soils over the weak rock of Fernando Formation, as illustrated in Figure 4.5-1, is a geologic tunneling hazard. If tunneling is located fully below the geological interface, and there is some Fernando Formation between the tunnel and interface, there exists a reduced potential hazard. If the interface is located just above the tunnel, or within the face of the tunnel being excavated, the hazard is that the alluvial materials would run uncontrolled into the tunnel during construction. With the presence of ground water, this condition would cause an uncontrolled flow into the tunnel under construction. Tunneling through alluvium conditions with open face or SEM techniques has a high risk of losing control of the tunneling face due to the lack of face support, which can result in an uncontrolled flow of alluvium and other soils into the tunnel. The uncontrolled flow of soils into the tunnel creates a void in front of and above the tunnel heading causing substantial subsidence of the ground surface including possible sink holes open to the surface. Additionally, the void created in an uncontrolled flow of material into the tunnel can cause significant settlement and damage to existing utilities and adjacent structures. Most importantly, an uncontrolled flow of ground into the tunnel creates a serious safety hazard with a potential for serious injuries or death to the underground construction workers and public on the surface.

Geologic conditions may be mitigated by grouting to create non-running/non-flowing ground conditions, or by using another method, such as use of earth pressure balance machines (EPBMs), which inherently can safely address with Flower Street segment geotechnical conditions. The *Draft Flower Street Tunneling Method Alternatives Report (2014)* identified that even when jet grouting is used, substantial risks of utility damages would remain due to the grouting operation, along with risks of excessive settlement and tunnel failures due to incomplete coverage of the grouted mass or migration of groundwater along abandoned tie-backs located under Flower Street.

Methane and hydrogen sulfide (H_2S) are anticipated to be encountered as described in the Geotechnical Baseline Report (GBR) prepared for the Final EIS, and experienced on recent construction projects in the project area (Wilshire Grand Plaza at 7th Street/Figueroa Street). Several sections of the tunnels are to be constructed through Methane Buffer Zones. Cal/OSHA has classified all of the underground construction for the Regional Connector project as "potentially gassy." Geotechnical investigations performed during Advanced Conceptual Engineering, Preliminary Engineering, and Advanced Preliminary Engineering indicate the various presence of methane gas (CH_4) and hydrogen sulfide (H_2S) in the ground along Flower Street. For example, a maximum field H_2S reading of 5 parts per million (ppm) was detected in Boring E2-2, which is located near the intersection of Flower Street and 3rd Street. Close to this location, a methane gas concentration of 1,000 ppm was detected in Boring MB2. In addition, a methane gas concentration as high as 87 percent was detected during the basement excavation of the Los Angeles Central Library located on the southeast corner of Flower Street and 5th Street. Hydrogen sulfide is highly toxic and could result in human health effects to individuals who are exposed, particularly construction workers. Methane is explosive if allowed to accumulate to a range of five to twelve percent at atmospheric oxygen level.

Metro Rail Design Criteria (MRDC) requires specific underground designs where gassy conditions are present. In order to prevent the entry of gases into the tunnel and underground stations, a gas barrier must be incorporated into the design either with the use of EPBMs, and installation of a double-gasket, segmental precast tunnel lining, or encasing the station and tunnel cast-in-place structures with a high density polyethylene (HDPE) membrane.

4.5.2 Environmental Consequences

The following sections summarize the evaluation of potential impacts of geotechnical conditions, soils, seismicity, hazardous materials, and subsurface obstructions that would occur with construction of Alternatives A and B.

4.5.2.1 Alternative A – EPBM/Open Face Shield/SEM Project Profile

In this alternative, EPBM-bored tunnels would be constructed following the Project alignment to south of 4th Street, with open-face shield tunnel excavation from 4th Street to 5th Street, and SEM tunnel construction from 5th Street to the 7th Street/Metro Center Station tail tracks structure.

Sequential Excavation Method (SEM) tunneling for the segment south of 4th Street would allow for removal of tie-backs through the face of the shield or within the SEM excavation. However, without the undertaking of special mitigating measures, such as complete ground stabilization, Alternative A would have a high level of risk of tunnel face instability with the potential for soil runs during tunneling by open-face shield or SEM, particularly when dealing with the tie-backs under Flower Street. The open-face shield section of the alignment would occur in the diminishing thickness of the Fernando Formation above the shield. There would be approximately five feet of Fernando Formation cover above the open-face shield section.

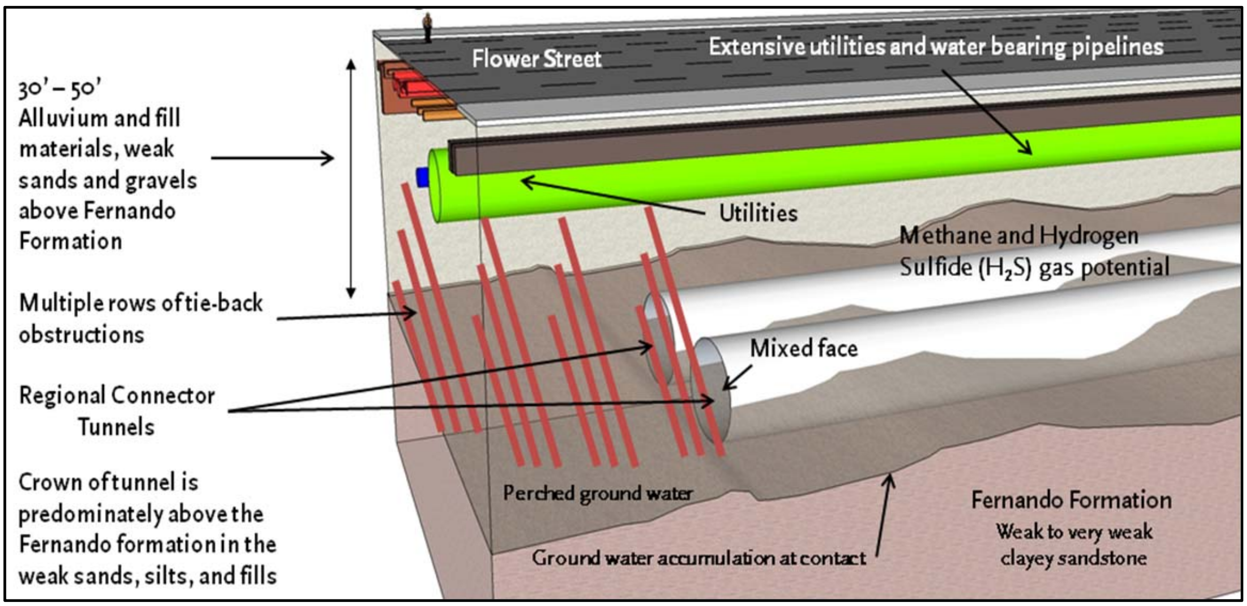
In addition, the top of the Fernando Formation is an erosional surface, and the geologic profile is based on a limited number of borings. Thus the thickness of the Fernando Formation above the tunnel has uncertainty and the stability of the ground surface on Flower Street is not guaranteed. Significant ground improvement would be required as previously discussed in Chapter 2, Alternatives Considered. For the SEM portion of the tunneling, the single twin-track tunnel diameter is very large and the tunnel would have varying amounts of mixed face geologic conditions in the tunnel heading. In this situation, there would be a high risk of creating sinkholes or subsidence on Flower Street. Ground improvement by jet grouting would be required for Alternative A. Mitigation of impacts may not be successful given the complexity and severity of the Flower Street underground conditions.

The jet grouting for the SEM portion of this alternative would require drilling grout holes on a six-by-six foot pattern throughout the area to be grouted as illustrated in Figure 2.3-1. Grout holes would extend from the ground surface through weak fill and alluvial soils to just into the relatively stronger Fernando Formation. A 50-foot-wide zone in Flower Street would be grouted and requires setting up a grout plant on Flower Street. Depending on the number of required grout holes, two to four drill rigs would be utilized to drill and grout. For Alternative A, a total of approximately 1,900 grout holes would be drilled and grouted.

Although jet grouting would improve the ground conditions for ground control during SEM tunneling, significant risk of ground loss and excessive settlement due to SEM would remain, and these risks cannot be mitigated. This is primarily because grouting must be done through a series of borings designed to have overlapping grout columns. Given mixed face soil conditions, ground water inflows and ground loss can still occur which would damage utilities and existing buildings, basements, and other structures and pose a safety threat to workers, the public, and construction operations. Also, with the significant number of existing utilities under the street and with a dense grout pipe pattern required, the existing utilities would have a high risk of being damaged by the high pressure grouting operation, which could result in adverse impacts or interruption of utility services even before the tunneling starts.

Due to the potential gassy conditions under Flower Street, using SEM tunneling, or open-shield TBM, would increase risks of hazardous gas for construction and likely require significant additional measures to mitigate these safety issues. An open face shield allows hazardous gasses into the tunnel at the tunnel face. SEM has greater safety risk of gas on account of greater exposure to the excavated ground. Whereas hazardous gas can be safely handled in a cut and cover excavation, a SEM-mined cavern would need significant ventilation to meet Cal/OSHA standards.

Figure 4.5-1: Flower Street Subsurface Conditions



In summary, construction of Alternative A would require ground improvement along Flower Street utilizing jet grouting for mitigation of mixed face instability and potential excess ground settlements associated with Open Face Shield and SEM tunneling. The risk assessment provided in *Draft Flower Street Tunneling Method Alternatives Report (2014)* identified that even when jet grouting is used, a high level of risk resulting in utility damages would remain due to the grouting operation, along with the high level risks of excessive settlement and tunnel failures due to incomplete coverage of the grouted mass or migration of groundwater along abandoned tie-backs located under Flower Street.

Implementation of Alternative A would result in high risk of adverse effects due to mixed face instability and potential excess ground loss, settlement, and sinkholes.

4.5.2.2 Alternative B – EPBM/SEM Low Alignment

For this alternative, EPBM-bored tunnels would be constructed on a deep alignment to south of 5th Street transitioning to SEM tunneling from south of 5th Street to the 7th Street/Metro Center Station tail tracks. The EPBM-bored tunnels would be extended to south of 5th Street in a deeper alignment to avoid abandoned tie-backs. The EPBM would be disassembled and removed through the tunnel to the Mangrove portal site with the EPBM shield left in place. For the SEM tunneling section, the single twin-track tunnel has a larger diameter and the tunnel will have varying amounts of mixed face geologic conditions in the tunnel heading. In this situation, there would be a high risk of creating sinkholes or subsidence on Flower Street. Ground improvement by jet grouting would be required for Alternative B, with approximately 1,000 grout holes required as illustrated in Figure 2.3-1.

With extension of tunneling further south to the 7th Street/Metro Center Station tail tracks structure through the use of SEM, there would be a significant increase in the amount of excavated materials being handled through the Mangrove site in Little Tokyo over the Project conditions. Cut and cover excavation materials would be handled from locations along Flower Street under the Project, while tunnel muck from the EPBM and SEM operations would be handled through Little Tokyo.

In addition, due to the potential gassy conditions under Flower Street, using SEM tunneling would have a high level of construction risks related to hazardous gas and likely require significant additional measures to mitigate these safety issues. SEM would also have a higher level of safety risk for workers due to gas conditions from the greater exposure to excavated ground. Whereas hazardous gas can be safely handled in a cut and cover excavation, a SEM-excavated cavern would require significant ventilation to meet Cal/OSHA standards.

In summary, construction of Alternative B would require ground improvement along Flower Street utilizing jet grouting for mitigation of mixed face instability and potential excess ground settlements associated with SEM tunneling. The risk assessment provided in the *Draft Flower Street Tunneling Method Alternatives Report (2014)* identified that even when jet grouting is used, a high level risk of utility damages would remain due to the grouting operation, along with the risks of excessive settlement and tunnel failures due to incomplete coverage of the grouted mass or migration of groundwater along tie-backs located under Flower Street.

Implementation of Alternative B would result in a high risk of adverse effects due to mixed face soils instability and potential excess ground loss, settlement, and sinkholes.

4.5.3 Mitigation Measures

Mitigation measures to reduce potential geotechnical impacts during construction were identified in the Final EIS for the Project; implementation of mitigation measures GT-1 through GT-21 would apply for Alternatives A and B. Below is a summary of these mitigation measures and a detailed description can be found in Appendix G:

- GT-1: Before construction, survey of structures and geotechnical/ settlement monitoring plans in place as well as gathering of soil data during and after final design
- GT-2: Use of ground improvement methods such as grouting where potential settlement during excavation
- GT-3: Grouting of tunnel alignment prior to construction to minimize settlement

- GT-4: Monitoring of settlement and leveling surveys prior to tunneling to monitor ground movement
- GT-5: Description of tunneling monitoring requirements in contract documents and soil documentation of soils encountered during construction in Geotechnical Baseline Report
- GT-6: Preparation of a Contaminated Soil/Groundwater Management Plan
- GT-7: Notification to appropriate agencies if contaminated soil or groundwater is encountered
- GT-8: Sampling of soil and/or groundwater if impacted by hazardous materials
- GT-9: Procedures for proper handling of contaminated soil and/or groundwater with regulatory agencies
- GT-10: Use of dust control measures shall be implemented for contaminated soil
- GT-11: Proper collection, treatment, and discharge of groundwater per applicable standards
- GT-12: Preparation of a Worker Health and Safety Plan
- GT-13: Appropriate measures, such as impermeable grout, to avoid spreading of contaminated groundwater
- GT-14: Testing for subsurface gases conducted along all portions of underground alignment
- GT-15: Construction will be consistent with City of Los Angeles Methane Mitigation Standards
- GT-16: Specialized excavation methods shall be implemented to protect workers and public
- GT-17: Surveying of asbestos prior to demolition and appropriate removal
- GT-18: Implementation by contractor of Best Management Practices (BMPs)
- GT-19: Consistency with municipal code requirements for structures within methane/buffer zones
- GT-20: Development by Metro of an Environmental Site Assessment program
- GT-21: Development and implementation of plans by Metro for pre-demolition and demolition abatement of hazardous building materials

The mitigated impacts of Alternatives A and B are expected to be greater than those of the Project, as even when jet grouting is used, the possibility of substantial risk of utility damages due to the grouting operation and excessive settlement would remain high.

Table 4.5-1: Summary of Benefits and Challenges of Alternative A and B

Alternative	Description	Advantages	Disadvantages
Alternative A	• EPBM to 4th Street • Open face shield TBM to 5th Street • SEM from 5th to 7th Street/Metro Center Station • Depth to top of rail: 40’ • 2nd/Hope Station depth: 96’	• Total amount of excavation materials is reduced due to replacement of cut and cover section.	• High risk of excessive settlement on Flower Street due to removal of existing tie-backs encountered by digger shield and SEM. • Removal of tie-backs encountered by digger shield and SEM would be time consuming and result in a significant delay to the project schedule. • Jet grouting is required to mitigate ground instability for digger shield and SEM excavations. • High risk of sinkholes and subsidence on Flower Street exists because of the large SEM cross section and potential imperfection of grouted ground mass; risk of tunnel collapse cannot be mitigated. • High risk of existing utilities being damaged due to jet grouting operations. • High risk of hazardous gas impacts due to open face shield and SEM excavations. • Major increase in tunnel spoils handled through Mangrove Site; would result in higher level of environmental impacts in Little Tokyo.
Alternative B	• EPBM to south of 5th Street • SEM from 5th Street to 7th Street/ Metro Center • Depth to top of rail: 40’ to 105’ (at sag) • 2nd/Hope Station depth: 128’	• Total amount of excavation materials is reduced due to replacement of cut and cover section. • Conflicts with existing tie-backs between 3rd and 4th Streets would be minimized.	• Jet grouting is required to mitigate ground instability for SEM section. • High risk of sinkholes and subsidence on Flower Street exists because of the large SEM cross section and potential imperfection of grouted ground mass; risk of tunnel collapse cannot be mitigated. • High risk of existing utilities being damaged due to jet grouting operation • High risk of hazardous gas impacts due to SEM excavations. • 2nd/Hope Station depth increase of 32 feet would increase project construction cost. • Major increase in spoils handled through Mangrove Site; would result in higher level of environmental impacts in Little Tokyo.

Note: EPBM – earth pressure balance tunnel boring machine; SEM – sequential excavation method