CHAPTER 2

Alternatives Considered

2.0 ALTERNATIVES CONSIDERED

This chapter provides the background of the Regional Connector Project (Project) and the two alternatives for tunnel construction on the Flower Street segment as directed by the U.S. District Court in the Summary Judgment Order, Order re Injunctive Relief and Judgment. The Regional Connector Project, including the Flower Street Segment evaluated in this SEIS, is illustrated in Figure 2.1-1. The Flower Street segment extends north from the existing 7th Street/Metro Center Station tail tracks structure to the south side of 4th Street. The northern limit for the Flower Street segment was identified as 4th Street as this is the location where construction of the Project and the two tunnel construction alternatives changes from tunnel boring machine to various construction techniques south to connect with the existing tail tracks structure of the 7th Street/Metro Center Station. There is no change in the location of the Project or the Project Area studied, which remains as presented in the Final Environmental Impact Statement/Environmental Impact Report (EIS/EIR).

This chapter provides a discussion of: 1) the **Project Background** with an overview of the Regional Connector Project study process, including a discussion of the alternative development and evaluation process, which resulted in the identification of the Locally Preferred Alternative (the Project), and a description of the construction methods and staging needs of the Project along the Flower Street Segment; 2) **Development of Alternatives** discussing the basis for the identification and evaluation of the tunneling method alternatives, including Flower Street segment surface and underground constraints, and the tunneling construction methods considered; and 3) **Alternatives Considered in the SEIS** providing a description of the two alternatives for tunnel construction identified as the tunneling method alternatives in this SEIS.

2.1 PROJECT BACKGROUND

This section provides an overview of the Regional Connector Project study efforts leading to the identification of the Locally Preferred Alternative (LPA) or the Project, in actions taken by the Metro Board of Directors and as documented in the ROD issued by the FTA. A description of the Project's construction methods and staging needs is provided.

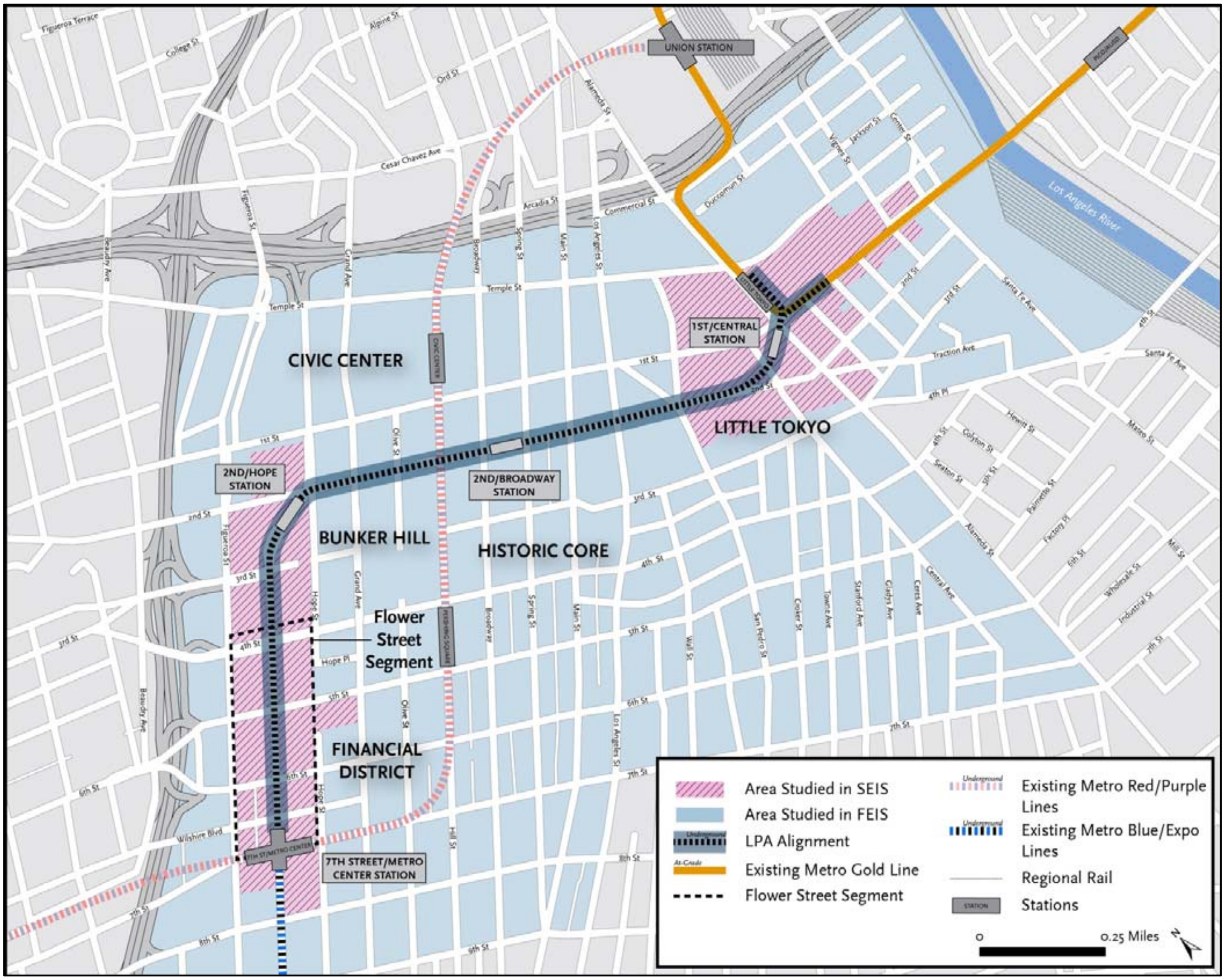
2.1.1 Efforts Leading to the Identification of the Project

Alternatives for the Regional Connector Project were identified and evaluated as documented in the *Final Alternatives Analysis Report (December 2008)*, the *Draft EIS/Environmental Impact Report (EIR) (2010)*, the *Supplemental EA/Recirculated EIR (2011),* and the *Final EIS/EIR (2012)*.

During the Alternatives Analysis (AA) study phase, an extensive outreach, research, and analytical process included the following activities:

- Comments received from community involvement activities, including meetings with stakeholders, public agencies, local jurisdictions, and the public.
- Analysis of the engineering and geographic constraints of building new infrastructure in a dense central business district.

Figure 2.1-1: Project Area from the Final EIS/EIR for the Locally Preferred Alternative



- Surveys of land use and travel patterns to determine the most ideal routes and station locations.

The AA process identified and screened 36 potential transportation alternatives in light of the project's purpose and need, goals, and objectives. The process included initial technical analyses and community and public agency feedback gathered at meetings and public workshops. Alternatives considered in the AA represented the full spectrum of reasonable means of achieving the goals and objectives of the Regional Connector project. The AA evaluated the potential alternatives based on their environmental impacts, efficiency, cost, effectiveness, and equity.

From the AA effort, the No Build, Transportation System Management, and three build light rail transit (LRT) alternatives emerged which were analyzed further in the Draft EIS and were confirmed and refined based on a unique and intense community engagement process. Based on this extensive public outreach effort, the Fully Underground LRT Alternative evolved to more adequately address the community of Little Tokyo's concerns. The Metro Board of Directors voted in February 2010 to add this alternative to the Draft EIS analysis.

On October 28, 2010, the Metro Board concurred with staff's recommendation to designate the Fully Underground LRT Alternative as the LPA, with elimination of the 5th/Flower Station, and authorized the project to proceed into the Final EIS phase. The LPA is essentially the same configuration as the Fully Underground LRT Alternative as analyzed in the Draft EIS, except that the LPA does not include the 5th/Flower Station and it has been further refined to reduce impacts. Key refinements in the Flower Street segment included creation of an enhanced pedestrian walkway along the east side of Flower Street between 4th Street and the existing 7th Street/Metro Center Station entrance. Changes were made in the Little Tokyo area, including the decision to insert the Tunnel Boring Machine (TBM) at the Mangrove property (formerly known as the Nikkei development) where it would begin excavating westward. Tunnel boring activities from the Mangrove property insertion site would allow tunneling to proceed farther down Flower Street to 4th Street instead of ending at the proposed 2nd/Hope Station.

Metro published a Supplemental Environmental Assessment (EA) document to formally introduce refinements made to the LPA (the Project) after the publication of the Draft EIS in July 2011. The Supplemental EA was recirculated through a 45-day comment period from July 22, 2011 to September 6, 2011. The preparation of the Final EIS/EIR was completed in January 2012, and the Metro Board of Directors approved the Project on April 26, 2012 with a ROD issued by the FTA on June 29, 2012.

2.1.2 Construction Methods of the Project

As discussed in the Final EIS/EIR, the Flower Street segment of the Project would be constructed with a combination of cut and cover and a tunneling method known as earth pressure balance tunnel boring machine (EPBM) method as summarized below and illustrated in Figure 2.1-2:

- 2nd/Hope Station to 4th Street – EPBM construction would be used to bore a single tunnel south to 4th Street where a reception pit would allow for the extraction of the EPBM for reuse on the second parallel tunnel drive. The use of EPBM tunneling was identified as the most viable tunneling method given the unique underground conditions along this portion of the alignment, discussed in detail below, and to be in conformance with Metro tunneling policies. The depth of the tunnel was designed to avoid conflicts with abandoned construction tie-backs and adverse impacts to the existing 4th Street Bridge foundations, to accommodate a future 5th/Flower Station, and to provide sufficient ground cover over the tunnel at the reception pit south of 4th Street. Retrieval of the EPBM would be through a reception pit that would be backfilled as part of cut and cover tunnel construction project completion activities.
- 4th Street to the 7th Street/Metro Center Station Tail Tracks – This section of the Flower Street alignment would be built with the cut and cover construction method, which would require the relocation of utilities and the installation of soldier piles to create the required alignment structure box in Flower Street from 4th to 6th Street. Excavation of the top portion of the street and provision of a temporary concrete decking system between the solider piles would

occur in a phased approach to minimize impacts to Flower Street traffic by allowing a minimum of three traffic lanes to remain open during the day time period.

2.1.3 Construction Staging for the Project

During construction, the Project, similar to any tunneling project, would require construction staging areas for:

- Equipment assembly and storage
- Construction materials delivery and storage
- Materials production
- Dewatering activities
- Construction worker parking
- Access roads
- Temporary trailer offices
- Demolition staging
- Removal of excavated materials, including truck staging areas
- Other related construction activities.

Construction staging areas are temporary as they would only be required during duration of construction activities, which is estimated to be 37 months on Flower Street and 38 months in Little Tokyo for the Project. Staging areas would be located either within the street right-of-way or in off-street locations. As documented in the Final EIS/EIR, construction staging activities in the Flower Street segment from 4th and 6th Streets would be accommodated through temporary two lane traffic lane closures for the duration of construction as illustrated in Figure 2.1-3, with some additional short-term closures for specific construction activities, such as for solder pile efforts for cut and cover construction. Street detours and closures would be coordinated with the Los Angeles Department of Transportation (LADOT).

During construction of the Project, removal of tunneling material excavated in this segment would be handled from the construction staging areas along Flower Street, while tunnel boring spoils would be transported back along the alignment within the newly constructed tunnels and removed at the Mangrove site (former Nikkei site) located at the northeast corner of 1st and Alameda Streets in Little Tokyo. As illustrated in Figure 2.1-3, the Project would use two locations within the cut and cover excavation area along the eastern side of Flower Street to remove excavation materials and allow access to construction activities under the temporary concrete decking:

- Location 1: On Flower Street, just south of 4th Street; and
- Location 2: On Flower Street, just south of 5th Street.

Figure 2.1-2: Flower Street Segment Construction Methods of the Project

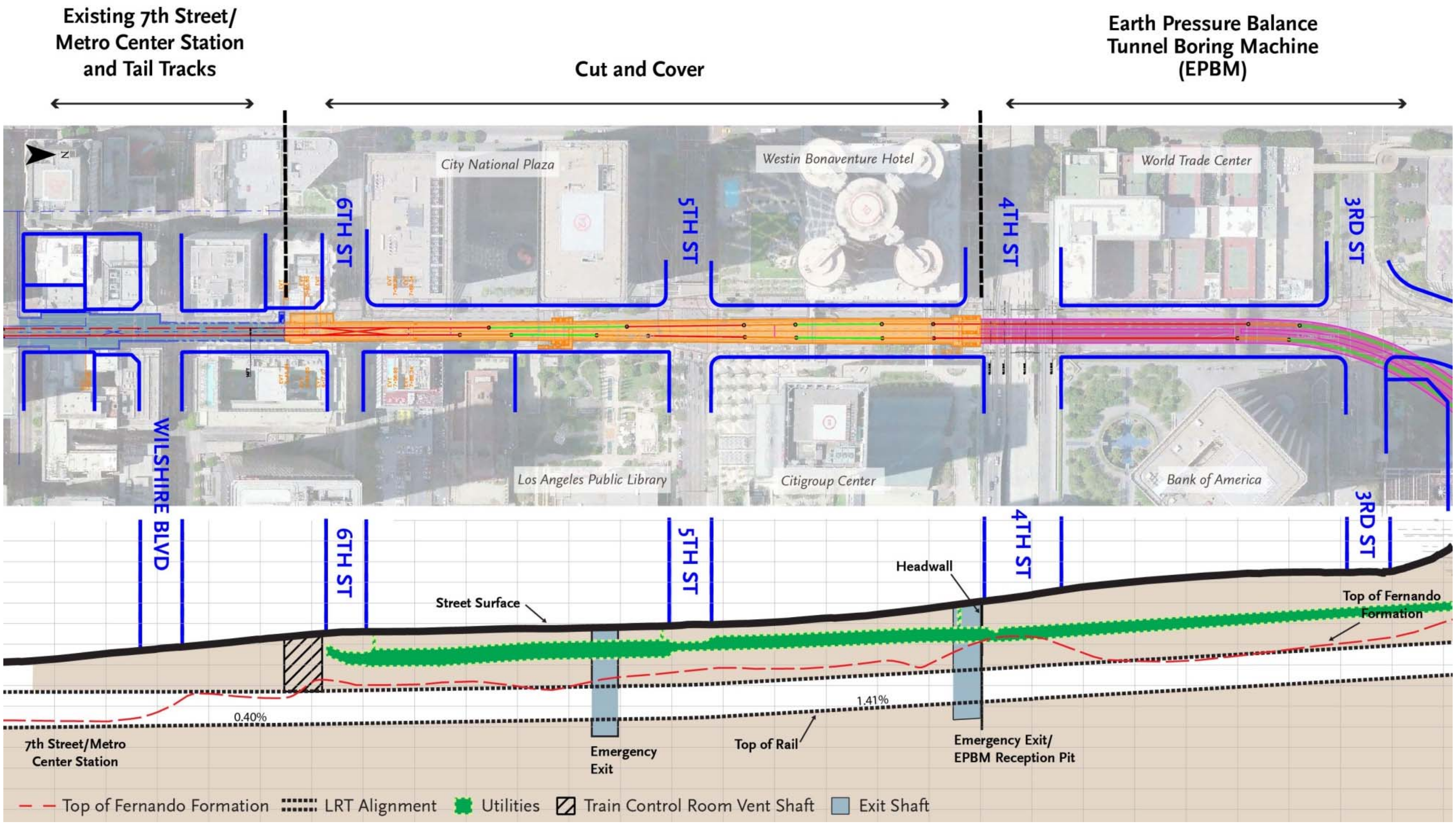
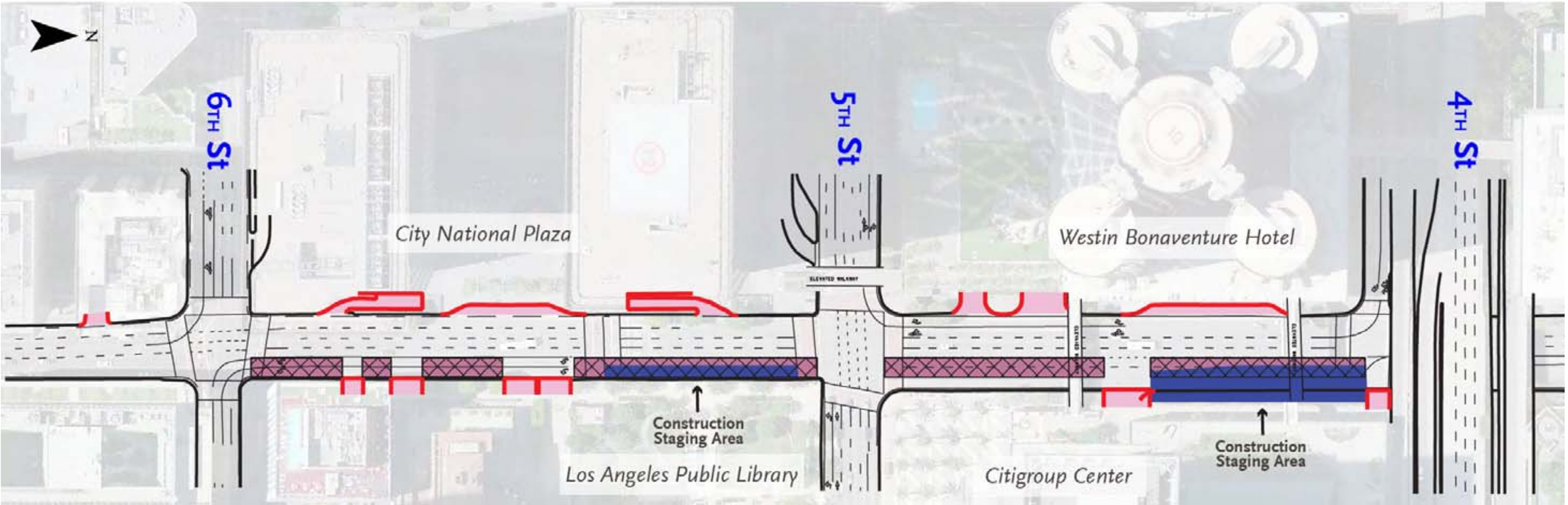


Figure 2.1-3: The Project – Construction Staging Areas



LEGEND

- 2-Lane closure for duration of construction
- Existing Driveways
- Underground Construction Access Locations

2.2 DEVELOPMENT OF ALTERNATIVES

This section presents the basis for identifying and evaluating the tunneling method alternatives in the SEIS. It includes a discussion of the Flower Street segment surface and underground constraints, Metro Rail Design Criteria (MRDC), and the tunneling construction methods that shaped the Project and the tunneling method alternatives. This section's discussion draws on and reflects the *Final Flower Street Tunneling Method Alternatives Report (2015)* (Appendix A) prepared to document engineering and construction study efforts to identify and evaluate viable tunneling method options. This effort resulted in the identification of two possible tunneling method alternatives for further evaluation. The alternatives presented in the following section of this chapter, Alternatives A and B, are the same as Alternatives A and B discussed in the tunneling method alternatives report.

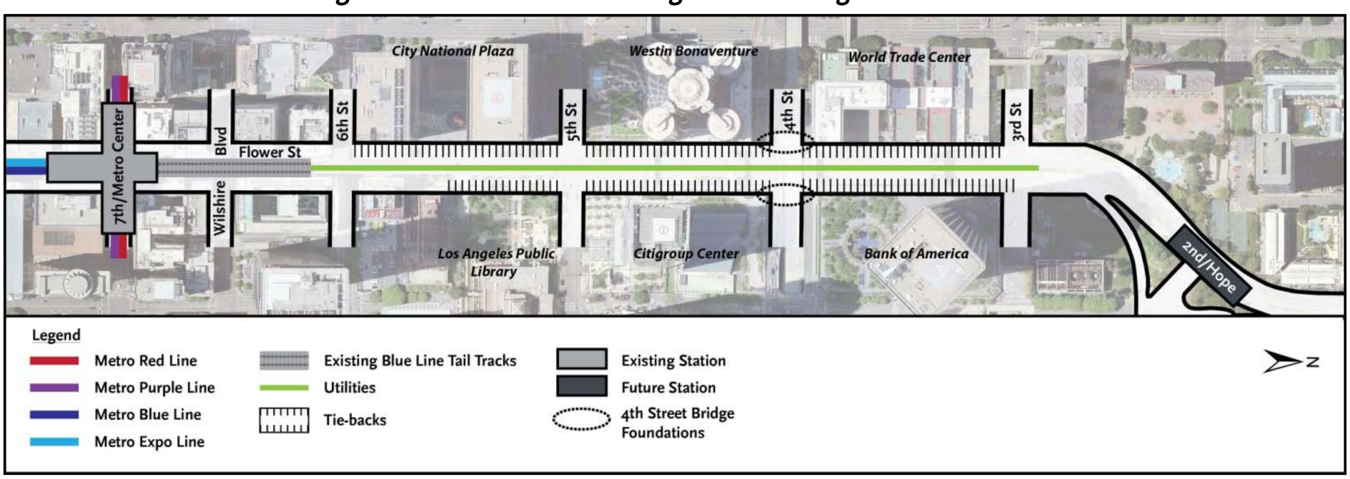
Alternatives A and B propose different combinations of underground construction methods as alternatives to the cut and cover method planned for the Project along Flower Street between 4th Street and 7th Street:

- Alternative A considers an open-face tunnel shield to construct a portion of the tunnels from 4th Street south to approximately 5th street followed by SEM construction of the balance of the tunnels and double crossover to the existing 7th/Street Metro Center Station.
- Alternative B considers extending EPBM tunneling on a lower alignment to avoid tie-backs from 4th Street south to approximately 5th Street followed by SEM construction of the balance of the tunnels and double crossover to the existing 7th/Street Metro Center Station.

2.2.1 Flower Street Existing Conditions

There are a significant number of surface and underground constraints combined with the requirements of the MRDC and desired future operations of the Regional Connector Project that have framed the design and construction of the Flower Street section, as illustrated in Figure 2.2-1.

Figure 2.2-1: Flower Street Segment Existing Conditions



Metro

2.2.1.1 Flower Street Segment Surface Context and Constraints

Flower Street has surface constraints to future subway construction which includes possible impacts to vehicular, bus, and shuttle traffic, impacts to pedestrian and bicycle circulation, and restricted access to off-street parking and adjacent properties. Flower Street is a one-way southbound major arterial ranging in width from five lanes between 3rd and 6th Streets to four lanes south of 6th Street. The street is heavily used by cars, local delivery trucks, buses, shuttles, and bicycles without a designated bike lane. There is heavy pedestrian activity on the sidewalks on both sides of the street, which is heaviest on weekdays with growing activity on weekends due to increasing numbers of residents and visitors.

Flower Street is lined with a diverse land use mix including high and mid-rise buildings consisting of commercial, office, hotel, and residential properties. Some of the specific properties include the Citigroup Center and Bank of America along the east side of the street, and the City National Plaza and World Trade Center on the west side; mid-rise office buildings converted to residential uses; the Standard Hotel and Westin Bonaventure Hotel; the California Club and Maguire Gardens; and the Los Angeles Central Library garage.

2.2.1.2 Flower Street Underground Context and Constraints

There are significant underground constraints which pose challenges to the design and construction of the future rail tunnel on the Flower Street segment of the Regional Connector Project. These constraints include: 1) connecting with the existing narrow, shallow rectangular tail tracks structure of the 7th Street/Metro Center Station; 2) numerous abandoned underground tie-backs (used to support the excavation of building foundations) extending into the path of the future rail tunnel from adjacent building foundations along both sides of Flower Street south of 3rd Street; 3) unstable soil conditions; 4) many utilities; and 5) the 4th Street Bridge foundations which restrict the location of a future rail tunnel to a narrow vertical and horizontal corridor between the foundation piers.

Metro Rail Design Criteria (MRDC) has been developed and documented to reduce construction risks and to ensure the design and construction of rail system projects will meet Metro's long-term operational requirements. For the Flower Street segment of the Regional Connector project, MRDC criteria were used to design the Project and to evaluate the two tunneling method alternatives. In addition to the very constrained physical setting noted above, the design of the Project and two tunnel alternatives included rail transit operational considerations to address: 1) the alignment and grade of the connection with the existing 7th Street/Metro Center Station; 2) provisions for a new track crossover; 3) accommodation of a future 5th/Flower Station; and 4) design of the vertical alignment to facilitate the final operational speed of this vital central regional segment in the Metro light rail transit (LRT) system which will carry more trains than any other rail segment in Los Angeles. Changes to the vertical alignment will have potential impacts to the depth of the 2nd/Hope Station.

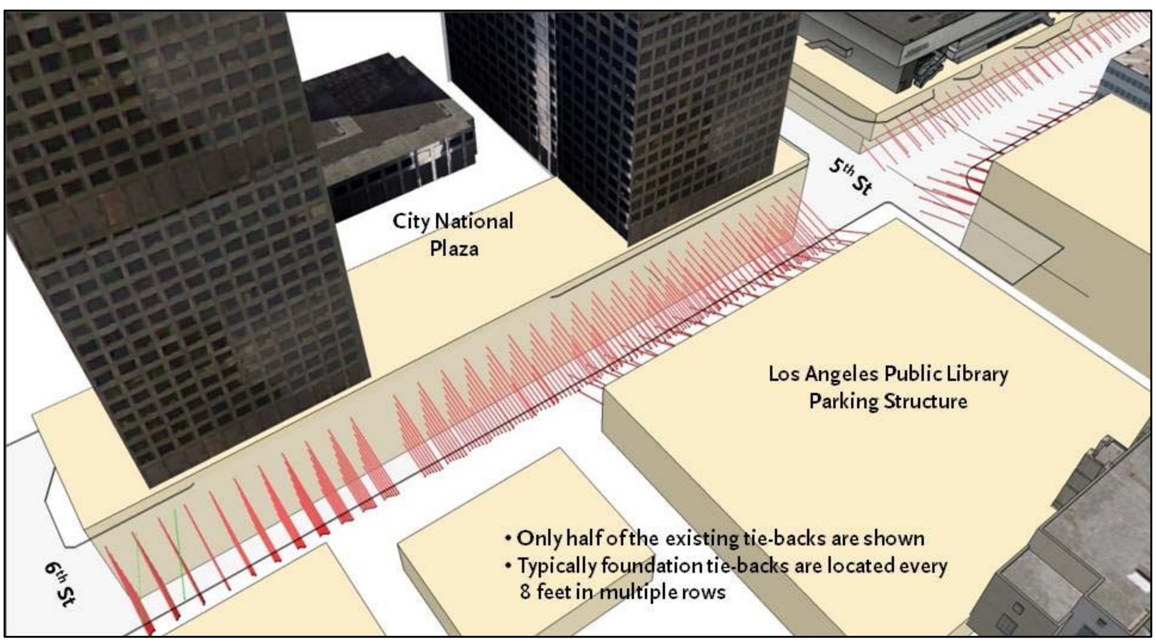
Connection to Existing 7th Street/Metro Center Station

In the Flower Street segment, the Regional Connector project alignment will connect with and operate from the existing 7th Street/Metro Center Station tail tracks structure located just north of the station's side loading platforms. Any tunneling connection must be designed to consider the fit with the geometry and size of the tail tracks structure as well as the alignment gradient required to ensure a smooth operational connection. In addition, a new double track crossover will be necessary north of the existing tail tracks as the Regional Connector project is a trunk system which will accommodate a significant number of LRT system trains. As identified in the MRDC, this new double crossover with No. 10 turnouts will provide operational flexibility during single-track operations, such as when one track is required to store a disabled train.

Tie-Backs

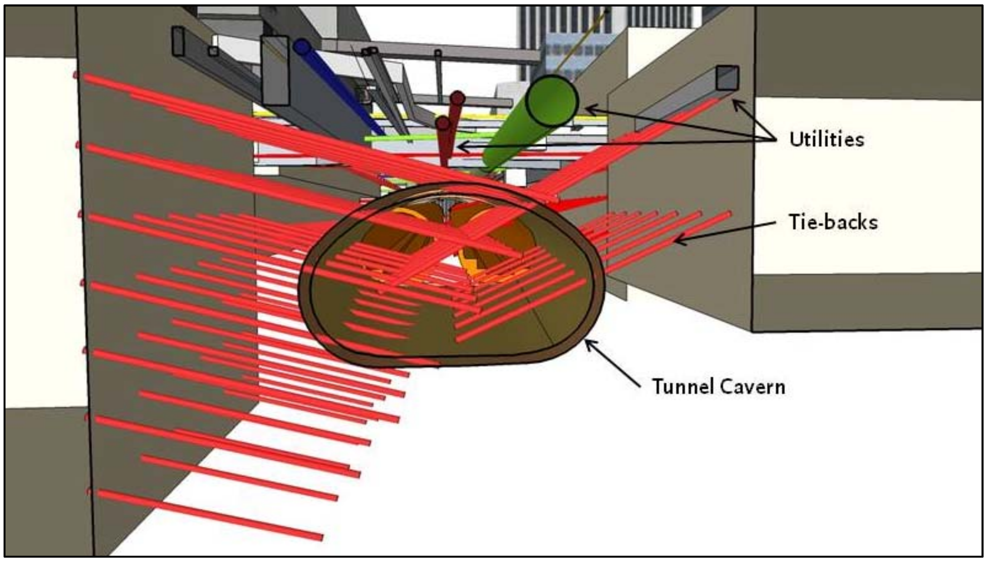
Tie-backs consisting of steel bars or cables grouted in the ground were used to laterally support the excavations for and construction of parking and building foundations for the Los Angeles Central Library garage, the Citigroup Center, and Bank of America along the east side of Flower Street, and the City National Plaza, Westin Bonaventure Hotel, and World Trade Center on the west side as shown in Figures 2.2-1, 2.2-2, and 2.2-3. Following industry practice, these tie-backs were abandoned within the street after construction was complete but it is uncertain if the tie-backs were de-tensioned. Along Flower Street, steel tie-backs are typically located every six to eight feet, and range in size from 30 to 90 feet in length, and extend below ground at a 15 to 45 degree angle across the width of the street right-of-way from both sides. There are multiple rows consisting of hundreds of tie-backs forming a “mesh” that are located within the Flower Street segment tunnel alignment, particularly south of 4th Street and with an even higher density south of 5th Street.

Figure 2.2-2: Overview of Flower Street Tie-back Locations



These tie-backs pose a major obstruction to tunnel construction under Flower Street, particularly for tunnel boring machines whose cutter heads could become entangled with the steel and cable tie-backs. Any construction method used on Flower Street must address removal of tie-backs by torch cutting or avoidance through a deeper alignment. Tie-backs pose another risk to tunneling activities as many of the existing tie-backs were installed when quality control of hole drilling and concreting was not as well-developed as it is today, and the tie-backs may become pathways for surface or groundwater to flow into the tunnels or excavation areas. During tunneling, groundwater flow along the edge of the tie-back can erode the surrounding soil resulting in potentially large amounts of soil and water flowing into the tunnel. If uncontrolled, this can progressively lead to ground settlement, which if allowed to continue can create a sinkhole at the ground surface.

Figure 2.2-3: Flower Street Segment Cross Section at Tunnel Cavern before Transition to Twin Tunnels (South of 5th Street) showing Tie-backs



Ground Conditions

The geologic conditions include the presence of groundwater, unstable soils, a challenging geologic interface between different soil or rock strata (mixed face), and hazardous gases. A description of these conditions and the challenges they pose to tunneling are presented below.

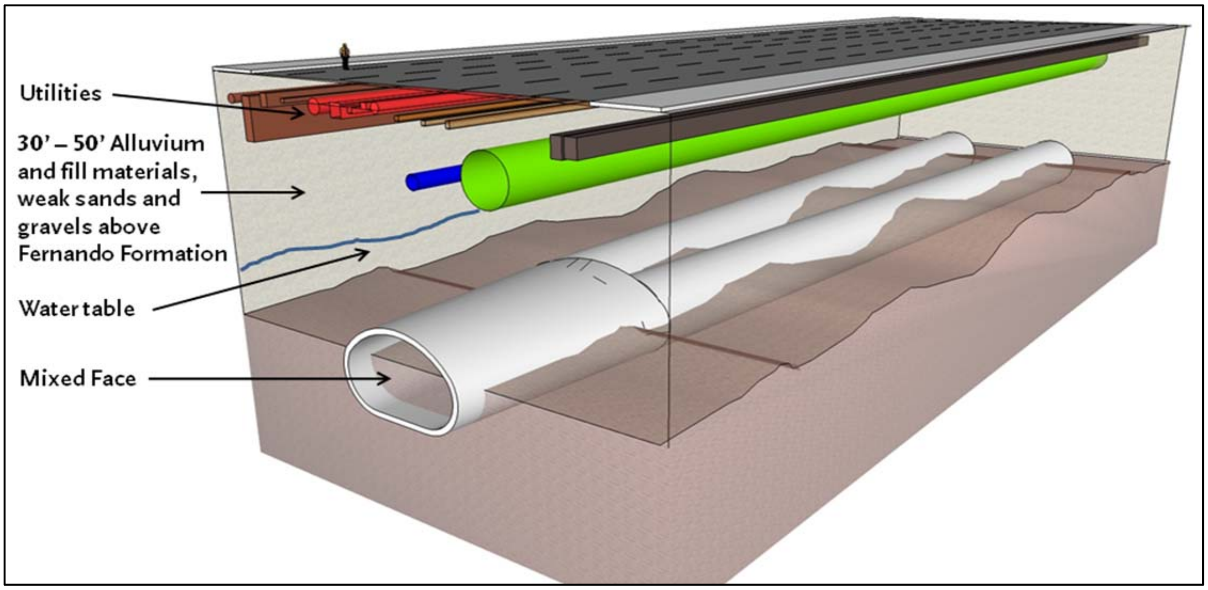
Before development of downtown Los Angeles, Flower Street served as a natural drainage path which became a stream during rainfall with seasonal variations of groundwater below ground. Today, development has affected groundwater flow due to cuts and fills altering the street's topography, the leveling and paving of streets, and constructing of buildings with deep parking structures. Groundwater is anticipated to follow the historic underground water course and pose problems for the stability of open-face tunnel excavations. Borings made for building sites along Flower Street between 5th and 7th Streets have encountered groundwater seepage at relatively shallow depths ranging from 15 to 35 feet, which is close to or within the proposed tunnel envelope. Groundwater within the lower portion of the alluvial deposits, most likely perched above the Fernando Foundation, has been reported at depths of 18 to 27 feet adjacent to Flower Street between 2nd and 5th Streets.

Ground conditions under Flower Street consist of fill and alluvial soils overlaying the Fernando Formation found at approximately 40 feet below ground surface, as shown in Figure 2.2-4:

- The fill is a combination of gravel, sand, silt, and clay mixed with construction debris. The depth of fill material varies along Flower Street.
- The water-bearing alluvial deposit consists of interlayered silty clays, sandy silts, clayey sands, and silty sands, with some sand layers containing variable gravel and cobbles.

- The Fernando Formation is primarily comprised of weak to very weak siltstone/claystone.

Figure 2.2-4: Flower Street Segment Ground Conditions



The Fernando Formation is comprised of a "weak" to "very weak" mix of siltstone and claystone which is a qualitative statement about its relative strength to support tunneling based on its unconfined compressive strength and the rock strength category of the International Society of Rock Mechanics (1978). The siltstone and claystone are weakly cemented or held together, which does not provide a strong condition for tunneling with an unsupported face, especially near the interface between the fill and alluvial soils and the Fernando Formation.

The geologic interface where the alluvial soils meet the Fernando Formation is a recognized geologic tunneling hazard. If the tunnel is located fully below the geologic interface, and there is adequate depth in the Fernando Formation (one tunnel diameter or approximately 22 feet) between the top of the tunnel and interface, tunneling risks are reduced. High tunneling risks occur when the geologic interface is located just above the tunnel, or within the face ("mixed face") of the tunnel being excavated.

When tunneling through weak rocks, the "stand-up" time, or the time the rock could accommodate an unsupported tunnel face, would not be long enough to avoid a collapse and ground loss resulting in tunnel failure without ground stabilization. Ideal tunneling conditions are competent ground void of water without any mixed-face conditions or obstructions with good "standup" time that accommodates an unsupported mining face for several hours without the risk of ground loss and resultant settlement. The existing top layer of alluvium, fill materials, sands, and gravels is unstable and not suitable for tunneling purposes without significant ground stabilization efforts as discussed below in Section 2.2.3.5. Even with extensive ground stabilization, such as grouting, total ground stability is not assured given the geologic conditions along Flower Street.

The major ground condition hazard on Flower Street is the alluvial materials running in an uncontrolled flow into the tunnel, and with the presence of groundwater, that risk is increased.

Typically these risks are mitigated by either modifying the soft ground using grouting techniques to create ground conditions that inhibit water flow or through the use of pressurized-face (closed-face) TBMs, which can safely deal with such conditions with limited risk of ground loss.

In the past, both sides of the current I-110 Freeway were lined with oil wells. Today, construction still encounters methane and hydrogen sulfide (H2S), with recent methane gas occurrences observed during construction of the Wilshire Grand Plaza located at Figueroa and 7th Streets one block west of the Flower Street alignment. Several sections of the project tunnels will be constructed through Methane Buffer Zones; and Cal/OSHA has classified all of the underground construction for the Regional Connector as "potentially gassy." Metro requires specific designs and tunneling methods where gassy conditions are present including the use of pressurized face tunnel boring machines and the installation of double-gasketed segmental precast tunnel lining to prevent methane from entering the tunnels.

The aforementioned geologic conditions on Flower Street can contribute to ground instability, ground loss, and settlement if not addressed by the construction method including cut-and-cover or tunneling with ground stabilization techniques, such as grouting, to reduce the risks. Even with grouting, total ground stability during tunneling is not assured given the geologic conditions along Flower Street.

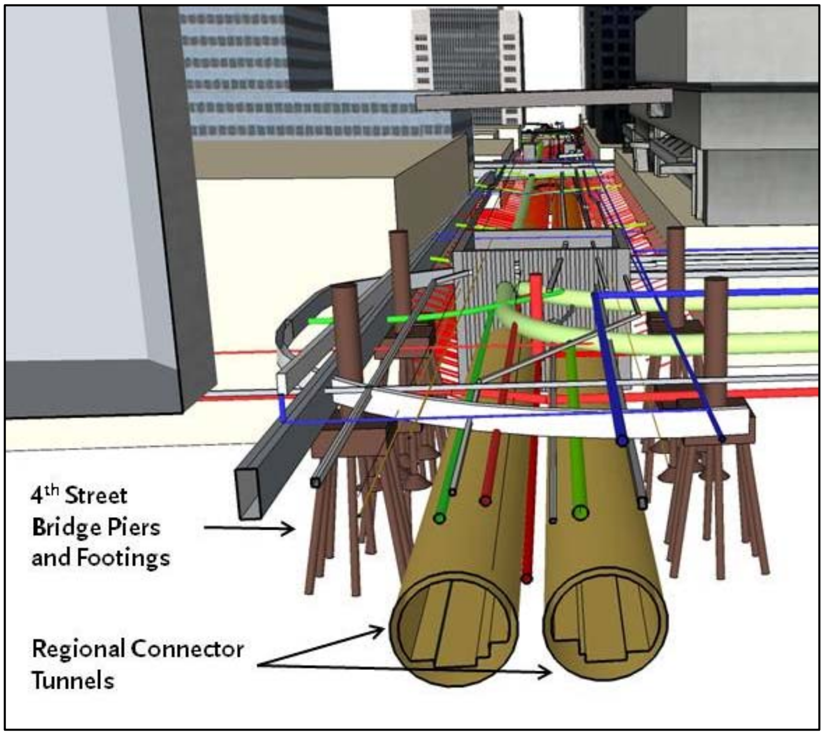
Utilities

Construction of underground stations and guideway tunnel structures would result in impacts to existing utilities located under Flower Street. The utilities include gas, electricity, water, sewer, communication lines, and storm drains. The storm drains range in size up to an 84-inch diameter reinforced concrete pipe approximately 18 feet below the ground surface. Utility relocation will be required as part of the project for impacted utilities, regardless of the construction technique. Impact mitigation to existing utilities is typically provided by relocating and/or protecting the utilities in place. For the Project, utilities would be protected by hanging them underneath the street decking system provided in the cut and cover sections on Flower Street with construction occurring below the utilities. The exception is those utilities that are in conflict with installation of the street decking and support of excavation structures. For the other identified tunneling methods, such as the use of tunnel boring machines, utility relocation would be necessary for utilities that are located within a three to four foot zone known as the "support of excavation system corridor" around the tunnel. As discussed below in Section 2.2.3, tunneling methods other than cut and cover in the Flower Street segment have been identified as requiring ground stabilization due to poor ground conditions as discussed above and illustrated in Figure 2.2-4. The recommended ground stabilization technique is high-pressure grouting to stabilize ground conditions to enable tunneling.

4th Street Bridge Foundations

The 4th Street Bridge crosses Flower Street at a raised elevation to connect the west side of downtown with the higher Bunker Hill area to the east. The bridge is built on four sets of bridge piers located on either side of Flower Street with foundations that extend 64 feet below the surface on the west side and 83 feet below on the east side as shown in Figure 2.2-5. These foundations include piles that are "battered" or slanted at approximately 10 degrees from the vertical. Any tunnel located in this portion of Flower Street must "thread the needle" between these piers, or use a deeper alignment to avoid impacting the piers.

Figure 2.2-5: Flower Street Segment: 4th Street Bridge Foundations Looking South from 3rd Street



Future 5th/Flower Station

While the 5th/Flower Station is not included in the funded Regional Connector project, the Flower Street segment is required by action of the Metro Board of Directors to be designed and constructed so as not to preclude a future 5th/Flower Station. This station would be constructed between 4th and 5th Streets under Flower Street. Based on the MRDC, the future station should be built on a 370-foot long tangent alignment with a maximum vertical grade of one percent. The Project alignment using cut and cover construction allows for the construction of a station in the future. The ability of each of the tunneling alternatives to accommodate a future 5th/Flower Station is discussed in Section 2.3 of this chapter.

2nd/Hope Station

The Flower Street portion of the Regional Connector project has the challenge of connecting at one end with the existing and relatively shallow 7th Street/Metro Center Station tail tracks structure (42 feet from the surface to top of rail) and at the other end with the future 2nd/Hope Station located under Bunker Hill at a depth of 96 feet from top of rail (TOR) to the ground surface. This proposed station depth is due to the significant elevation variation from Flower Street to the higher Bunker Hill area where the 2nd/Hope Station is located. As the TOR elevation is fixed at the existing station and tail tracks, any modification to the project's vertical alignment depth along Flower Street, such as proposing a deeper alignment to avoid conflicts with the hundreds of tie-backs located under the street, may impact the elevation of the future 2nd/Hope Station. A deeper alignment along Flower Street would require shifting the 2nd/Hope Station even deeper resulting in higher risks associated with the construction of a deeper station.

2.2.2 Little Tokyo

Any changes to tunneling methods on Flower Street would have impacts in the Little Tokyo area. A deeper tunnel alignment to avoid tie backs in order to tunnel further under Flower Street than proposed in the Project would increase the amount of tunnel excavation materials to be handled through the tunnel portal at the Mangrove site in Little Tokyo. Under the Project, 81 percent of the tunnel excavation materials from construction of the Flower Street segment would be handled on Flower Street and 19 percent through the Mangrove site. Any reduction in cut and cover construction and the related reduction in the handling of the excavation materials along the Flower Street segment would increase the quantity of tunnel muck excavation materials at the Mangrove site in Little Tokyo.

2.2.3 Tunnel Construction Methods

This section provides an overview of tunnel construction methods considered for the Flower Street portion of the Regional Connector, both through the AA/DEIS/FEIS process described in Section 2.1.1 and for this SEIS as documented and supported in the *Final Flower Street Tunneling Method Alternatives Report (2015)* (Appendix A). This report documented engineering and construction evaluation efforts to identify viable tunneling method options if possible to the planned cut and cover construction, and resulted in the identification of two possible construction method alternatives for further evaluation in this SEIS. As discussed below, the alternative construction methods considered include: earth pressure balance pressurized face tunneling, sequential excavation method, and open-face shield tunneling. Ground improvement techniques required to support implementation of the proposed tunneling alternatives are also discussed.

2.2.3.1 Cut and Cover Method

Cut and cover is a tunneling excavation method in which a concrete deck is installed over the underground construction site to minimize disruption to surface street operations, while allowing for construction activities to occur below. The excavation support system provides temporary support for the adjacent ground while the permanent cast-in-place concrete structures are constructed. The deck is then removed and the excavation is backfilled and the street is restored. This construction method involves a sequence of five activities illustrated in Figure 2.2-6. Cut and cover has been successfully used on past Metro rail projects, where the excavation support system of braced soldier pile and lagging minimized settlement and accommodated surface traffic operations and underground utility requirements. This construction technique is relatively unaffected by the variations and uncertainty related to the presence of man-made and natural obstructions and geologic conditions, such as those that exist along Flower Street.

Key benefits of this method for the Flower Street segment is that it allows for the easy removal (cut in place) of tie-backs as they are encountered during excavation, and that the support system can be revised to adapt to unforeseen underground conditions. Given the challenging geologic conditions in this segment, including perched groundwater and a geologic strata consisting of fill and alluvium over "weak rock," can be managed based on past cut and cover construction experience in downtown Los Angeles. The presence of weak rock, which is generally stiffer than the alluvium, provides for positive conditions for excavation stability with the soldier piles drilled into the relatively stiff Fernando Formation.

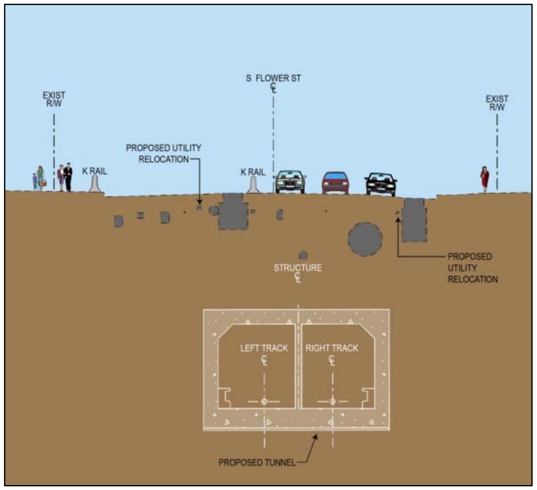
As this method has been used successfully for construction of all of the underground transit stations and major modern buildings in downtown Los Angeles, cut and cover was identified as the preferred construction method for the Flower Street segment of the Project north from the 7th Street/Metro Center Station tail tracks structure to the southern side of 4th Street, where tunnel construction would shift to the use of an EPBM tunnel boring machine. Small segments of the tunneling method alternatives studied in this SEIS also would be constructed with the cut and cover method, including shafts for tunnel boring machine retrieval, emergency exits, and a train control room.

2.2.3.2 Earth Pressure Balance Tunnel Boring Machine Method

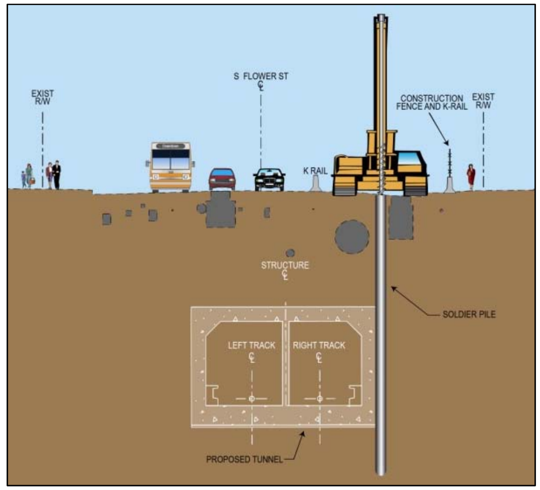
Earth pressure balance tunnel boring machines, commonly known as EPBMs, are one type of a pressurized face tunnel boring machine. EPBM refers to a pressurized closed-face TBM with the ability to apply pressure in the cutterhead chamber that is equal to the pressure of the ground being excavated by the rotating cutterhead located at the front of the machine as shown in Figure 2.2-7. The cylindrical shield behind the cutterhead is sealed and provides ground support accommodating safe installation of the tunnel lining. The soil excavated by the cutterhead is removed as a semi-solid in muck cars by rail or a conveyor as shown in Figure 2.2-8. EPBMs are most suitable for tunneling through soft soil and weak rock. They are the preferred type of tunnel boring machine for tunneling in the Los Angeles area due to past experience.

Pressurized face tunnel boring machines became the tunneling method of choice for underground rail projects in the Los Angeles area following the Metro Red Line construction experience with open-face tunneling, which resulted in excessive settlement on Hollywood Boulevard. Based on the recommendations of a specially convened Metro Tunnel Advisory Panel in 1995 the Metro Board instituted the policy to reduce or avoid construction risk of excessive settlement resulting from use of open-face tunnel shields by requiring pressurized-face (EPBM) tunneling. Since then, pressurized closed-face TBMs, and specifically EPBMs, have been used successfully for Metro Projects, such as the Metro Gold Line Eastside Extension project.

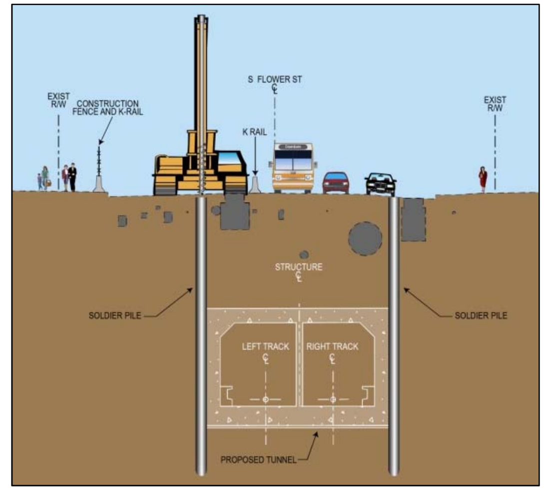
Figure 2.2-6: Cut and Cover Construction Method Stages



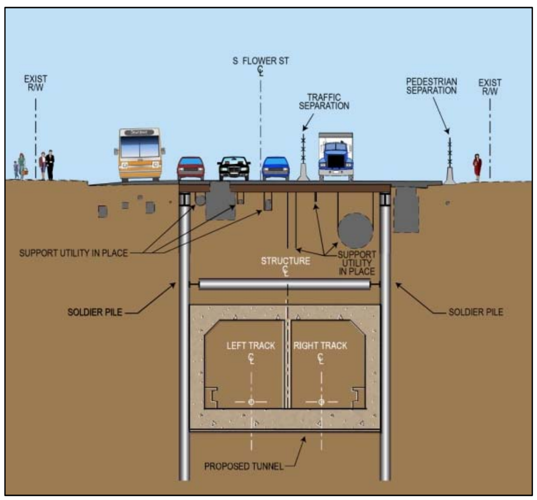
STAGE 1: Relocate Utilities



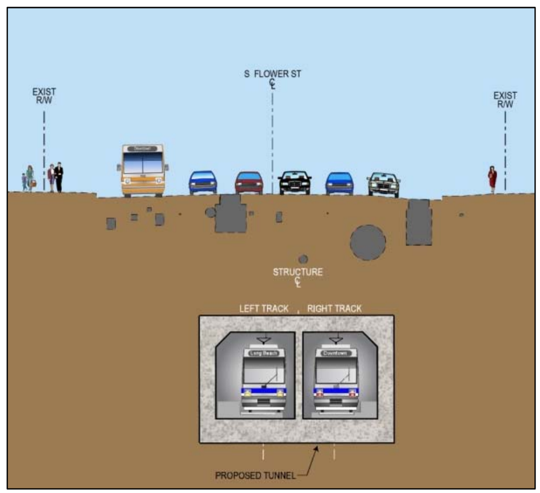
STAGE 2: Install soldier piles and construction shoring system



STAGE 3: Complete shoring system and excavate down from ground surface



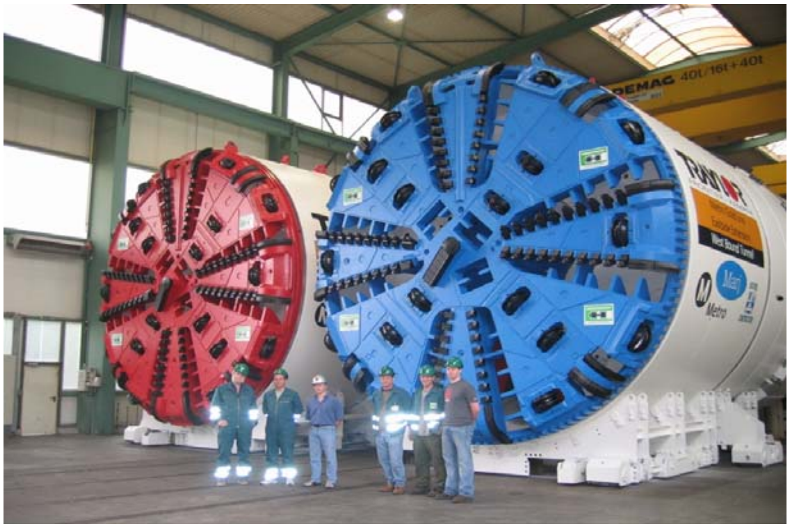
STAGE 4: Place a temporary concrete deck over excavated area and construct rail tunnel



STAGE 5: Backfill and restore surface once tunnel box is complete

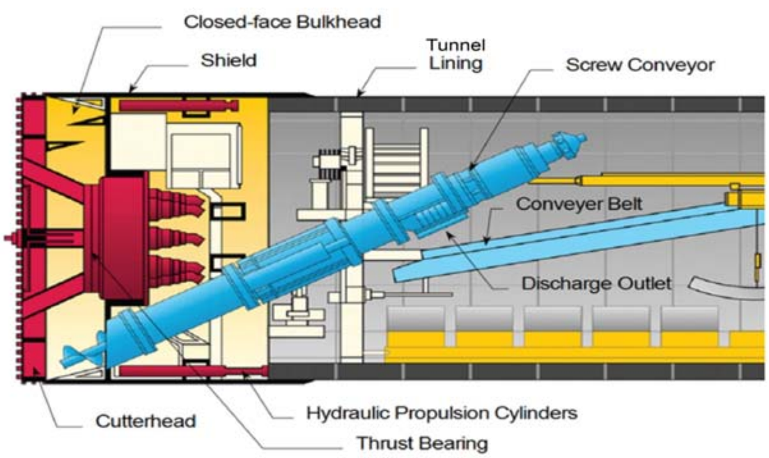
Metro

Figure 2.2-7: EPBMs Used for Construction of Los Angeles Eastside LRT Tunnels



The primary risk to the use of EPBMs under Flower Street is the presence of the many tie-backs. These represent a hazard to closed-face tunneling as the cutterhead is not capable of "chewing-up" or otherwise processing the steel tie-backs. If tie-backs were to become entangled with the cutterhead, the entangled and displaced tie-backs could disturb surrounding soils causing raveling of the adjacent ground resulting in settlement beneath utilities, roadway surfaces, and adjacent structures. To remove tie-backs in advance of the EPBM requires a very hazardous and time consuming process working through the spokes of the cutterhead or ahead of the cutterhead to manually cut and remove the tie-backs. For the Project, the overall risk in encountering the numerous tie-backs along Flower Street will be reduced through the recommended use of cut and cover construction south from 4th Street with EPBM tunneling only north of this location where tie-back locations are minimal and fairly well known.

Figure 2.2-8: Cross-section of Typical EPBM



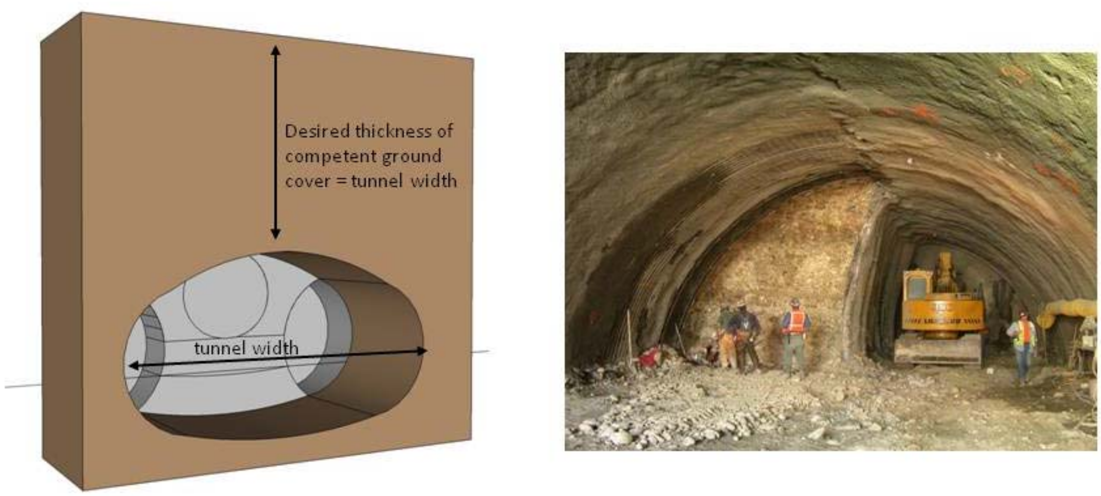
For the Project, EPBM tunneling has been recommended for use along Flower Street between the south side of 4th Street north to the 2nd/Hope Station with the provision that limited number of tie-backs are identified and removed in advance of tunneling by excavating tie-back removal pits with cut and cover techniques to remove the tie-backs within the tunnel corridor.

The two tunneling method alternatives studied in the SEIS assume that tunneling from Little Tokyo to the 4th and Flower Street intersection would be constructed as defined in the Project using EPBMs. Alternative B evaluates the extension of EPBM tunneling activities further south to the south side of 5th Street.

2.2.3.3 Sequential Excavation Method

Sequential Excavation Method (SEM) is a tunnel mining method that involves a sequence of excavation and installation of initial ground support systems, shown in Figure 2.2-9. In soft ground conditions, it typically uses conventional excavation equipment, such as excavators or roadheaders, together with an initial ground support system including lattice girders and sprayed-on concrete (shotcrete). SEM was considered for the Flower Street portion of the Project, but was identified as having a high risk for creating possible ground collapse and settlement conditions due to the shallow tunnel cover and unstable soil conditions. It is preferable to use SEM in deep tunnel alignments with adequate ground cover and favorable ground conditions not requiring extensive ground stabilization, such as through the use of grouting.

Figure 2.2-9: SEM Construction Technique



Industry practice: Ground cover should be no less than the width of the tunnel excavation.

Small tunnel sections are excavated and temporarily supported in a specific sequence.

SEM risk is reduced with a layer of competent ground cover above the tunnel equal to or greater than the width of the tunnel. Less cover increases the risk of ground settlement and large ground loss, and requires the use of extensive pre-support and ground stabilization efforts. If used on Flower Street, the SEM excavation would be approximately 60 feet in width to accommodate the two track system and double crossover. An SEM excavation of this size would require a suitable ground cover of 60 feet or more. Due to the alignment and grade constraints, an SEM tunnel on Flower Street would only have approximately 20 feet or less of poor soil cover. The low cover combined with ground water and gas conditions and a close proximity to utilities result in a high risk for excessive ground settlement, subsidence, or collapse. In addition, SEM relies upon the natural arching effect of the ground, and minimal arching is anticipated under Flower Street due to low ground cover, poor ground, and existing utilities. Use of SEM would require extensive use of ground stabilization, such as grouting discussed below. Even with grouting, total ground stabilization is not assured given the geologic conditions along Flower Street, and the high risk for ground settlement would remain.

While tie-backs, shown in Figure 2.2-10, would be directly removed from the tunnel face under SEM, the absence of a tunnel shield, which stabilizes the soil, increases the risk of creating unstable conditions where mixed-face conditions are present, as they are along Flower Street. Tie-backs can act as conduits for water to enter tunnel excavations, and may block effective grouting efforts.

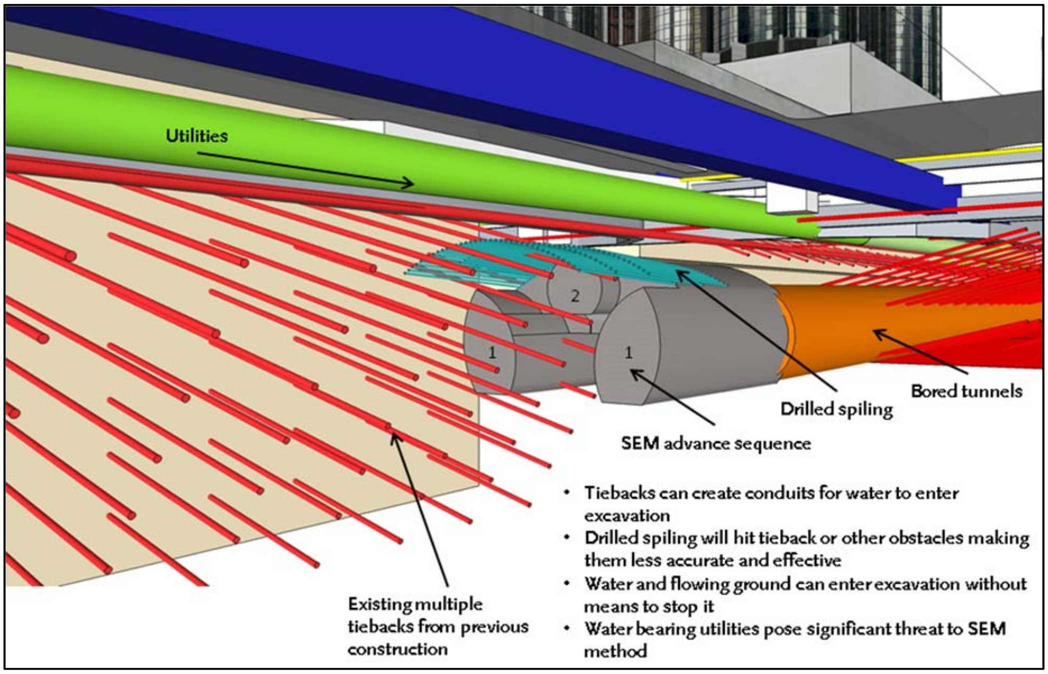
For the Project, SEM has been recommended for use in portions of the project alignment with stronger soil conditions and for smaller spaces, such as cross passages. Use of SEM has been identified and evaluated for construction of the two tunneling method alternatives in the portion of the Flower Street alignment that connects south from 5th Street to the 7th Street/Metro Center Station and tail tracks structure as described in Section 2.3, Alternatives Considered in the SEIS as follows:

- Alternative A – Open-face shield tunneling to just south of 5th Street where construction would change to SEM for one block to the south side of 6th Street where construction would become cut and cover to provide the connection to the existing 7th Street/Metro Center station tail tracks structure; and
- Alternative B – Earth pressure balance tunnel boring machine (EPBM) to the south side of 5th Street where construction would change to SEM for approximately one-and-a-half blocks to connect with the existing 7th Street/Metro Center station tail tracks structure.

During initial preparation of this SEIS, an alternative using SEM construction for the Flower Street segment from south of 4th Street south to the 7th Street/Metro Center Station, or possibly a full SEM alternative was considered. The use of SEM construction in the 4th to 5th Street Flower Street segment or further north to 3rd Street was identified as having a significantly higher risk than construction using an open-face shield or EPBM tunnel boring machine due to the existing ground conditions, and was removed from further consideration.

An SEM alternative would have a high risk for excessive settlement, uncontrolled subsidence, or collapse due to the width of the tunnel compared to the minimal thickness of poor soil cover possible along Flower Street. SEM increases the risk of tunnel collapse and threatens public and worker safety due to the absence of a tunnel boring machine (TBM) shield which assists in supporting the Flower Street segment's weak ground. Potential mitigation against subsidence or tunnel collapse with SEM methods, such as a pipe canopy or other support system, would be inadequate and too costly and slow to implement an SEM alternative.

Figure 2.2-10: SEM Construction Through Flower Street Tie-backs Looking North



2.2.3.4 Open-Face Shield Tunneling

An open-face TBM also called a "digger shield," is a steel shield equipped with an excavator like a backhoe to excavate the tunnel. The excavated material (muck) is moved by the excavator through the shield to muck cars or conveyor systems behind the shield. The shield provides ground support for erection of the precast segmental lining behind the excavator as the machine advances forward. The disadvantage of open-face tunnel boring machines compared to a pressurized closed-face TBM is the inability to support the face and prevent ground loss and groundwater and gas inflows. Ground control risks are always present when an open tunnel face is in alluvium and where water is present, or where a mixed-face heading is present, such as alluvium over the Fernando Formation, as occurs along Flower Street, as shown in Figure 2.2-4. In such conditions, the ground at the heading of the open-face shield could become unstable with a high risk of unacceptable loss of ground, raveling, running, or flowing of disturbed soil into the tunnel heading all of which can result in excessive ground settlement and possible creation of a sinkhole at the ground surface.

This was the case during the construction of the Metro Red Line A146 contract (segment between Pershing Square and 7th Street/Metro Center stations) when the tunnel was constructed using the open "digger" shield shown in Figure 2.2-11. In portions of the alignment, the upper part of the tunnel encountered cohesionless sand, which ran uncontrolled into the tunnel face and created a void ahead of and over the tunnel shield. A number of ground losses occurred during tunneling with volumes as great as 36 cubic yards (more than the size of a full-size automobile). Further surface settlement was avoided by a soil stabilization program consisting of holes drilled from the ground surface to backfill the voids created by the ground losses with concrete, known as compaction grouting.

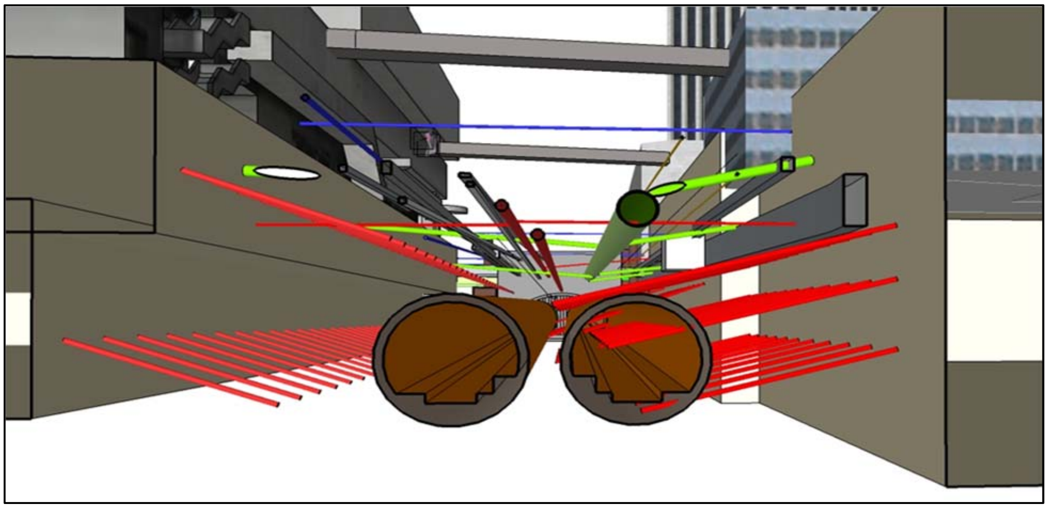
Figure 2.2-11: Open-Face of Digger Shield used to Construct Metro Red Line Contract A146 Tunnels

Open-face shield tunneling has the advantage that when an obstruction, such as a tie-back is encountered, it can be more easily removed via openings in the shield as illustrated in Figure 2.2-12. The tunnel face is accessible and the tie-back can be removed in pieces manually by torch cutting or metal cut-off saw. It is a time-consuming effort that requires grouting where unstable soils are present.

The Metro Red Line Hollywood experience with ground loss and collapse using open-face shield tunneling served as the baseline example of the methods and risks that the Metro Board of Directors has directed staff to avoid on future subway projects. Based on that Metro tunneling experience, open-face tunnel shields, and any tunneling method that would have to rely upon grouting from inside the tunnel to ensure safe construction, with the exception of grouting for cross passage construction, are now deemed by Metro to result in an unacceptable level of risk to workers and the public. Grouting from the tunnel face does not reliably provide the needed ground improvement beneath streets and utilities, particularly under large storm drains similar to the one located in the center of Flower Street, and would result in "windows" of ungrouted soil which would become unstable as shown in Figure 2.2-13.

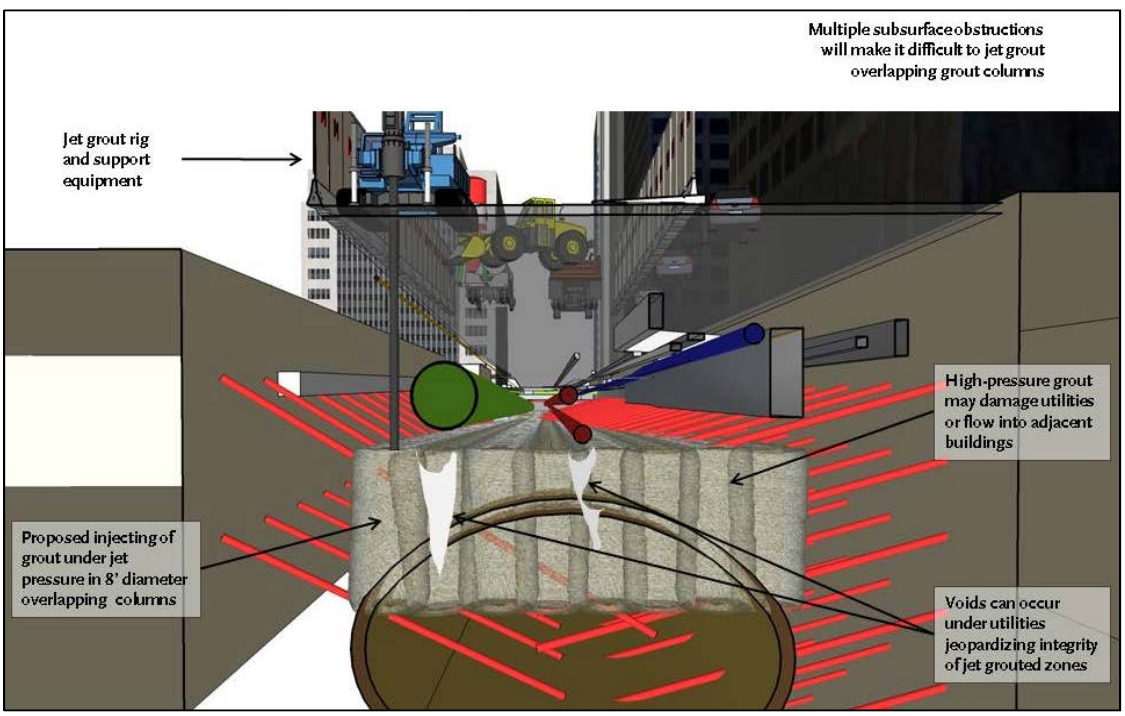
For the Regional Connector Project, open-face shield tunneling was considered and rejected for the Project due to high risks related to possible uncontrolled settlement in the alluvial and fill materials underlying the street and the mixed-face geologic conditions identified along Flower Street. The resulting instability of the tunnel face would pose unacceptable risks without complete soil stabilization, such as the use of grouting. Even with grouting, total ground stabilization is not assured with the geologic conditions along Flower Street, and the risk for ground settlement would remain.

Figure 2.2-12: Open-Face Shield Tunnel Construction Through Flower Street Tie-backs (at SEM Cavern Interface with Twin Tunnels)



Open-face shield tunneling was considered and evaluated in Alternative A for construction of an approximately one block portion of the tunnels between 4th and 5th Streets. The balance of the underground construction considered in Alternative A from the end of the open-face shield tunneling at 5th Street to the 7th Street/Metro Center Station evaluated the SEM method of underground construction using the constructed tunnels at 5th Street for underground access.

Figure 2.2-13: Possible Grouting Impacts Related to SEM Construction



2.2.3.5 Ground Improvement Methods

Given weak ground soils, perched groundwater, and mixed-face geologic interface conditions along the Flower Street segment, ground improvement methods have been identified and evaluated for SEM, open-face shield, or EPBM tunneling south along Flower Street from 4th Street. These ground improvement methods include permeation grouting, ground freezing, compaction grouting, compensation grouting, and jet grouting, and would be performed from the ground surface as discussed below.

Permeation Grouting

Permeation grouting involves filling the pore spaces in soil with chemicals or fine cement, while individual soil grains are not disturbed or moved, to solidify the soil and reduce the capacity for water to flow through the soil. The structure and dimension of the soil pore spaces dictate the type of grout that can be effectively used. Generally, permeation grouting is suitable for sandy soils containing less than 10 to 20 percent silt or clay. As documented in *The Geotechnical Baseline Report*, the silt and clay content varies from 70 percent in the alluvial soils layer to greater than 90 percent in the Fernando Formation.

For tunneling projects, permeation grouting is done from the ground surface or, when unusual or extreme conditions dictate, from the tunnel face. This grouting method requires drilling and injecting grout into the targeted ground areas requiring stabilization. Typical drilling spacing is four to six feet between grout holes. Working from the surface permits control of the grouting to the targeted ground requiring improvement. Permeation grouting from the tunnel face requires horizontal and sub-horizontal grout holes which can easily miss the targeted areas, and therefore not able to achieve the required ground improvement. In addition, the resulting grouting may be compromised by the many tie-backs and utilities located under Flower Street. Locating conflicting utilities to avoid issues with grouting efforts would be similar to cut and cover utility relocation efforts and would require additional time and cost, and still may result in extensive construction impacts due to the unknown exact location of some utilities.

This ground stabilization technique was not recommended for further consideration on Flower Street due to the soils content (silt and clay) of the alluvial conditions which would limit the extent of grout permeation, making it difficult to improve the ground conditions. The interlayered nature of the sands and fine soils would also make it difficult to achieve a uniformly grouted condition, and some areas would not be groutable or marginally groutable due to soil conditions. With so many utility lines located under Flower Street, there is a high risk that permeation grouting would damage or penetrate existing and relocated utility lines causing service disruptions and halting construction. The inherent and unavoidable but temporary impact from permeation grouting is the significant surface disturbance due to grouting equipment and possible grouting spillage.

Ground Freezing

Ground freezing is based on withdrawing heat from the ground soil as the process converts in-situ water in the soil pore spaces into ice. The ice binds the soil particles imparting strength to the frozen soil mass. For the creation of a frozen soil body, a pattern of vertical, and sometimes horizontal, freeze pipes are installed in drilled holes. Each freeze pipe consists of an open-end inner pipe and a closed-end freeze pipe. The inner pipe is filled with a cooling medium, usually brine or liquid nitrogen. The coolant removes the heat from the soil, and the freeze takes place over time as the frost penetrates the soil. Setting up for the freeze, establishing the freeze, tunneling, and demobilizing the freezing is time-consuming taking months to complete and would occupy a minimum of two to three traffic lanes on the surface. It is not feasible to do freezing from an underground position due to the challenges in drilling shafts to position the pipes at exactly the right location around the future tunnel envelope. There is also a significant challenge in obtaining a full freeze zone coverage due to the significant number of utilities and tie-backs located under this street segment.

This ground stabilization technique was not recommended for further consideration and was identified as not feasible on this project. In the Flower Street segment, once the limited perched groundwater is frozen, the freeze could not continue because the alluvial soils are substantially dry and do not contain a sufficient quantity of water to freeze. Along Flower Street, the freeze would be incomplete, not uniform and continuous, and would provide insufficient ground stability for tunneling.

Compaction Grouting

Compaction grouting involves injection of very stiff grout at a high pressure into the ground creating grout columns and densifying the surrounding soils at the injection points. The grout holes are typically vertical and spaced on a grid of six to 12 feet apart. The resulting grout columns are not designed to overlap or even touch each other, as the soils left in place between the columns are presumed to be densified. Developed in the 1970s, compaction grouting has had limited use as subsequent compensation grouting development provided a more manageable and effective technique for tunneling applications. Today, compaction grouting is seldom used as a tunneling settlement mitigation method. The introduction of pressurized-face tunneling has reduced tunneling ground losses, which further decreases the need for the use of this technique.

This ground stabilization technique was not recommended for further consideration as it was seen as not being effective for preventing large ground loss and reducing the risk of surface subsidence along Flower Street if tunneling were continued south of 4th Street. The alluvial deposits located along the Flower Street segment would be difficult to improve by compaction grouting and would not prevent an unstable tunnel face with raveling or running ground. Keeping the placement of the grout in a globular mass sufficient to provide density required for tunneling would be difficult due to the interlayered nature of the ground soils, as well as the many utilities and abandoned tie-backs located under Flower Street. Relocation of utilities would require additional time and cost, and may still result in extensive construction impacts due to the unknown precise location of some utilities.

Compensation Grouting

Compensation grouting is used concurrently with tunneling or excavation to mitigate ground settlement resulting from excavation or tunneling activities. Steel or plastic grout pipes with sleeve ports are installed in holes drilled from the surface or grout pits prior to tunneling. Compensation grouting displaces the surrounding soils at the grouting points along the grout pipe to compensate for settlement caused by construction activities. As the grout penetrates the ground, it forms a network of wedges and displaces and "heaves" the ground to compensate for settlement. As tunneling advances and settlement occurs, compensation grouting is activated to maintain settlement within acceptable limits. Once the ground movement is stabilized, the grouting pipes and equipment are abandoned in place. Implementation along Flower Street would require shafts to be drilled within the street ROW to install the grout pipes, whose placement may be constrained by the tie-backs and utilities located under Flower Street. Similar to other grouting techniques, utility relocation would require additional time and cost, and may still result in extensive construction impacts due to the unknown precise location of some utilities.

This ground stabilization technique was not recommended for further consideration to provide ground improvement in support of tunneling efforts on Flower Street. Compensation grouting would be only suitable for mitigation of settlement of utilities along this segment of the project, and would be completely ineffective in avoiding ground loss and collapse of the tunnel face leading to a sinkhole in the street by open-faced TBM or SEM tunneling.

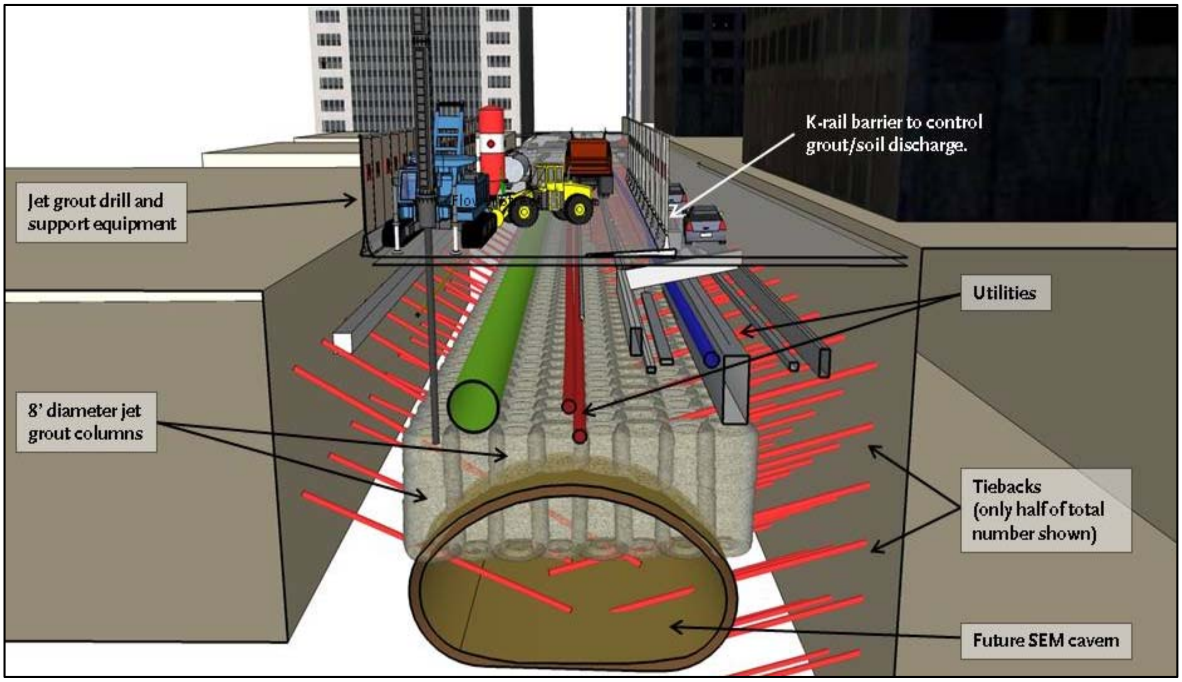
Jet Grouting

Jet grouting mixes cement grout with the in-situ soil to result in a stronger mixed grout-soil material. With jet grouting, the weak soils under Flower Street would be strengthened resulting in "firm" ground conditions that would allow for tunneling and in some cases, reduce tunneling risks. The technique requires drilling grout holes on a five- to-10 foot spacing throughout the area to be grouted such that the neighboring grout-soil mix columns would overlap or touch each other. Grout holes would typically extend from the ground surface creating vertical grout-soil mix columns extending approximately 40 feet from the ground surface to reach the relatively stronger Fernando Formation, as shown in Figure 2.2-14. The resulting grout columns would improve ground stability, but may be compromised by the many tie-backs and utilities along Flower Street.

Jet grouting was identified as the most suitable method to improve the existing soil conditions along Flower Street, and to provide adequate strength given the width and depth of the required grout-soil mix block above the tunnel crown. The method has relatively good control over assuring the quality of grouted soil blocks but has remaining concerns of extensive environmental impacts on the street, the risk of utility damages, and the risk of incomplete ground improvement. A jet grouting canopy, installed by horizontal drilling, alone would not provide adequate support for the tunnel under Flower Street. A major risk is the interference created by utilities that prevent full coverage by jet grouting. As previously illustrated in Figure 2.2-13, it would not be possible to fully jet grout below the 84-inch diameter storm drain and a "window" of ungrouted ground would be present above the tunnel. The ungrouted ground would tend to transmit groundwater and, if intersected by the tunnel excavation using SEM or open-face shield methods, would be the point where an uncontrollable run or flow of soil in the tunnel would start, which in turn could lead to a sinkhole at the street surface.

Ground stabilization through jet grouting would be required for the open-face shield tunneling and SEM tunnel construction portions of both tunneling alternatives A and B primarily due to the unstable soil conditions along Flower Street. Without an extensive jet grouting program, construction of these alternatives would have a substantial risk of tunnel face instability with the high potential for soil runs during tunneling by open-face shield or SEM, particularly when dealing with tie-backs.

Figure 2.2-14: Grouting Equipment and Impacts



This method has extensive street level environmental impacts due to the type and size of grouting equipment required for grout production and delivery, and the challenge in controlling grouting activities. Grouting equipment includes grout drilling rigs, a mixing plant, compressors, pumps, generators, cement delivery trucks, and support machinery. The drilling rigs are typically more than 100 feet in height. Jet grouting requires high grouting pressure, typically 6,000 pounds per square inch (psi), and this high pressure makes it difficult to control spills and unintended grout discharges. Grouting spills and discharges typically occur when uncoupling hoses and when the grout under pressure breaks out either around the grout pipe casing or through the ground. With so many utility lines located under Flower Street, there is a high risk that high pressure grouting can damage or penetrate into the utility lines causing major service disruptions and halting construction. An example of probable jet grouting equipment and resulting impacts are shown in Figure 2.2-15 for a similar LRT tunneling project when under construction in San Francisco for the MUNI system.

As discussed in Section 2.3 of this chapter and in Chapter 3, Transportation and Circulation, Section 4.1 Visual Quality, Section 4.2 Air Quality, Section 4.2 Climate Change, Section 4.4 Noise and Vibration, 4.6 Energy Resources, and Chapter 5, Comparison of the Alternatives, grouting would have traffic and transit, air quality, climate change, noise and vibration, visual and aesthetic, historic resource, and environmental justice impacts.

Figure 2.2-15: Grouting Equipment and Impacts (San Francisco, MUNI LRT Tunneling, 2013)

2.3 ALTERNATIVES CONSIDERED IN THE SEIS

As analyzed and documented in the *Final Flower Street Tunneling Method Alternatives Report (2015)* (Appendix A) and summarized in Table 2.3-1, Alternatives A and B propose different combinations of underground construction methods as alternatives to the cut and cover method planned for the Project along Flower Street between 4th Street and 7th Street. This section presents an overview of the construction methods for each of the tunneling method alternatives, including the need for ground stabilization for the proposed construction methods along the Flower Street segment, construction staging requirements, and an evaluation of the tunneling method alternatives.

2.3.1 Construction Methods and Staging for Tunneling Method Alternatives

Construction methods for Alternatives A and B propose different combinations of underground construction methods as alternatives to the cut and cover method planned for the Project along Flower Street between 4th Street and 7th Street.

1. EPBM/Open-Face Shield/SEM Project Profile Alternative (Alternative A) – a combination of EPBM, Open-Face Shield and SEM construction methods; and with similar horizontal and vertical alignment profiles to that of the Project.
2. EPBM/SEM Low Alignment Alternative (Alternative B) – a combination of EPBM and SEM construction methods with a similar horizontal alignment profile, but a lower vertical alignment profile, than that of the Project.

The two tunneling alternatives have the following alignment variations from that of the Project in order to address geologic conditions and other subsurface project constraints as previously discussed:

- Horizontal alignment – Along Flower Street, Alternatives A and B remain located under the existing street right-of-way. The horizontal alignments of these alternatives continue on tangent track from the 2nd/Hope Station south through the 4th Street Bridge foundation piles to 5th Street. The alignments then would transition from a wider oval track center to a narrow track center as the alignment approaches the planned double crossover immediately north of the narrow, rectangular 7th Street/Metro Center Station tail tracks structure.

  As further discussed below in Section 2.3.2.1 describing Alternative A and Section 2.3.2.2 presenting Alternative B, these alternatives would have a short horizontal transition distance from the 5th Street section of the alignment to the double crossover located before the existing tail tracks structure, which would limit the LRT operating speed to 35 mph as compared to the 55 mph specified by the MRDC Operating Standards, and provided by the Project.

- Vertical alignment – Alternative A would have the same vertical profile as the Project with an average depth of 40 feet to top of rail (TOR) below ground level. The vertical alignment of Alternative B has a "sag" or a low point of 105 feet to TOR below ground level. The sag alignment reduces the probability of the tunnel alignment impacting the 4th Street Bridge foundations and encountering tie-backs located under Flower Street between 4th Street and just south of 5th Street. The abandoned steel tie-backs typically range from 30 to 90 feet in length, and extend below ground at a 15 to 45 degree angle to a depth of approximately 45 to

64 feet across the width of the street right-of-way from both sides. The 4th Street Bridge foundations extend 64 feet below the surface on the west side and 83 feet on the east side. Alternative B's lower alignment profile at 105 feet to TOR avoids tunneling impacts from the tie-backs and bridge foundations. It does result in a greater depth for the 2nd/Hope Station (128 feet) compared to the station depth for the Project and Alternative A (96 feet).

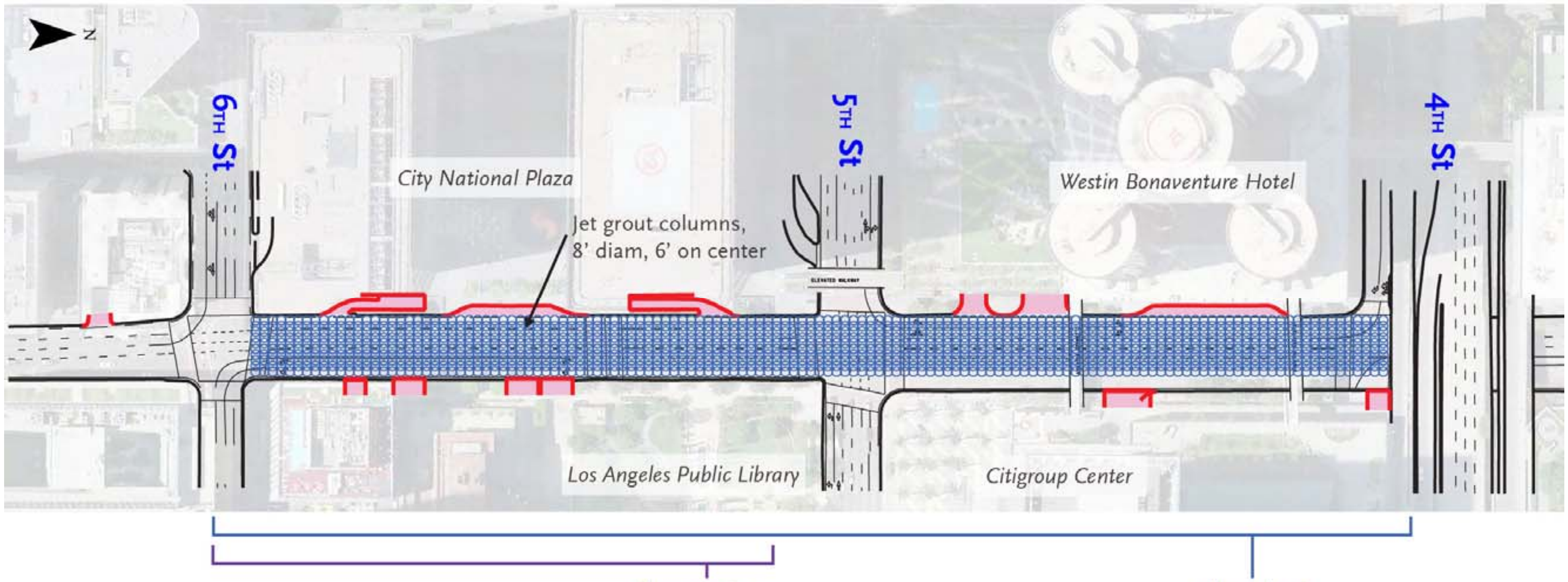
In addition to the construction methods described above, the tunneling method alternatives would require small segments of cut and cover construction for shafts to allow for emergency exits, tunnel boring machine retrieval, and train control room ventilation. Both alternatives would require the use of grouting to stabilize Flower Street soil conditions to allow for tunnel construction as shown in Figure 2.3-1. Alternative-specific shaft requirements are described in the discussions about each alternative below.

Table 2.3-1: Comparison of Project and Tunneling Method Alternatives

	The Project	Alternative A EPBM/Open-Face Shield/SEM Project Profile	Alternative B EPBM/SEM Low Alignment
Construction Description[1]	• EPBM to south of 4th Street • C&C from 4th Street to 7th Street/Metro Center Station tail tracks	• EPBM to 4th Street • Open-face shield TBM to 5th Street • SEM from 5th to 7th Street/Metro Center Station tail tracks	• EPBM to south of 5th Street • SEM from 5th Street to 7th Street/Metro Center Station tail tracks
Horizontal Alignment	Baseline	Slight shift to west of Project alignment	Slight shift to west of Project alignment
Depth To Top of Rail	40’	40’	40’ to 105’ (at sag)
Mucking Locations	• Flower Street • Mangrove site in Little Tokyo	• Flower Street (for emergency exits and train control room vent only) • Mangrove site in Little Tokyo	• Flower Street (for emergency exit and train control room vent only) • Mangrove site in Little Tokyo
Handling of Flower Street Segment Excavation Materials (by location)	Flower Street Site: 81% Mangrove Site: 19%	Flower Street Site: 25% Mangrove Site: 75%	Flower Street Site: 20% Mangrove Site: 80%
Corresponding Excavation Materials/ Construction Trucks Per Day	On Flower Street segment: 32 In Little Tokyo: 8	On Flower Street segment: 18 In Little Tokyo: 22	On Flower Street segment: 8 In Little Tokyo: 32
Construction Shaft	TBM retrieval shaft at 4th Street (part of cut and cover construction)	TBM retrieval shaft south of 4th St.	EPBM removed through Mangrove portal
Permanent Shafts	• Emergency exit south of 4th Street • Emergency exit south of 5th Street • Train control room vent shaft 7th Street/ Metro Center tail tracks structure	• Emergency exit south of 4th Street • Emergency exit south of 5th Street • Train control room vent shaft 7th Street/ Metro Center Station tail tracks structure	• Emergency exit south of 5th Street • Train control room vent shaft 7th Street/ Metro Center Station tail tracks structure
2nd/Hope Station Depth	96’	96’	128’
Maximum Design Speed	55 mph	35 mph	35 mph
Double Track Crossover Before 7th Street/Metro Center Station	Yes	Yes	Yes
Future 5th/Flower Station	Center platform with mezzanine	Side platform with no mezzanine	Side platform with mezzanine Requires tunnel reconstruction
Project Delivery Duration (months) • **Construction** • **Pre-Construction Activities**[2] • **Total Duration (difference)**	78 -- 78	93 (+ 15 months) 29 122 (44 months or 3.7 years longer)	85 (+ 7 months) 29 114 (36 months or 3 years longer)
Project Cost (Millions, YOE)3	$171	$295-332[4] (+$124 to $161 more than the Project)	$295-332[4] (+$67 to $95 more than the Project)

Notes: [1] **Construction Techniques** include C&C - Cut and cover; EPBM- earth pressure balance tunnel boring machine; SEM- sequential excavation method. [2] **Pre-construction Activities** include engineering design revisions and re-procurement of the design-build construction contract. [3] **Project Cost YOE** is the year of expenditure using 2017 as mid-point of construction. [4] **Project Cost** Range for two alternatives provides a low and high cost estimate based on risk. The range does not include increased costs resulting from procurement delay, construction delay, or escalation due to delays.

Figure 2.3-1: Grout Holes Required on Flower Street for Alternatives A and B



LEGEND

- Jet Grout Column
- Existing Driveways

Alternative B:

- Jet grouting south of 5th St to 6th St
- Two lane closure required at a time
- Grouting duration estmated to be a total of 8 months (possibly up to 16 months depending on underground conditions encountered) for this alternative assuming 2 drill rigs and the following:
  - 5-day mobilization
  - 5 working days per week
  - One ten-hour shift per day
  - 3-holes per shift per rig
- Grouting is performed concurrent with construction

Alternative A:

- Jet grouting south of 4th St to 6th St
- Two lane closure required at a time
- Grouting duration estmated to be a total of 12 months (possibly up to 24 months depending on undergound conditions encountered) assuming 2-4 drill rigs and the following:
  - 5-day mobilization
  - 5 working days per week
  - One ten-hour shift per day
  - 3-holes per shift per rig
- Grouting is performed concurrent with construction

Metro

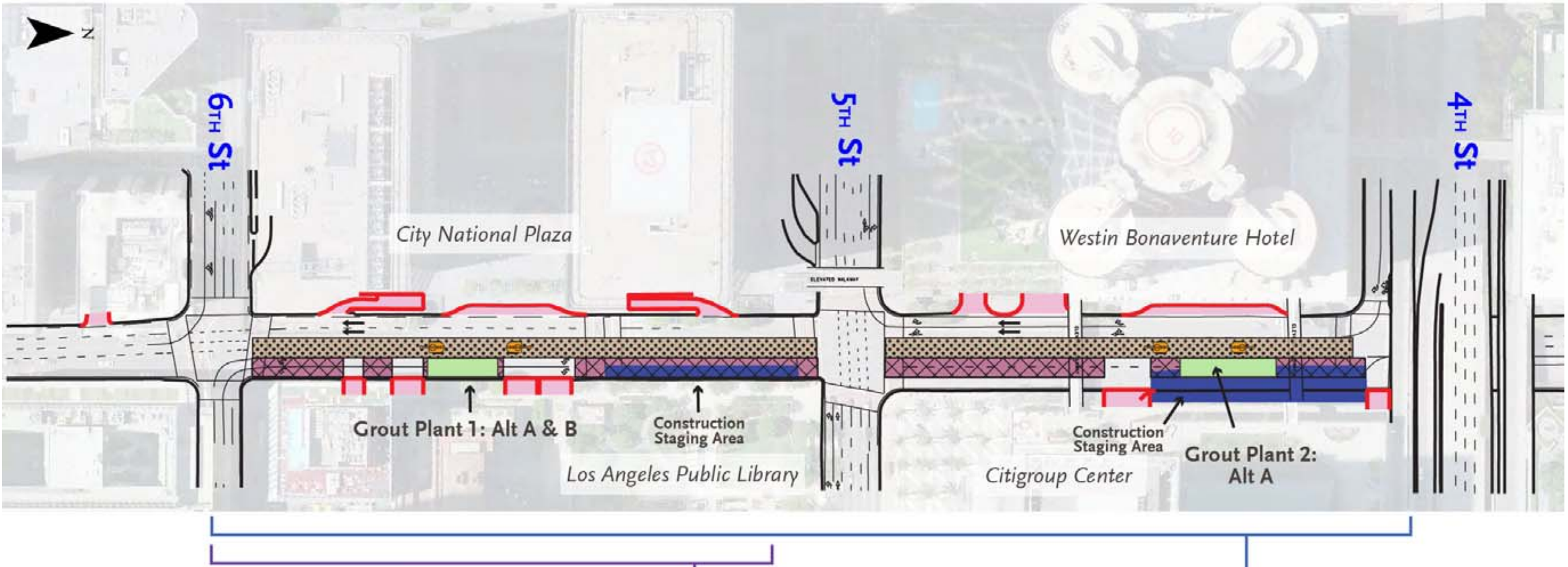
2.3.1.1 Construction Staging Areas

Similar to the Project as discussed in section 2.1.3, Alternatives A and B would require construction staging areas. Construction staging areas are temporary for the duration of construction, and would be located either within the street right-of-way or in off-street locations. Potential construction staging areas have been identified for Alternatives A and B and are summarized in Table 2.3-2 in comparison to the Project. Two grouting phases are required for the tunneling method alternatives to allow for the shifting of grouting activities from one side of Flower Street to the other to accommodate the reach of the grouting rigs. The two phases of grouting activities are illustrated in Figures 2.3-2 and 2.3-3 with construction and grouting staging activities in the Flower Street segment accommodated through temporary traffic lane closures between 4th and 6th Streets. Detours and closures would be coordinated with the LADOT.

During construction of the two tunneling method alternatives, removal of excavated materials in the Flower Street segment would be handled either along Flower Street or would be transported back along the alignment within the newly constructed tunnels and removed at the Mangrove site in Little Tokyo. As shown in Table 2.3-3, the two alternatives would significantly decrease the amount of tunnel excavation materials handled along Flower Street and correspondingly increase the materials handled through the Mangrove site. Under the Project, the higher percentage (81 percent) of the total excavation materials from the Flower Street segment handled along Flower Street is due to cut and cover construction that would be loaded into trucks on-site. With the reduction in cut and cover construction proposed by the two alternatives, the increase in tunneling would be handled with tunnel boring spoils transported back along the alignment within the newly constructed tunnels and removed at the Mangrove site at the northeast corner of 1st and Alameda Streets where it would be removed by trucks traveling through Little Tokyo.

Under Alternative B, extending EPBM tunneling to 5th Street, along with a deeper alignment, is proposed under Flower Street. The deeper alignment would require lowering the 2nd/Hope Station deeper from 96 feet to 128 feet below the ground surface. This added tunnel length and alignment depth would result in an increased quantity of tunnel excavation materials to be handled through the Mangrove site. The additional excavated materials for the deeper 2nd/Hope Station also would be removed from the station site.

Figure 2.3-2: Alternatives A and B – Grouting Activities Phase I



LEGEND

- 2-Lane closure for duration of construction/grouting
- 2-Lane closures at a time
- Existing Driveways
- Underground Construction Access Locations
- Grouting Rig
- Grouting Plant Area

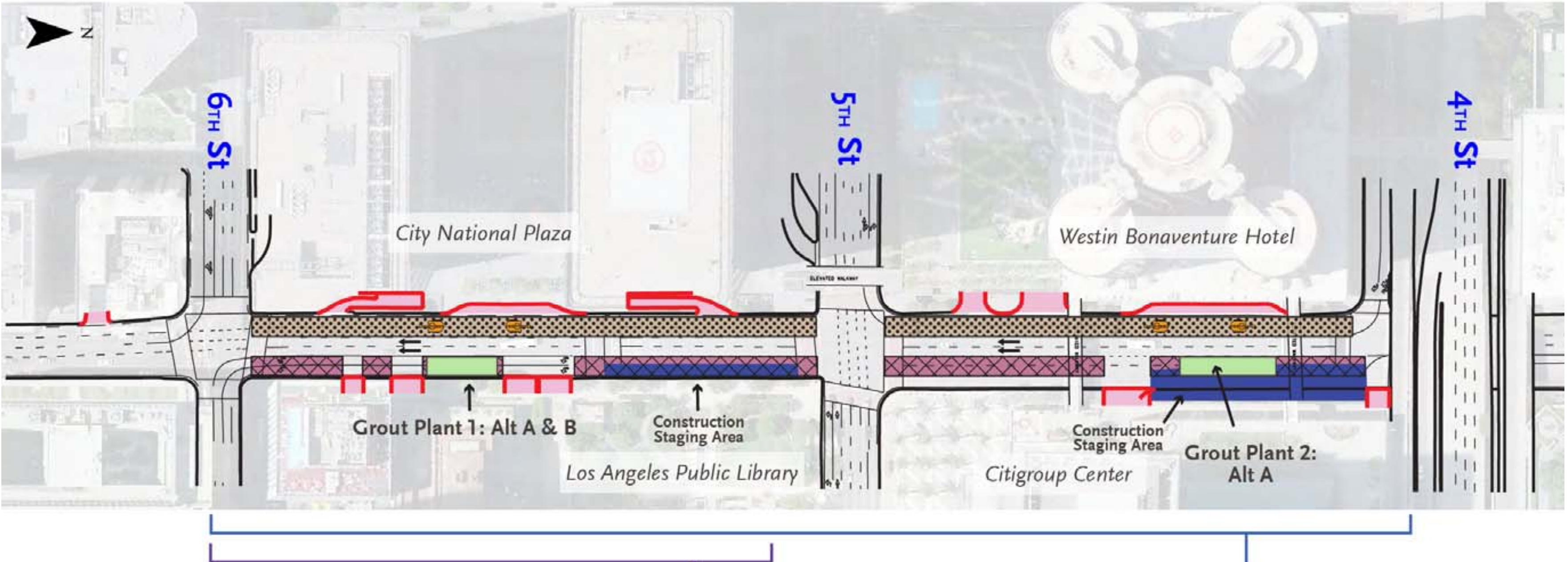
Alternative B:

- Jet grouting south of 5th St to 6th St
- Two lane closure required at a time
- Grouting duration estmated at 4 months during this phase (possibly up to 8 months depending on underground conditions encountered) assuming 2 drill rigs and the following:
  - 5-day mobilization
  - 5 working days per week
  - One ten-hour shift per day
  - 3-holes per shift per rig
- Total grouting duration (both phases) is 8 months (possibly up to 16 months)

Alternative A:

- Jet grouting south of 4th St to 6th St
- Two lane closure required at a time
- Grouting duration estmated at 6 months during this phase (possibly up to 12 months depending on underground conditions encountered) assuming 2-4 drill rigs and the following:
  - 5-day mobilization
  - 5 working days per week
  - One ten-hour shift per day
  - 3-holes per shift per rig
- Total grouting duration(both phases) is 12 months (possibly up to 16 months)

Figure 2.3-3: Alternatives A and B – Grouting Activities Phase II



LEGEND

- 2-Lane closure for duration of construction/grouting
- 2-Lane closures at a time
- Existing Driveways
- Underground Construction Access Locations
- Grouting Rig
- Grouting Plant Area

Alternative B:

- Jet grouting south of 5th St to 6th St
- Two lane closure required at a time
- Grouting duration estmated at 4 months during this phase (possibly up to 8 months depending on underground conditions encountered) assuming 2 drill rigs and the following:
  - 5-day mobilization
  - 5 working days per week
  - One ten-hour shift per day
  - 3-holes per shift per rig
- Total grouting duration (both phases) is 8 months (possibly up to 16 months)

Alternative A:

- Jet grouting south of 4th St to 6th St
- Two lane closure required at a time
- Grouting duration estmated at 6 months during this phase (possibly up to 12 months depending on underground conditions encountered) assuming 2-4 drill rigs and the following:
  - 5-day mobilization
  - 5 working days per week
  - One ten-hour shift per day
  - 3-holes per shift per rig
- Total grouting duration(both phases) is 12 months (possibly up to 16 months)

Technically every station along the project alignment could serve as a tunnel spoil removal site, but the Final EIS/EIR restricts tunnel spoil removal to the Mangrove site due to the potential for additional impacts the other station locations and the right-of-way constraints. Handling tunnel spoils at the 2nd/Hope station area adjacent to the Disney Hall, the Music Center, the Colburn School of Music, the Broad Museum, the Museum of Contemporary Art, and two high-rise residential buildings would be difficult given the built-out nature of this station area with noise-sensitive land uses. Similarly, the 2nd/Broadway Station cannot serve as a spoils removal location due to the built out nature of surrounding land uses. In addition, the right of way is narrow and congested at this segment of 2nd Street.

Spoil removal under Alternatives A and B assumes that the excavated materials by tunneling methods under Flower Street are removed through the bored tunnels to the portal at Little Tokyo using the tunneling conveyor or muck transport systems in the tunnels which are not designed to accommodate discharge at 2nd/Broadway station. Changing the muck conveyance system to discharge at 2nd/Broadway station would adversely affect the construction of the 2nd/Broadway cut and cover station causing significant delay to the project. Additionally, the 2nd and Broadway station site is a narrow site in a heavily built up area with limited surface area to accommodate muck handling and disposal operations from the tunnel.

Table 2.3-2: Flower Street Construction and Grouting Staging and Grouting Activity Areas for the Project and Tunneling Method Alternatives

	Construction Staging Two locations occupying two travel lanes on east side of Flower Street: • South of 4th Street • South of 5th Street	**Grouting Staging Areas** Two locations occupying two travel lanes on east side of Flower Street: • South of 4th Street • Between 5th and 6th Streets	**Grouting Activities** Two phases occupying two travel lanes at a time: • Phase I – two middle travel lanes • Phase II – two travel lanes on west side of street
The Project	Both locations	--	--
Alternative A	Both locations	Both locations	Both phases
Alternative B	Both locations	North of 6th street only	Both phases

A comparison of the quantity of Flower Street segment excavation materials that would be handled either along Flower Street or through the Mangrove site by Alternatives A and B as compared to the Project is provided in Table 2.3-3. As discussed below in the description of each tunneling method alternatives, with the extension of tunneling further south on Flower Street, there would be a major shift in the handling of excavated materials from Flower Street to Little Tokyo. This would have a corresponding increase in the number of excavation trucks required to handle the higher quantity of excavated materials at the Mangrove site. Under Alternative A, Flower Street truck activity would be approximately cut in half, while the number of trucks operating through Little Tokyo would more than double. Alternative B has a more significant impact on Little Tokyo with quadruple the number of trucks. For both alternatives, the duration of the impacts would increase by 7 months under Alternative B to 15 months under Alternative A.

Table 2.3-3: Comparison of Flower Street Segment Excavation Materials Handling

Impact	The Project	Alternative A	Alternative B
Hauling of Excavated Materials from Flower Street			
- On Flower Street • Percentage of total Flower Street excavation materials • Duration of hauling activities	81% 9 Months	25% 1 Month	20% 1 Month
- In Little Tokyo • Percentage of total excavation materials • Duration of hauling activities	19% 2.5 Months	75% 19 Months	80% 17 Months
Excavation/Construction Trucks Per Day			
- On Flower Street	32	18	8
- In Little Tokyo	8	22	32
Duration of Truck Impacts (for hauling excavated materials)	9 Months	19 Months (10 months longer than the Project)	17 Months (8 months longer than the Project)

Source: *Final Flower Street Tunneling Method Alternatives Report (2015)*

2.3.2 Description of Tunneling Method Alternatives

2.3.2.1 Alternative A – EPBM/Open-Face Shield/SEM Profile Alternative

Alternative A would extend tunneling south to the 7th Street/Metro Center Station through the use of a combination of open shield tunnel boring and sequential excavation method (SEM) construction techniques. The EPBM/Open-Face Shield/SEM Project Profile Alternative, as illustrated in Figure 2.3-4, is defined as follows:

> EPBM-bored tunnels are constructed following the Project alignment to south of 4th Street, then open-face shield tunnel excavation from 4th Street to 5th Street (abandoning the shields underground), and SEM tunnel construction from 5th Street to the 7th/Metro Center Station tail tracks structure

The Flower Street horizontal alignment of this alternative would remain similar to the Project with a slight shift to the west with the alignment continuing south on tangent track from the 2nd/Hope Station through the 4th Street Bridge piles to 5th Street. It would transition from a wider track center to a narrow track center by the time the alignment approaches the required double crossover immediately north of the narrow 7th Street/Metro Center Station tail tracks structure.

The vertical alignment for this alternative would be similar to that of the Project with a tunnel alignment depth of approximately 40 feet to TOR below the street surface. Alternative A would allow for construction of a double track crossover and a future 5th/Flower Street Station; and the 2nd/Hope Station would be located at the same depth (96 feet) as the Project. For this alternative, the operational speed would be limited to 35 mph due to the short horizontal transition distance from the 5th Street segment to the double crossover before the existing tail tracks structure. The future 5th/Flower Street Station configuration would have to be a side platform station without a mezzanine, as the narrow center-to-center spacing of the twin tunnels would preclude construction of a center platform, and the relatively shallow depth would not provide sufficient distance for a mezzanine. Passengers would not be able to make cross-platform transfers, but would have to exit the station to transfer from one travel direction to the other. Deviations would be required from Metro rail design standards to accommodate the site-specific conditions.

Alternative A would require three separate cut and cover excavation sites for: 1) emergency exit construction and tunnel boring machine retrieval shaft south of 4th Street; 2) an emergency exit construction located south of 5th Street; and 3) a train control room vent shaft south of the 7th Street/Metro Center Station tail tracks structure. Similar to the Project, cut and cover excavation materials would be handled from the construction staging sites located along Flower Street, while tunnel muck would be removed through the bored tunnel to the Mangrove portal site in Little Tokyo.

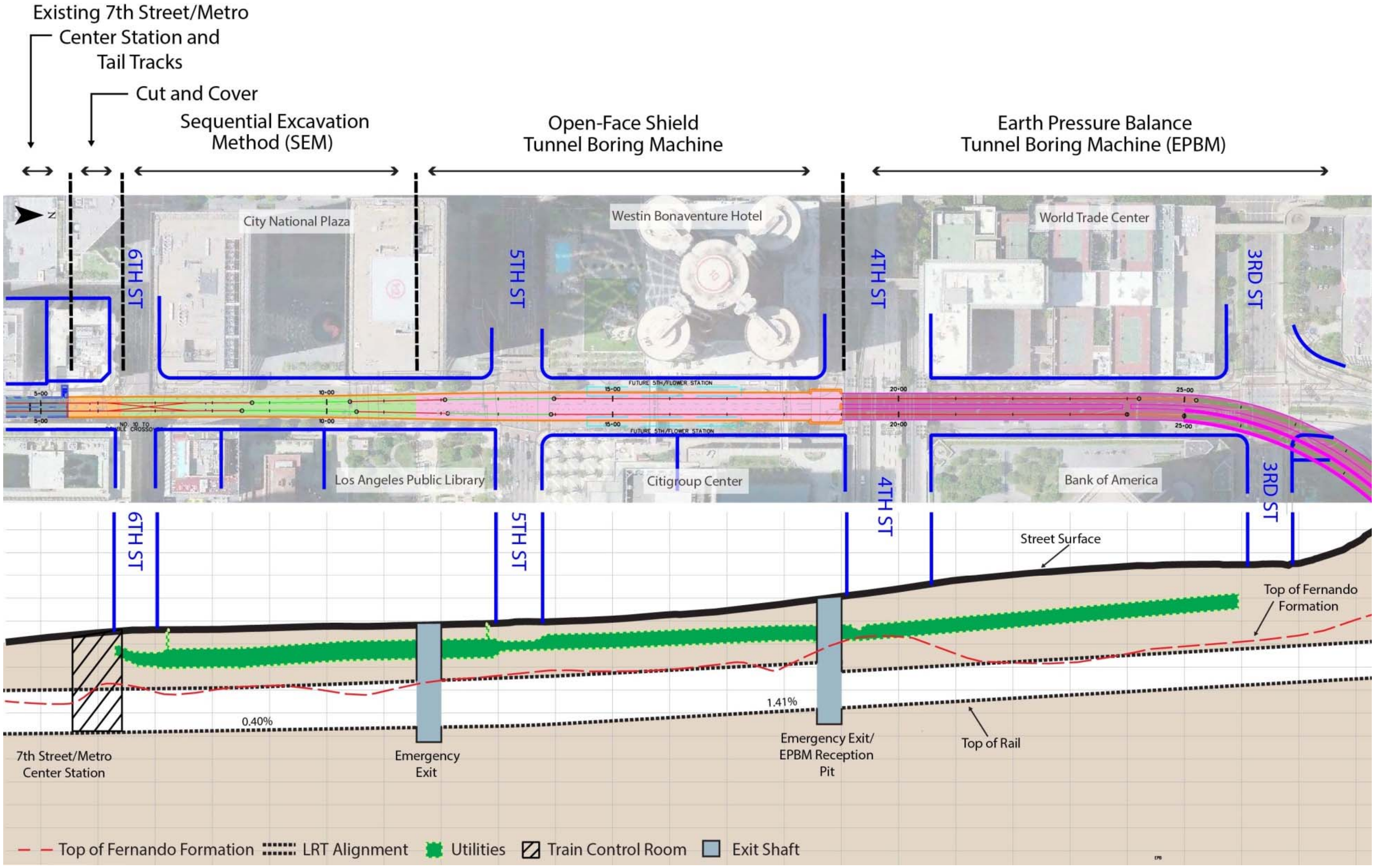
With the lengthening of tunnel boring activities further south on Flower Street, there would be a corresponding increase in the amount of excavated materials handled through the Mangrove site over the Project conditions. For Alternative A, it is estimated that 25 percent (compared to 81 percent for the Project) of the excavated materials would be handled from locations along Flower Street, with an increase to 75 percent (compared to 19 percent under Project conditions) of tunneling materials would be accommodated through the Little Tokyo site.

Construction Method Risks and Need for Grouting

The Flower Street SEM excavation for the crossover may be as wide as 60 feet, but would only have approximately 20 feet thickness or less of poor soil cover combined with close proximity to utilities, ground water, and methane gas conditions making it a very high risk for excessive settlement, uncontrolled subsidence or collapse. SEM relies on the natural arching effect of the ground, and not much arching can be expected along Flower Street due to the low ground cover, poor soils conditions, and many utilities. In such poor ground conditions, SEM construction is more susceptible to earthquake forces and its seismic design requirements would be greater compared than those for cut and cover excavation.

Due to the use of a combination of open-face shield tunnel boring and SEM tunnel construction techniques, the use of extensive jet grouting would be required from south of 4th Street to 6th Street for Alternative A. Without grouting, this alternative has substantial risk of tunnel face instability with the high potential for soil runs during tunneling by open-face shield or SEM, particularly when dealing with tie-backs. There would be approximately five feet of the Fernando Formation above the open-face shield section. Based on the limited number of borings, the location of the Fernando Formation has substantial uncertainty and the stability of the open-face shield tunnel face is not guaranteed. Ground improvement would be required. In addition, the open-face shield tunneling would encounter the Pacific Electric tunnel which may include pea gravel backfill between its final lining and the surrounding ground as commonly used in earlier tunneling methods. As the open-face shield tunnel approaches, this backfill may run into the new tunnel creating large voids around the Pacific Electric tunnel directly underneath Flower Street and the adjacent properties. For the SEM portion of the

Figure 2.3-4: EPBM/Open-Face Shield/SEM Profile (Alternative A)



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tunneling, the single twin-tunnel is larger and the tunnel will have varying amounts of mixed face conditions in the tunnel heading. In this situation, there would be a high risk of subsidence creating sinkholes on Flower Street and therefore jet grouting would be required.

The jet grouting for the open-face shield and SEM portions would require drilling grout holes on a six-foot by six-foot pattern throughout the area to be grouted as previously shown in Figure 2.3-1. Grout holes would extend from the ground surface through the weak fill and alluvial soils to just into the relatively stronger Fernando Formation, a distance of more than 40 feet. Alternative A would require a 50-foot-wide zone in Flower Street to be grouted. Depending on the number of required grout holes, two to four drill rigs would be utilized to drill and grout this area. Approximately 1,900 jet holes are expected for Alternative A and would require approximately 12 months (with a risk of doubling the effort for up to 24 months) using two drill rigs.

For Alternative A, the horizontal tunnel alignment is shifted slightly to the east between 5th and 6th Streets, and the tunnel alignment occupies the middle of Flower Street between 4th and 5th Streets. Therefore, the jet grouting staging areas would occupy the east side of Flower Street during a majority of the jet grouting activities. As previously presented, Figures 2.3-2 and 2.3-3 illustrate the grouting and staging areas required along Flower Street for Phases I and II of grouting activities for this alternative. As shown in the figures, construction of Alternative A would require long term closure of two travel lanes on the east side of Flower Street for location of the grouting plant and equipment storage, along with an additional two lane closure on the west side to accommodate grouting activities. A total of four lanes would be closed for 12 months, possibly up to 24 months due to unforeseen underground conditions, when grouting is taking place.

Schedule Impacts

Implementation of Alternative A would extend the project construction duration by 15 months over the Project, and the longer construction duration is due only to construction changes along Flower Street and related impacts to Little Tokyo. Under the Project, cut and cover excavation and construction work would occur concurrently with the excavation of the bored tunnels and other construction activities throughout the alignment. For Alternative A, the primarily tunneling work needs to be performed sequentially, which results in a longer construction timeframe. While the required grouting activity can be performed concurrently with the EPBM tunneling work, but not the SEM effort, grouting activity will further impact construction duration with Alternative A requiring two to four grouting rigs for approximately 12 months, and possibly up to 24 months depending on the underground conditions experienced along Flower Street during construction. In addition, muck removal for this alternative would occur through the westbound track tunnel to the Mangrove portal, and with the extension of tunneling further south on Flower Street, would require longer tunnel runs with increased amounts of excavated materials over those of the Project. Extending the use of the westbound tunnel track would delay the construction of all station facilities, which are dependent on the completion of tunneling operations.

The resulting construction method-related schedule changes are not simply add-ons to the construction schedule duration identified for the Project. The Regional Connector project construction schedule is complex and involves the carefully considered interrelationships between many activities, some that can be performed concurrently, while other activities are sequential. Due to the need to remove all Flower Street segment tunnel spoils through the Mangrove portal, the tunneling operation would continue until excavation and construction of the Flower Street segment. This would hold the start of station construction work for the 2nd/Hope and 2nd/Broadway stations and all cross passages until after the Flower Street segment tunneling is complete.

Table 2.3-4: Construction Duration Comparison

	Project (Months)	Alternative A (Months)	Alternative B (Months)
Pre-construction[1]	--[2]	29	29
Construction	78	93	85
Total Duration	78	122	114
Duration Difference Compared to the Project			
Months	--	44	36
Years	--	3.7	3.0
Revenue Service Date	Mid 2020	Early 2024	Mid 2023

Note: [1] Pre-construction Activities include engineering design revisions and re-procurement of the design-build construction contract.
[2] Pre-construction activities already completed
Source: *Final Flower Street Tunneling Method Alternatives Report (2015)*

As shown in Table 2.3-4, implementation of Alternative A would require 44 months over the Project's schedule. The longer duration is due to: 1) an additional 29 months for pre-construction activities; and 2) a longer construction duration by 15 months. Pre-construction activities for this alternative would include the preparation of detailed engineering design plans, re-procurement activities for the design-build project contract, and re-permitting efforts. As the Project is currently under construction, implementation of either tunneling method alternative would require stopping current construction activities and re-mobilization efforts for the new alternative project configuration using different construction techniques and equipment than the Project. Alternative A would have a longer construction duration as the identified tunneling excavation and construction activities would have to be performed sequentially rather than concurrently as under the Project. Additional construction time would be required for the jet grouting activities that must be performed prior to tunneling efforts to provide needed ground stabilization. In summary, under Alternative A, the duration of construction activities along the Flower Street segment would be reduced, while the duration of construction activities in Little Tokyo would increase. For this alternative, the total project schedule from initiation of construction to start of revenue service would be 10.2 years compared to 6.5 years for the Project.

2.3.2.2 Alternative B – EPBM/SEM Low Alignment Alternative

Alternative B would extend tunneling south to the 7th Street/Metro Center Station through the use of a combination of earth pressure balance tunnel boring machine (EPBM) and sequential excavation method (SEM) construction techniques. The EPBM/SEM Low Alignment Alternative, as shown in Figure 2.3-5, is defined as follows:

EPBM-bored tunnels are constructed on a deep alignment to south of 5th Street and then when the track centers are too close to permit use of EPBMs, construction changes to SEM tunneling the remaining distance to the 7th/Metro Center Station tail track structure.

The Flower Street horizontal alignment of this alternative would remain similar to the Project with a slight shift to the west with the alignment continuing south on tangent track from the 2nd/Hope Station through the 4th Street Bridge piles to 5th Street, and transitioning from a wider track center to a narrow track center by the time the alignment approaches the required double crossover immediately north of the narrow 7th Street/Metro Center Station tail tracks structure. The operational speed would be limited to 35 mph due to the short horizontal transition distance from 5th Street to the double crossover before the existing tail tracks structure.

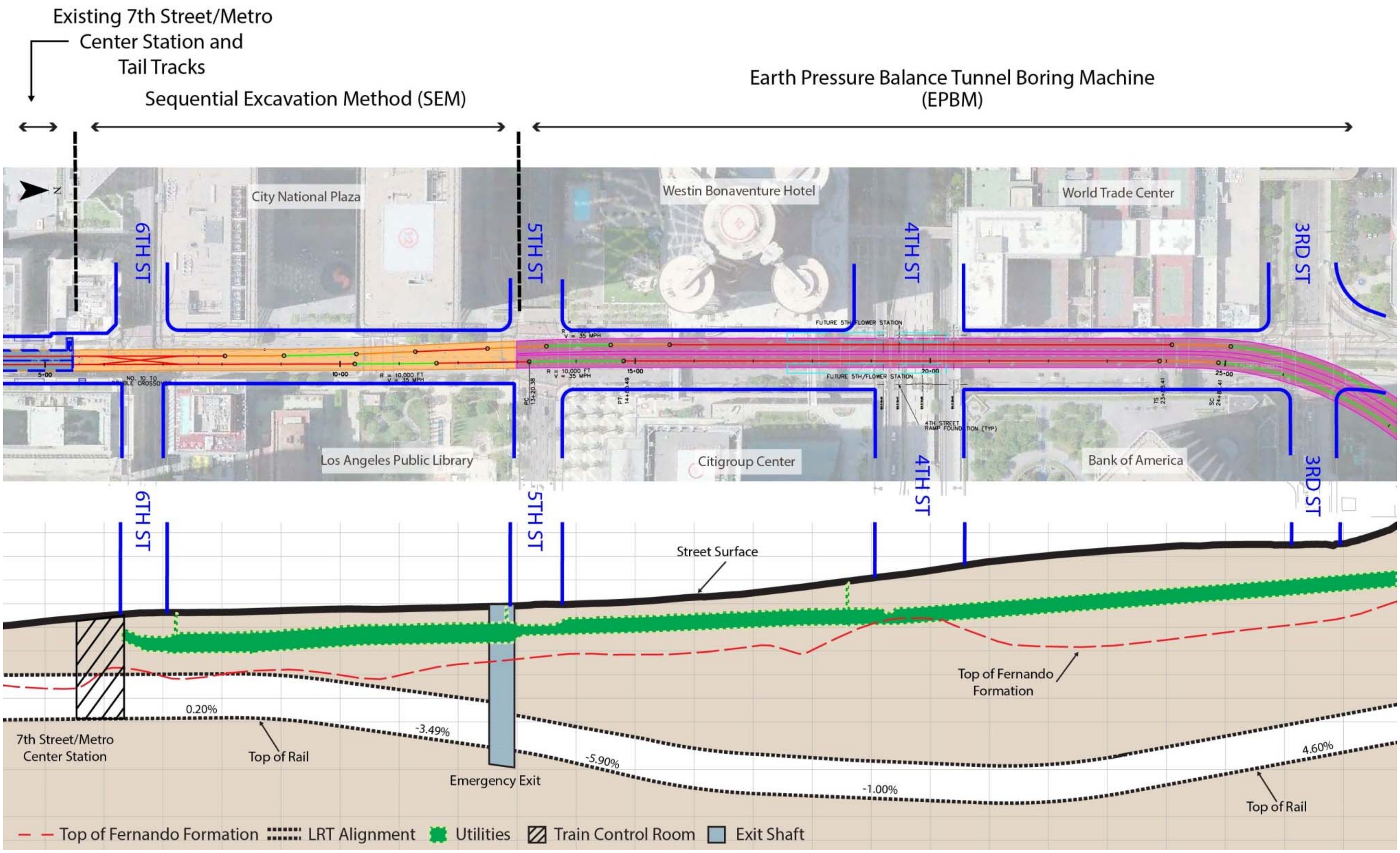
The vertical alignment for Alternative B would be designed with a modified "sag" to reduce the probability of the tunnel alignment encountering tie-backs located under Flower Street between 4th Street and impacting the 4th Street Bridge foundations. This alternative's vertical alignment design would result in an alignment depth varying from 40 feet at the high point to 105 feet to TOR below street surface at the low point. The resulting 5.9 percent gradient on the south end and a 4.6 percent gradient on the north end of the sag would also contribute to the reduction of the Flower Street segment's operational speed from 55 mph under the Project to 35 mph for this alternative.

On steep grades, Metro design criteria limits the grade of the track profile for three-car LRT trains to prevent train slippage. The design criteria identifies a maximum grade of five percent grade change for a track length of 500 to 1,000 feet between vertical points of intersection with flatter segments, and six percent for a grade length of less than 500 feet between vertical points of intersection. Provision of horizontal and vertical curves in the same track segment further reduce the maximum allowable grades. A track profile that does not follow the criteria can result in a reduced design speed that may not meet the Metro Design Criteria requirement for operating headways. The desired operational speed for the Flower Street segment is 55 miles per hour (mph), as identified by MRDC Section 10 – Operations, which is provided by the Project.

The deeper alignment proposed by Alternative B would have significant impacts on the future 5th/Flower and the 2nd/Hope stations:

- The modified sag provides for a flat spot at a one percent grade to accommodate a future 5th/Flower Station. The future station would have to be configured as a side platform since the narrow center-to-center spacing of the twin tunnels would preclude construction of a center platform. The depth of this alternative's tunnels would accommodate construction of a mezzanine. Construction of the future station side platforms would require demolition of a portion of each tunnel in order to provide an opening to connect with the two side platforms.

Figure 2.3-5: EPBM/SEM Low Alignment Alternative (Alternative B)



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Transit service would be interrupted for a substantial length of time to permit this major construction work to take place. Deviations would be required from Metro rail design standards to accommodate the site-specific conditions.

- Due to this alternative's greater depth, the 2nd/Hope Station would be shifted down by 32 feet from the Project station depth (96 feet) to 128 feet from TOR to the street surface. This station location would be deeper because the low point in Alternative B was shifted to the north to accommodate a future 5th/Flower Station. The greater station depth would have an increased risk to stability and safety of excavation shoring; this is an unprecedented depth for work of this nature in Los Angeles, which is not addressed by Metro Support of Excavation standards. Excavating at this depth would increase the difficulty in ventilating the excavation pit during construction, and increase the risk of exposure to hazardous gases. The greater depth would increase the amount of spoils (23,000 cubic yards) handled at the 2nd/Hope station site.

Alternative B would require a minor amount of cut and cover construction for two shafts: 1) an emergency exit south of 5th Street; and 20 a train control room vent shaft north of the 7th Street/ Metro Center Station rail tracks structure. This alternative would not require a tunnel boring machine retrieval shaft as the EPBM would be disassembled and removed through the tunnel to the Mangrove site in Little Tokyo with the EPBM shield left in place. Similar to the Project, cut and cover excavation materials would be handled from excavation sites located along Flower Street, while tunnel muck would be handled through the construction tunnel to the Mangrove portal site in Little Tokyo.

With the extension of tunneling activities further south on Flower Street, there would be a corresponding increase in the amount of excavated materials handled through the Mangrove site over the Project conditions. For Alternative B, it is estimated that 20 percent (compared to 81 percent for the Project) of the excavated materials would be handled from locations along Flower Street, with an increase to 80 percent (compared to 19 percent under Project conditions) of the tunneling would be accommodated through the Little Tokyo site.

Construction Method Risks and Need for Grouting

For Alternative B, ground stabilization would be required for the SEM section of the tunneling, but not the EPBM portion. For the SEM portion of the tunneling, the single twin-track tunnel is larger 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. Mitigation by jet grouting would be required.

The jet grouting for the SEM portion would require drilling grout holes on a six-foot by six-foot pattern throughout the area to be grouted as previously shown in Figure 2.3-1. Grout holes would extend from the ground surface through the weak fill and alluvial soils to just into the relatively stronger Fernando Formation, a distance of more than 40 feet. Alternative B would require a 50-foot-wide zone in Flower Street to be grouted. Approximately 1,000 jet holes would be drilled and grouted for this alternative requiring require approximately 8 months (with a risk of doubling the effort for up to 16 months) using two drill rigs as shown in Figure 2.3-1.

The SEM tunneling and related grouting activities for Alternative B would be located between south of 5th Street to just south of 6th Street. As shown in Figures 2.3-2 and 2.3-3, the jet grouting staging areas would occupy the east side of Flower Street during a majority of the jet grouting activities. As shown in the figures, construction of Alternative B would require long term closure of two travel lanes on the east side of Flower Street to house the grouting plant and for equipment storage, along with an additional two closure on the west side to accommodate grouting activities. A total of four lanes would be temporarily closed for eight months, possibly extending to 16 months due to unforeseen underground conditions, when grouting is taking place.

Schedule Impacts

Implementation of Alternative B would extend the project construction duration by seven (7) months over the Project, and the longer construction duration is due only to changes on Flower Street and related impacts to Little Tokyo. As stated previously, under the Project, cut and cover excavation and construction work would occur concurrently with the excavation of the bored tunnels and other construction activities throughout the alignment. For Alternative B, the primarily tunneling work needs to be performed sequentially, which results in a longer construction timeframe. While the required grouting activity can be performed concurrently with the EPBM tunneling work, but not the SEM work, grouting activity will further impact construction duration with Alternative B requiring two grouting rigs for approximately eight months, and possibly up to 16 months depending on the underground conditions experienced along Flower Street during construction. Due to the need to remove all Flower Street segment tunnel spoils through the Mangrove portal, the tunneling operation would continue until the SEM work is complete. This would hold the start of station construction work for the 2nd/Hope and 2nd/Broadway stations, and of the 2nd/Broadway SEM cavern and all cross passages until after the Flower Street segment tunneling is complete.

The resulting construction method-related scheduled changes are not simply add-ons to the Project construction schedule. As shown previously in Table 2.3-4, implementation of Alternative B would require 36 months over the Project's schedule. The longer duration is due to: 1) an additional 29 months for pre-construction activities; and 2) a longer construction duration by seven (7) months. Pre-construction activities for this alternative would include the preparation of detail engineering design plans, re-procurement activities for the design-build project contract, and re-permitting efforts. As the Project is currently under construction, implementation of this alternative would require stopping current construction activities and re-mobilization efforts for the new alternative project configuration using different construction techniques and equipment than the Project. Alternative B would have a longer construction duration as the identified tunneling excavation and construction activities would have to be performed sequentially rather than concurrently as under the Project. Additional construction time would be required for the jet grouting activities that must be performed prior to tunneling efforts to provide needed ground stabilization. In summary, under Alternative B, the duration of construction activities along the Flower Street segment would be reduced under this alternative, while the duration of construction activities in Little Tokyo would increase. For Alternative B, the total project schedule from initiation of construction to start of revenue service would be 9.5 years compared to 6.5 years for the Project.