Appendix E—Construction Methods

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Metro

APPENDIX E—CONSTRUCTION METHODS

E.1 Summary of Construction Methods, Techniques, and Equipment

This Appendix presents an overall summary of the construction methods followed by more detailed descriptions of the construction stages, station and tunnel construction methods anticipated.

E.1.1 General Construction Scenario

In general, conventional construction techniques and equipment will be used, consistent with other similar projects in Southern California. This will include the use of specialized pressurized-face Tunnel Boring Machines (TBMs) to excavate the tunnels. Construction would follow all applicable Federal, State and local laws for building and safety. Standard construction methods would be used for traffic, noise, vibrations and dust control, consistent with all applicable laws.

The major project elements are tunnels, underground stations, station-related facilities, maintenance and operations yards and buildings, trackwork, ventilation equipment, and specialty systems such as traction power, communications and signaling equipment. For the selected alternative, construction would begin simultaneously at several locations along the route, with overlapping construction of the various project elements. Working hours would be varied to meet special circumstances and restrictions. Also, the number of workers present at any one time will vary depending on the activities being performed. During peak construction periods, work will be underway at several station sites while tunnel excavation progresses concurrently.

In addition to the primary system features of tunnels and stations, the following are common to the Build Alternatives:

- Building protection measures such as underpinning or ground improvement (including grouting) to protect structures, as necessary.
- Relocation, modification, or protection of existing utilities.
- Removal or relocation of structures at construction staging sites and station entrances.
- Entrances to the underground stations.
- Urban design enhancements around station entrances.
- Surface and subsurface drainage systems.
- Traction power substations with electrical power feeds.
- Trackwork, ventilation, traction power, communications and signaling systems for train operations.
- Emergency (backup) power systems.
- Station finishes including fare vending equipment, elevators, escalators, landscaping, signage, and other necessary amenities.
- System integration testing and simulated revenue operation test runs
- Final commissioning of the system.

A generalized sequence of activities that would occur, independent of which alternative becomes the selected alternative, is shown in Table E-1. The time necessary for each activity would vary by alternative, depending on the amount of tunneling required and number of stations. Other factors would include the number and type of utilities requiring relocation, subsurface conditions, and the location and condition of nearby surface and subsurface structures. A schematic of the tunnel and station profile for MOS-2 is shown in Figure E-1. The profile shows the relationship between the tunnel and the ground surface and the distance between stations.

Table E-1. Generalized Sequence of Construction Activities

Activity	Tasks	Average Time (months)[1]
Survey & Preconstruction	Locate utilities; establish ROW and project control points and centerlines; and establish/relocate survey monuments.	4 – 6
Site Preparation	Relocate utilities and clear and grub ROW (demolition); widen streets; establish detours and haul routes; erect safety devices and mobilize special construction equipment; prepare construction equipment yards and stockpile materials.	12 – 18
Heavy Construction	Construction of stations and entrances, tunnels and associated structures; major systems facilities; disposal of excess material; backfilling of stations and portal, and refinish roadways and sidewalks.	24 – 36
Medium Construction	Lay track; construct surface facilities (including above-ground structures), drainage, and backfill; and pave streets.	12 – 24
Light Construction	Install all system elements (electrical, mechanical, signals, and communication), traffic signals, street lighting where applicable, landscaping, signing and striping; close detours; clean-up and test system.	6 – 12
Pre-Revenue (Human Use) Service	Testing of power, communications, signaling, and ventilation systems; training of operators and maintenance personnel.	5 – 6
Project Operations Begin		

[1] Note: Portions of activities will be conducted at the same time as other activities.

E.1.2 Station Construction

Construction of the underground stations would employ the cut-and-cover construction technique. This technique generally begins by opening the ground surface to an adequate depth to permit support of existing utility lines and to install soldier piles, or other earth retaining structures. The surface opening is then covered with a temporary street decking so traffic and pedestrian movement can continue overhead while excavation proceeds beneath the decking. The temporary excavation will be retained by an approved excavation support system, known as a shoring system. Adjacent building foundations will also be supported as necessary. A concrete station box structure is then built within the excavated space, backfilled up to street level, and the surface is restored.

E.1.3 Tunnel Construction

Tunneling is expected to be performed with pressurized-face Tunnel Boring Machines (TBMs). The TBM type used for different reaches of the tunnels will be subject to varying, site-specific requirements, including geologic conditions. For instance, where hydrocarbons and/or gases are expected to be encountered it is likely that a Slurry-Face TBM will be required. Where there is less contamination, it is expected that either a Slurry-Face or Earth-Pressure Balance (EPB) TBM will be used. The distinction between these machine types is presented later in this Appendix.

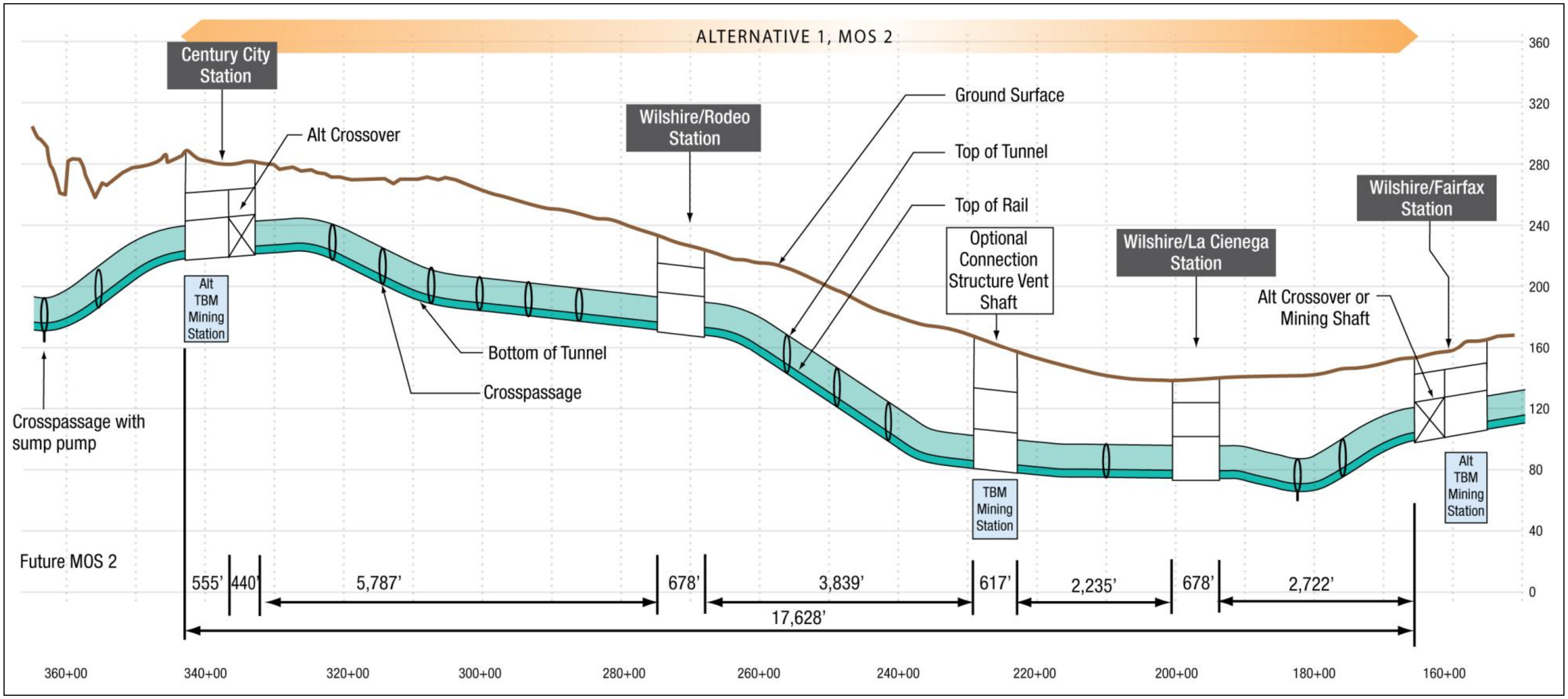

Figure E-1. Schematic Profile, West Hollywood Extension

The project will consist of two circular tunnels, approximately 20 feet in diameter, bored side-by-side and separated by a pillar of ground between. An alternative is an “over-under” configuration where one tunnel is bored directly above the other. This stacked arrangement is recommended only where right-of-way is constrained or where special design circumstances are present, such as at transfer/interchange structures between separate rail lines.

E.1.4 Staging Areas

Staging areas, also known as "lay down" areas, will be necessary for construction of station excavations, tunneling, station entrances, crossover boxes, pocket tracks, mid-line structures, traction power sub-stations (TPSS) and ventilation or emergency exit shafts. Staging areas also are used for storage and preparation of precast concrete segments, temporary spoil storage, shaft support (air, water, electricity, spoil hoisting), workshops, mixing and processing slurry for excavation support or tunnel excavation, and post-excavation slurry treatment (separation), which would include filters, centrifuges and vibrator equipment. Furthermore, these areas will be used for temporary storage of delivered materials and excavated spoils prior to removal from the site, ventilation lines and other tunnel utility lines. The TBMs require staging areas for assembly, setup, materials storage, and operation. Typically, these areas will be at station excavation sites to facilitate access to the tunnel.

Temporary easements, typically a portion of the sidewalk, traffic lanes, and/or parking areas may be required at various locations for staging. Construction staging within the streets is also envisioned where no off-street areas can be identified.

In addition, contractors and construction managers will establish field offices in existing office space near work areas or in temporary jobsite trailers at the staging areas. Often these offices are operational on a 24-hour basis, consistent with construction activities.

E.1.5 Preconstruction

During final design and prior to any construction, pre-construction evaluations would be completed to determine existing conditions that could affect construction methods and timing, as described in the following sections. In addition, traffic control plans will be prepared for station and tunnel construction and activities where street closures and excessive truck traffic would disrupt normal street operations.

E.1.6 Surveys and Investigations

Local Business Surveys

Individual businesses will be interviewed to identify business usage, delivery, shipping patterns, and critical times of the day or year for business activities. This information will be used by Metro to develop construction requirements, worksite traffic control plans, identify alternative access routes, and requirements to maintain critical business activities.

Geotechnical Investigations

Subsurface (geotechnical) investigations will further evaluate geology, groundwater, seismic, and environmental conditions along the alignment. These investigations would be spaced along the alignment to evaluate soil, rock, groundwater, seismic and geo-environmental conditions, particularly to note locations where hydrocarbon or other contaminant deposits may be encountered. The results of these investigations will influence final design and construction methods for stations, tunnels, other underground structures, and foundations.

Cultural Resource Investigations

Paleontological Properties

Areas surrounding the Fairfax and La Brea stations are known to have tar deposits and/or tar sands with potential paleontological features that may have to be removed under special conditions. Because of this, preliminary preparation and excavation is likely to occur early-on to remove the identified resources and prepare the ground for excavation. Additional detail is provided in Section 4.14, Historic, Archaeological, and Paleontological Resources, of this Draft EIS/EIR.

In specific cases where paleontological resources are found, it may be possible to alter the cut-and-cover methods to allow sufficient time to evaluate and recover the resources without complete suspension of construction activities. It may be necessary to employ raised decking, which would allow traffic to be restored without disturbing the underlying resources. The decking system would be elevated above street level and would require ramps for traffic to transition to and from the decking.

Historic Properties

Specific historic properties will be identified for further analysis in the later stages of design. Such properties could include structures located above tunnels that are outside street limits, as well as structures adjacent to tunnels, stations, or cut-and-cover construction areas, or areas proposed for acquisition.

Structure and Building Analysis

The condition of existing buildings and other structures (such as multi-level parking garages) in proximity to the stations, tunnels and other underground structures will be evaluated with respect to excavation for underground stations and tunnels. This evaluation will determine whether additional protection work, such as special excavation support systems, underpinning or grouting, is necessary to mitigate settlement. The integrity of adjacent structures will influence the method of excavation and type of support systems that will be utilized.

E.1.7 Site Preparation and Demolition

Prior to construction, contractors will prepare work sites to accept workers, equipment and materials. This will include clearing, grubbing, and grading, followed by mobilization of initial equipment and materials.

At some sites, building demolition may be required to provide space for construction or construction work areas. Demolition necessitates strict controls to ensure that adjacent buildings and infrastructure are not damaged or otherwise affected. These controls include fencing and barricades, environmental monitoring, and limits on the types of equipment and demolition procedures. Demolition equipment typically includes bulldozers and front-end loaders, which are often specially developed or modified to allow for precise and controlled dismantling. Prior to demolition, contractors may salvage items such as fixtures, mechanical equipment and lumber. Where economical, materials such as steel and concrete may be recycled.

E.1.8 Utilities and Street Closures

Utilities Relocations

Underground utilities are researched and noted on drawings as part of the design phase. During preconstruction, existing utilities may be more closely inspected and evaluated, including depth, condition and exact location. An operation called “potholing” is typically done to physically locate certain utilities, which can then be appropriately marked or protected. It is necessary to relocate, modify or protect in place all utilities and underground structures that would conflict with excavations.

Where in-place protection is not sufficient, relocation is required. Utility relocations can be done prior to or during construction, depending on the sensitivity of the utility. Shallow utilities, such as maintenance holes or pull boxes, would interfere with excavation work and require relocation. Affected utilities are expected to include storm drains, sanitary sewers, water lines, power lines, gas pipelines, oil pipelines, electrical duct banks and transmission lines, lighting, irrigation lines, and communications such as phone, data and cable TV.

Utility relocations will be coordinated with the utility owner. Relocation and protection of underground utilities will require excavation to the depth of the existing utility line and installation of a replacement utility in a new location. This will occur within the affected ROW and on nearby streets, as required. Utility relocations often entail some form of temporary service interruptions. These are typically planned for periods of minimum use (such as nights or weekends), so that outages have the least impact on users.

Utilities such as high-pressure water mains and gas lines, which could be a hazard during station construction and that are not to be permanently relocated away from the work site, would be removed from the construction area temporarily. Utilities that do not require permanent or temporary relocation can be reinforced, if necessary, and supported in-place by hanging from deck beams.

In addition to utility relocations, various new utilities will be installed to accommodate construction needs. These include, but are not limited to, communications cables (including fiber optic lines), electrical duct-banks, drainage facilities, water supply lines and lighting.

Street Closures

Relocation of utilities occurs before excavation and may require closure of traffic lanes. In some instances, block-long sections of streets might be closed temporarily. Pedestrian access (sidewalks) would remain open, and vehicular traffic would be re-routed. Special facilities, such as handrails, fences, and walkways will be provided for the safety of pedestrians. Temporary night sidewalk closures may be necessary in some locations for the delivery of oversized materials. Minor cross streets and alleyways may also be temporarily closed, but access to adjacent properties will be maintained. Major cross streets would require partial closure while relocating utilities.

E.1.9 Underground Stations

All stations would be designed with approximately 450-foot-long platforms to accommodate Metro Heavy Rail six-car trains. Cut-and-cover construction is planned at all stations, which would have similar dimensions: approximately 680 feet long, 70 feet wide, and depths of 60 to 70 feet below street level. Side entrances would typically be about 60 feet long, 20 feet wide and 25 feet deep. A typical station excavation would occur over approximately eight months and result in approximately 90,000 cubic yards (CY) of excavated soil and approximately 25 to 50 haul truck trips per day to remove the excavated soils from the site.

Approximately 12 to 18 months will be needed to establish the surface work area, install the excavation support system, and complete excavation to the extent the station could be used for tunnel operations or could be concreted. The total sequences for underground station construction could be up to 48 months.

Excavation Support Systems

Earth support is an important factor in the construction of deep excavations, and there are various suitable methods, to achieve the needed support. The initial support system for the station excavation is considered "temporary" over the period of construction, however most of the materials place remain in the ground after the final structure is completed. The final support is provided by the concrete station box structure, a permanent work element.

Figure E-2 illustrates a typical cut-and-cover station excavation and construction sequence. The excavation’s initial support system(s) is typically comprised of braced soldier piles and lagging, although alternative systems could include reinforced concrete drilled-in-place piles, tangent pile walls, diaphragm walls (slurry walls), and tied-back excavations. Initial support provides vertical stability while soil is removed from the excavation. This support remains in place for the duration of subsurface work. Final support includes concrete slabs, walls, and walkways for the station entrances.

Some lateral movement of the excavation walls may occur during soil removal. The extent of movement depends on the excavation methods, wall design, and wall height. Project specifications require walls and adjacent ground to be monitored for lateral movement and surface settlement and to provide corrective measures as necessary.

Soldier Pile and Lagging

Soldier pile and lagging walls are a type of shoring system typically used along the perimeter of excavation areas to hold back the soil around the excavation. This is also the most common shoring system used in the Los Angeles area. This support system consists of installing vertical steel beams (soldier piles) at regular intervals and placing lagging between the piles to form the retaining structure. Pre-auguring is necessary for installation of the soldier piles. Pre-auguring involves drilling holes for each pile rather than pile driving. The lagging, which spans and retains the soil between the piles, is typically timber or sprayed-on concrete (shotcrete).

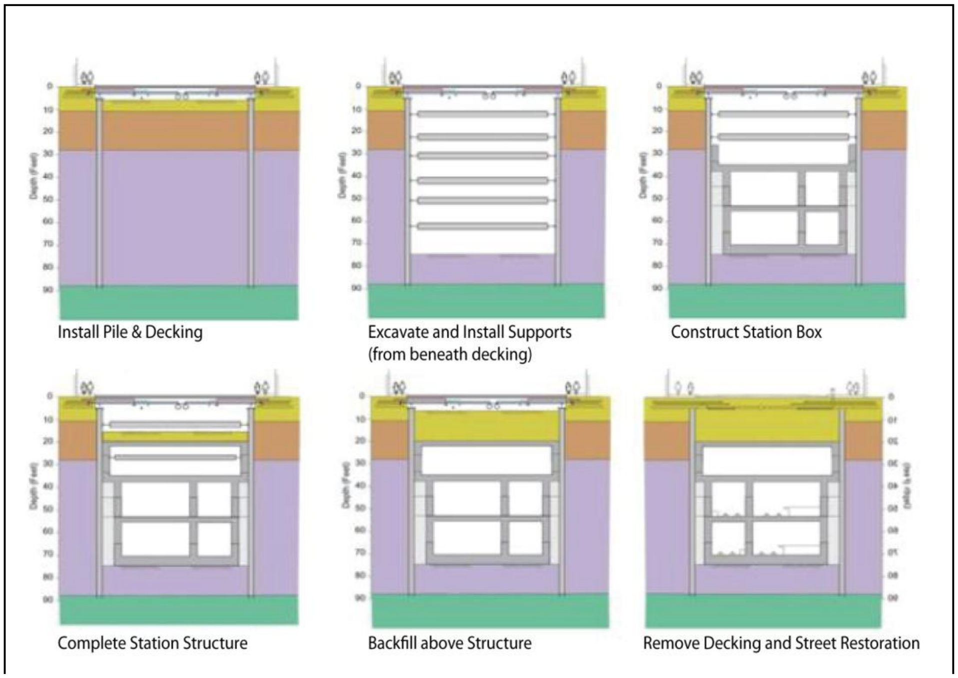

Figure E-2. Typical Cut-and-Cover Construction Sequence

A soldier pile and lagging excavation and support system is shown in Figure E-3. To install the piles, one side of the street is occupied to install one line of soldier piles. The soldier pile installation requires partial closures of traffic lanes where the equipment would be staged.

Figure E-3. Typical Soldier Pile and Lagging System (Metro Gold Line Eastside Extension)

After installation of soldier piles on both sides of the street at the station excavations, additional piles would be installed at the station ends, followed by installation of deck beams, installation of the precast concrete deck panels and bracing. The deck panels (decking) would be installed in progressive stages and would allow continued traffic and pedestrian movement, as the decking typically is installed flush with the existing street or sidewalk levels. Installation of the deck beams and deck panels requires substantial lane closures and traffic detours, so is often done at night or on weekends.

A soldier pile and lagging system is generally used where groundwater is not a hazard, or where lowering of the groundwater level (dewatering) can be used to reduce water seepage between piles. Alternatives to soldier pile and lagging walls include slurry walls and secant or tangent pile walls. Use of slurry wall construction can provide a nearly water-tight excavation.

Other Shoring Systems

In general, shoring design along the alignment will occur in one of three areas: areas of no groundwater; areas of shallow groundwater; and areas with asphaltic sands, and subsurface gases. For station and other excavations where water is not anticipated, conventional soldier piles and lagging, described above, are expected.

Groundwater along the alignment varies in depth and expected inflow rate. In the study area, underground excavations on the order of 50 to 60 feet deep have been constructed with minimum dewatering. Depending on the situation, dewatering can be successful with a few strategically located wells supplemented by gravel-filled trenches and sumps. In such cases, conventional soldier piles with lagging would be adequate.

However, at some locations along Wilshire Boulevard the groundwater is near the ground surface, potentially under artesian pressure. In such cases, dewatering through multiple wells is often necessary. Also, the use of soldier piles with lagging may be inadequate and a slurry (diaphragm) wall, secant pile or similar system may be required.

Tangent Pile or Secant Pile Walls

Tangent pile walls consist of contiguous drilled piles that touch each other. The contiguous wall generally provides a better groundwater seal than the soldier pile and lagging system, but some grouting or dewatering is sometimes needed to control leakage between piles. Similar to soldier pile installation, the contractor would occupy one side of the street and drill the piles sequentially to form the retaining wall.

A secant pile wall is similar to the tangent pile wall, but the piles have some overlap, resulting in better water tightness and rigidity. This method consists of boring and concreting the primary piles at centers slightly less than twice the pile diameter. Secondary piles are then bored between the primary piles, before the concrete can completely set. Because of the close spacing of tangent piles, utilities crossing the wall often require relocation.

Diaphragm/Slurry Walls

Figure E-4. Rebar Cage for Typical Slurry Wall Panel

Diaphragm walls (commonly known as slurry walls) are structural elements used for retention systems and permanent foundation walls. Slurry walls are constructed using deep trenches or panels that are kept open by filling them with a thick bentonite slurry mixture. Bentonite is a natural clay mineral that when mixed with water increases its density. After the slurry-filled trench is excavated to the required depth, structural elements (typically a steel reinforcing cage Figure E-4) are lowered into the trench, and concrete is pumped through a tremie pipe from the bottom, displacing the slurry.

Tremie concrete is then placed in one continuous operation through one or more pipes that extend to the bottom of the trench. As the concrete fills the trench, the concrete placement pipes are extracted. Once all the concrete is placed and has cured, the result is a structural concrete panel. Grout pipes can be placed within slurry wall panels to be used later in the event that leakage through wall sections is observed. The slurry that is displaced by the concrete is saved and reused for subsequent panel excavations.

Slurry wall construction advances in discontinuous sections such that no two adjacent panels are constructed simultaneously. Panels are usually 8 to 20 feet long, with widths varying from 2 to 5 feet. Slurry wall construction would occur in stages, working on one side of the street at a time. These walls have been constructed in virtually all soil types and provide a watertight support system in addition to improving wall stiffness to control ground movement.

Decking and Cross-Bracing

After installation of the temporary shoring (support) system and initial excavation, the deck beams are installed, followed by multiple sequences of excavation and installation of cross bracing. In special situations, such as where cross-bracing impedes access from above, tie-back systems may be used. Tie-backs are strong cable strands that are installed and grouted into pre-drilled holes that extend outward and downward from the excavation support wall. After the grout sets and the cables are firmly anchored into the ground, the tie-backs are tensioned to provide lateral support to the wall. The use of tie-backs may require temporary underground easements, if they extend into private property.

Decking is placed on the deck beams to allow traffic and pedestrian circulation to resume after the initial excavation. This decking is typically constructed of precast reinforced concrete and is installed flush with the existing street and sidewalk. Decking installation would require temporary street closures and would be installed in progressive stages.

Dewatering

Prior to installation of the ground support system, dewatering is likely to be required at the underground station sites to temporarily lower the groundwater level. This facilitates installation of the piles, improves soil stability, and allows excavation in dry conditions. Groundwater is pumped from wells installed around the perimeter of the area to be excavated. If contaminated water is encountered, it is typically treated at the site prior to discharge. At completion of construction, pumping is discontinued, and groundwater is allowed to return to its natural level.

In general, water will be pumped out of sump pits as the excavation proceeds downward. Ditches and gravity flow will be used to drain the water into the low-lying sumps. Based on prior experience along Wilshire Boulevard, deep basement excavation dewatering has been accomplished by pumping from a limited number of deep wells augmented by gravel-filled trenches and sumps. It is anticipated that dewatering flows will be processed on-site to remove oils and solids and then discharged to the local storm drain or sewer systems, according to permitting requirements. Contaminated water will require additional treatment and disposal procedures.

Settlement

Underground excavation for stations using the cut-and-cover technique can result in some ground relaxation and deformation of the retained soils. The magnitude of ground movement depends on the strength of the surrounding ground and the rigidity of the shoring system. The zone potentially susceptible to ground movement generally extends a lateral distance approximately equal to the depth of the excavation. Buildings within this zone will be evaluated for susceptibility to settlement and provided with additional protection measures as needed.

Presence of Existing Tie-backs

At station locations adjacent to existing deep basements, abandoned tie-backs may project into the space of the planned station. Although no longer in service, these tie-backs will interfere with the construction of shoring and station walls. In many cases, the locations of these tie-backs can be reasonably well established. Accordingly, if soldier piles and lagging are used, the soldier piles can be spaced to avoid the tie-backs during drilling, and they can later be de-tensioned and cut off. Abandoned tiebacks can be more problematic if tangent or secant piles are installed or if slurry wall systems are used. Specialized methods and equipment to de-tension and cut the tiebacks may be used, or a soldier pile and lagging system will be used where tie-backs are known to exist.

Existing Foundations

Many of the station excavations will be near existing foundations. Depending on specific situations, foundations may have to be protected. A typical approach to building protection where buildings are near the excavation is to design a more rigid excavation support system that can resist the additional loads imposed by the adjacent foundations. In such cases, a stiffer tangent pile, secant pile or slurry wall shoring system may be used. Pre-loading of excavation support bracing may also be implemented. For buildings adjacent to cut-and-cover construction, it is anticipated that the shoring system, in conjunction with internal bracing, will provide a relatively rigid temporary support for the proposed excavation. In some cases underpinning (added foundation systems) may be used to support the adjacent structures

Disposal of Excavated Materials

With the decking installed and the utilities supported, the major excavation work for the station box can proceed. Spoils from station sites would be moved to an off-street work site or closed parking/traffic lane and loaded into haul trucks. Assuming each station to be approximately 680 feet long, 70 feet wide and 60 feet deep, the average volume of material from the excavation is approximately 135,000 CY. This assumes the soils expand by approximately 30 percent through the excavation and loading process. For deeper or larger stations, this volume would be greater.

Assuming and the use of 20 CY haul trucks, the total number of excavation truck trips required for one station would be approximately 5,000 to 7,000 trucks. For a typical station configuration, this would be approximately 50 to 60 truck trips per day.

Contaminated soils are separated as soon as they are identified during the excavation cycle. These soils would be temporarily stockpiled separately and managed in accordance with applicable regulations for handling and transporting contaminated materials.

Traffic

Traffic flow can be affected during the entire period of construction, which is anticipated to be approximately 5 to 7 1/2 years, depending on the selected alternative. Mechanisms available to control and maintain traffic at constricted intersections include decking to temporarily replace pavement and sidewalks, and temporary bridges. Decking typically contains hatches or removable panels to facilitate lowering equipment or materials down into the excavation with minimal traffic disruption.

Cross streets will typically be carried through intersections on similar decked structures. Pedestrian access (sidewalks) would remain open, although portions of sidewalks may be closed temporarily. Where sidewalks are temporarily removed, pedestrian access will be maintained by bridges, temporary walkways, and other means. Some streets may also be temporarily closed under special circumstances, such as deck beam installation.

Normal truck deliveries of supplies are estimated to average 5 to 10 trucks per work-day for the duration of station construction. Worker/employee commutes would be greater. The number of workers will vary, but for a typical station would be approximately 85 personnel daily. This assumes two shifts of 35 workers each plus 15 office employees.

E.1.10 Station Construction - Finished Structure

The stations will be constructed with poured-in-place concrete, which will differ substantially depending on the length and the design configuration for each structure. The duration for completing the concrete and architectural work is expected to be 24 to 32 months. The amount of concrete will likely be upward of 30,000 CY, which will take approximately 3,000 transit mix truck loads for each station. Reinforcing steel will average a total of 3,500 tons per station.

The construction sequence for the station structures would include construction of the foundation base slab, followed by installation of exterior walls and any interior column elements. Slabs are typically poured as the columns and intermediate floor and roof wall pours progress. Station entrance locations are generally used as access points during construction. Exterior entrances would be constructed after completion of the structure.

During station construction, approximately 5 to 10 concrete trucks per day are anticipated. Occasional large pours would be needed, requiring 30 to 40 trucks per day. The larger pours are expected to be performed at night to ensure supply and delivery of concrete and to minimize traffic impacts. Other support and delivery trucks, up to 10 to 20 per day, would be anticipated during peak station construction periods to deliver materials such as rails, structural steel, and mechanical and electrical equipment.

Station concrete construction and architectural finish work will take place after tunnel construction is completed. Once station structure work is complete, the station excavation will be backfilled, and the permanent roadway will be constructed.

Station Construction in Gassy Ground

Special requirements for the permanent structure design of stations are included in Section 4.9 of this Draft EIS/EIR, Geotechnical/Subsurface/Seismic/Hazardous Waste and Materials.

Station Drainage

Most of the stations are not expected to require subdrain systems or permanent dewatering wells. The station structures in areas of shallow groundwater will be thoroughly waterproofed, and an internal sump pump system may be required at some stations. Within the gassy areas, a special waterproofing system will be required to also provide a barrier against gas intrusion.

Backfilling

Station excavations will require backfilling over the top (roof) of the structure to fill the area between the structure and the street. This backfilling is typically done with imported soils, which are delivered by truck. Backfilling will be carried out in the last three or four months as the station is completed. Depending on the station configuration, this operation will be done in stages. Each station will require approximately 20,000 CY of imported backfill, or roughly 1,000 truck-loads. During peak backfill periods, approximately 50 to 100 trucks per day would be expected.

The number of backfill deliveries can be reduced by stockpiling excavated materials on site for re-use. Soils excavated from station sites may be suitable for re-use. However, it will not be feasible to re-use excavated tunnel materials for backfill because of the conditioning agents and/or slurry used for tunnel excavation.

Ventilation Shafts and Emergency Exits

A number of ventilation structures and emergency exit structures will be required. The station structures will generally house emergency ventilation fan shafts plus separate emergency exit shafts at both ends of the stations. Ventilation fans are used for extracting smoke from tunnels and stairs for evacuation in the event of an emergency, such as a fire. These shafts are typically constructed as extensions of the station excavation.

Station Completion

Stations will include some above-ground structures that will be completed near the end of the station construction cycle. These above-ground structures may be limited to entrance features, stairways and elevator/escalator entry points. In some cases, Metro operations and maintenance spaces, including power equipment, communications facilities and/or control rooms, may be housed in above-ground structures. Street and site restoration activities and appurtenant features such as signage and landscaping will complete each station.

E.1.11 Tunnel Construction

Tunnel construction consists of a variety of activities. These include TBM procurement and mobilization, which also involves preparation of the work area and assembly of the machine and its components, followed by tunnel excavation. Tunnel excavation generally would range from 6 to 8 months for a one-mile length, but would vary, depending on the ground conditions encountered, site and work area constraints, and the number of TBMs used.

Tunnels will be constructed by pressurized-face TBMs to optimize control of the ground and to minimize settlement overlying and surrounding the tunnels (Figure E-5). In addition, this technology allows the tunnel lining to be installed concurrently and without lowering groundwater levels. Entrances for TBM operations (tunnel portal locations) would follow similar construction methods as the station excavations. Because the TBM entrance to the tunnel are typically from the station in street locations, side entrances are often required for access underground in adjacent off-street locations. In these cases, the excavation in adjacent off-street locations may remain open to ground surface level, so no decking would be used.

Figure E-5. Typical Pressurized-Face TBM

TBM Staging Areas

Construction staging areas would be necessary for tunnel construction, similar to what is required for stations and ancillary facilities. Off-street space will be needed for setup, insertion, operation and extraction of TBMs. Work areas to support tunnel excavation operations, including processing and removing tunnel spoils, handling precast concrete tunnel-lining segments, and tunnel utilities (such as ventilation, water supply, wastewater removal, power supply). In-street work areas will only be utilized when no off-street alternative exists.

Typically, a tunnel staging site of roughly 1 to 2 acres is required at the starting point of each tunnel drive. In addition to direct TBM support, this space is needed for loading/ unloading facilities, construction equipment, worker facilities and offices. TBM drives are the length TBMs may be "driven" from one station to the adjacent station area and continue beyond to the next station site - or further. Thus, not all station sites are required to be TBM staging areas.

TBM Transport, Delivery and Removal

TBM components will be shipped to the tunnel construction site by truck. Several oversize deliveries will be required, some during nights and weekends. However, these large component deliveries are limited to initial setup period for the TBM, as well as during the removal period. If a TBM is to be re-used to excavate a subsequent tunnel, the entire machine may be transported by road from one site to the next. This would require full or partial road closures, typically at night.

TBM Tunnel Excavation

TBMs are large-diameter horizontal “drills” that continuously excavate circular tunnel sections. There are two types of pressurized-face TBMs, Earth-Pressure Balance (EPB) or Slurry-Face TBM. Different machine types are designed for different geologic conditions. The excavated materials are removed through the tunnel using hopper-type rail cars, conveyor belt systems, or closed spoil transport pipelines. As the machine advances, both the ground in front of the machine and the horizontal "hole" it creates are continually supported by the TBM shield and pre-cast concrete tunnel liners that are installed as the machine progresses. This method creates a tunnel with little or no disruption at the surface, and is especially suitable for creating a circular opening at greater depths than would be practical for cut-and-cover construction. The concrete tunnel liner segments will have rubber gaskets between them to prevent water from entering the tunnel, and also allows the excavation to advance below the groundwater level.

The TBMs require a launching area to start each tunneling operation. Following excavation, the TBM would be dismantled and retrieved at the designated end point. The TBM can then be transported back to the launching area, reassembled, and repeat its journey for the second tunnel. As an alternative, two TBMs could be utilized at the same time.

A tunnel drive consists of a series of activities. The TBM is advanced a small distance (typically 4 to 5 feet) by means of hydraulic jacks, which push against the previously installed tunnel lining ring. Following a complete "push" to advance the TBM, the hydraulic jacks are retracted and the next lining ring is installed. This process is repeated as the tunnel advances from one station to the next. When starting a tunnel drive from a shaft or station excavation, a heavy steel frame is typically erected to allow a rigid structure for the TBM to react against so that it can start to push forward (Figure E-6). Temporary precast concrete segmental liners are erected behind the TBM, which allow for continued advancement. The initial tunnel lining segments erected within the shaft are later removed once the TBM is fully "buried" and is mining continuously.

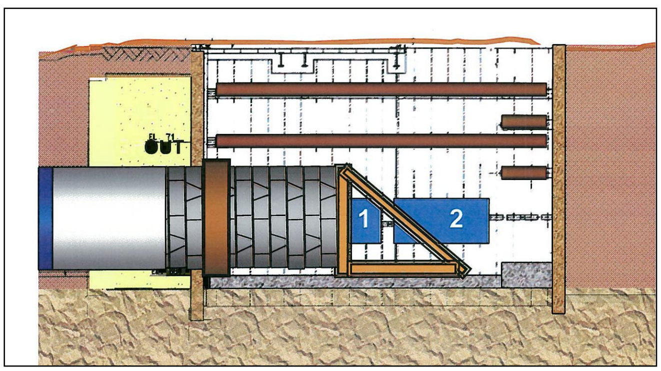

Figure E-6. Launching a TBM from the Station Excavation

Following tunnel excavation, the TBMs may be dismantled underground with the shield (outer shell) left in place. An alternative to dismantling the TBM would be to excavate a separate retrieval shaft. However, from a traffic management standpoint, due to traffic impacts at the retrieval shaft, retrieving the TBM is less desirable than dismantling it. An exception is if the TBM could be re-used immediately or in a reasonable time frame for constructing the next reach of tunnel. In such cases, the disruption caused by retrieval from the street may be justified.

The pre-cast concrete liners are pre-fabricated off-site and delivered to the site by truck. Segment loads are estimated to be 6 to 10 per day for the duration of tunneling based on an estimated overall excavation rate of 30 to 50 feet per day. Segments needed for at least several days' production are generally stored at the work site to allow continuous tunneling. Tunneling operations are typically continuous, occurring six or seven days a week, usually with two 10-hour shifts per day. A typical TBM tunnel is shown in Figure E-7.

Figure E-7. Typical TBM Tunnel during Construction

Excavated material (spoils) is moved to the rear of the TBM by a screw conveyor and deposited on a conveyor belt. The conveyor belt drops the spoils into hopper-type mine cars, which are then taken back to the launching area by a locomotive operating on temporary rail tracks fastened to the bottom of the tunnel. At the shaft, the mine cars are lifted out by a crane or hoist, and the material is loaded into trucks or temporarily stockpiled for off-site disposal. Alternatively, belt conveyor systems could be used to transport spoils through the tunnel and/or from the shaft to the surface. With the use of pressurized-face TBMs, the spoils must generally undergo partial treatment before being loaded on trucks for off-site disposal.

Disposal of Tunnel Spoils

Generation of Spoils

Spoils would transported off-site for disposal. However, because all tunneling would be performed with pressurized-face TBMs, the spoils would first undergo some treatment (such as drying or de-sanding) before being loaded onto trucks for off-site disposal. For mostly sandy soils, drying can likely be accomplished on-site. For soils with higher water content (clays), and in the event that the volume of such soils is substantial, an additional temporary off-site storage/drying location may be needed.

For a typical tunnel excavation, mining two tunnels at approximately 20 feet per 10-hour shift, the rate of spoil removal would be approximately 130 loose CY per hour. This material will be produced from two tunneling machines, often operating simultaneously. As a result, the spoils to be removed could be doubled, in the range of 250 loose CY per hour, or approximately 12 trucks per hour, or one truck every 4 to 5 minutes. With temporary stockpiling of spoils on the site, the hauling could be partially deferred to nights and weekends.

Anticipated Ground Conditions

Geologic conditions for the project area are described in Sections 4.8 and 4.9 of this Draft EIS/EIR. In tunnel terminology, the tunnels will be excavated through soft ground, not rock, and in some locations below the groundwater table. Some of the alignment may be in gassy ground conditions, including methane and hydrogen sulfide.

Selection of the type of pressure-face TBM, an EPB or Slurry-Face TBM may be determined based on the expected performance of the TBM in the anticipated ground conditions. To some extent, EPB TBMs are better suited to less permeable soils (clays), while Slurry-Face TBMs are better suited to more permeable soils (sands and gravels).

Earth Pressure Balance (EPB) TBMs

In North America, EPB TBMs are the most common and have been used successfully in the project area. These TBMs rely on balancing the thrust pressure of the machine against the soil and water pressures from the ground being excavated. The EPB TBMs are generally well suited for mining in soft ground, as expected with the proposed project. These TBMs can also mine through variable soils, and groundwater. The excavation method for an EPB TBM is based on the principle that tunnel face support is provided by the excavated soil itself (Figure E-8 - schematic of EPB TBM).

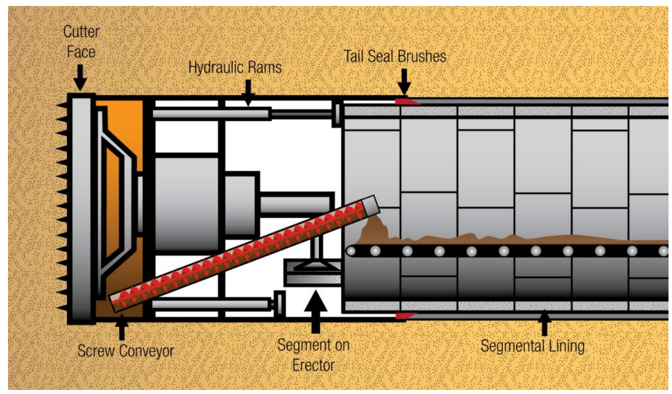

Figure E-8. Schematic of EPB TMB

Slurry-Face TBMs

Slurry-Face TBMs will likely be required for tunneling in gassy zones, where the addition of the slurry and the closed spoil removal system provides more protection against gas intrusion into the tunnel environment (Figure E-10 - Slurry Face TBM). Where lower gas concentrations are expected, EPB TBMs may be suitable.

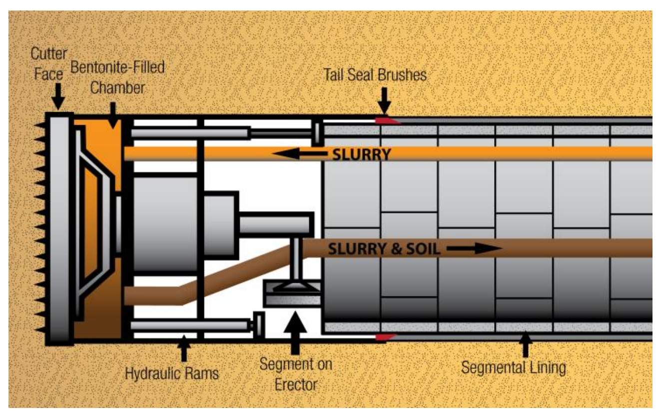

Figure E-9. Slurry Face TBM

With Slurry-Face TBMs, bentonite (clay) slurry is added in a pressurized environment at the tunnel excavation face. This combination of pressure and slurry stabilizes and supports the soils during excavation. Depending on the ground encountered, conditioners may be added to the slurry. Excavated soil is mixed with the slurry fluid and then pumped out of the tunnel to an above-ground separation plant through large (approximately 18” diameter) pipelines with in-line booster pumps The excavated materials are treated at a separation plant, where they are separated from the slurry mixture. This also allows safe dispersion of any potentially gaseous components without endangering tunnel personnel.

Slurry Treatment Plant

Figure E-10. Typical Slurry Mixing Plant

With the Slurry-Face TBM method of tunneling, bentonite slurry is used to apply fluid (hydraulic) pressure to the tunnel face and to transport soil cuttings from the tunneling machine's pressure chamber to the surface. The slurry mixed with soil cuttings is processed to separate the soil from the slurry. Soil is disposed of off-site, and the cleaned bentonite slurry is returned to the machine's cutting chamber. The slurry that would be mixed at a surface plant is pumped in and out of the tunnel, and the TBM pressure chamber through a series of pipes. As a result, excavated material is kept enclosed and in a fluid state until it reaches the surface-based slurry separation plant (Figure E-10. Typical Slurry Mixing Plant).

This method involves the setup of one or more temporary slurry treatment plants at the surface. The slurry treatment plant provides two basic functions: 1) prepares the bentonite slurry by mixing the slurry for use in the tunneling process, and 2) treats the used slurry (slurry discharge). The slurry discharge is pumped out via pipeline to the ground surface where undergoes a separation process for soil removal. The removal process involves settling and the use of sieves for separation of large particles and centrifuges for small particles. Once the excavated material is separated from the slurry, the resulting soil can typically be stockpiled at the plant grounds or at off-site locations for approximately two to three days to dry before being hauled to a landfill or other disposal facility.

The slurry plant is anticipated to require an approximately one-half-acre site for the equipment and enclosure. (Figure E-11 - Slurry Separation Facilities). Water removed from the discharge slurry would be recycled for further use in preparing the bentonite slurry. As necessary, treatment plants may be containerized for size reduction and sound proofing.

Figure E-11. Slurry Treatment Facilities (Stacked Configuration)

Tunnel Excavation Settlement and Settlement Protection

During the TBM tunnel excavation, the machine excavates slightly more soil than is taken up by the final lining. This is often referred to as "ground loss," the term for the small excess of excavated volume. Such ground loss can produce surface settlement. The settlement can occur during mining or, depending on ground conditions, days or weeks after the mining. The use of pressurized-face TBMs minimizes this settlement.

The amount of ground surface settlement will be a function of tunnel depth, tunnel size, proximity of adjacent tunnels, ground conditions, TBM characteristics and excavation techniques. In addition to ensuring adequate face pressures through the use of pressurized-face TBMs, the requirement for precast segmental linings, grouted as the TBM advances, also minimizes settlement potential. The grouting operation is performed within the tunnel behind the TBM to promptly fill the annular space between the segmental lining and the surrounding ground.

Pressure is maintained at the face of the TBM tunnel excavation to reduce the potential for ground loss, soil instability, and surface settlement. In addition, a rigid, precast, bolted, gasketed lining system would be employed. In combination with the face pressure, grout would be injected immediately behind the TBM, in the annular space between the installed precast concrete liners (tunnel rings) and the excavated ground.

For shallow tunnels below sensitive structures or utilities, additional measures described below can be employed to further reduce settlement. The measure utilized would depend on the ground conditions and structure details at specific areas.

Permeation Grouting

Permeation grouting is used to improve the ground prior to tunneling. Chemical (sodium silicate) or cement-based grouts are injected into the ground to fill voids between soil particles and provide the soils with greater strength and stand-up time. This grout can be placed through pipes from the surface before the tunnel reaches the grouted area, from pits or shafts adjacent to the grouted area, or in some instances from the tunnel face. In this latter case, the tunneling machine must be stopped for a period of time to drill ahead, install grout pipes, pump grout, and allow the grout to solidify. Permeation grouting is typically used in sandy soils, which are common in the project area.

Compaction Grouting

Compaction grouting involves consolidating the ground prior to or following tunnel excavation. Compaction grouting entails the controlled injection of a stiff grout (typically sand with a small amount of cement) into soils at and above the planned tunnel excavation. Grout pipes are installed in advance of tunneling, and grout is injected to pre-consolidate the ground prior to the TBM or to replace ground lost after tunnel excavation. In either case, the grout improves the soil integrity and makes the ground more resistant to deformation.

Compensation Grouting

With compensation grouting, the grout is injected as the tunnel is excavated. This involves controlled injection of grout between underground excavations and structures that require protection from settlement. For tunnel applications, the grout pipes are installed above the intended tunnel position, ahead of the TBM. Grout is injected above the tunnel crown as the TBM excavation advances. The grout thickens the soil above the tunnel crown and replaces some of the ground that may be lost during the tunneling. This method prevents ground loss from propagating to the surface, thus avoiding settlement. A key component in compensation grouting is monitoring both structures and ground movements to optimize the timing and quantities of grout injected.

Prior to grouting, surface preparation would likely be required (traffic controls, removal of landscaping, etc.) to allow space for drilling equipment, installation of grout pipes, and injection of grout. In cases where large structures are over the tunnel, access into the buildings or basements could be required. In such cases, the use of the building could be restricted during grouting operations. After grouting is completed, the area would be restored. These grouting methods can in some cases use directional drilling, which can be done from off-street locations and can allow for horizontal orientation of grout holes along the tunnel alignment.

Underpinning

As mentioned above for building protection adjacent to stations, underpinning involves supporting the foundations of an existing building by carrying its load-bearing element to deeper levels than its pre-construction configuration. This helps protect the building from settlement that may be caused by construction near that foundation and permanently extends the foundations of a structure to an appropriate level beyond the range of influence of the construction activity. This can be accomplished by providing deeper piles adjacent to or directly under the existing foundation and transferring the building foundation loads onto the new system.

Underpinning may not be appropriate if the building is directly above the tunnel alignment, as building foundations could impart additional loads on the tunnel lining. In such cases, the tunnel lining would be designed for the additional loads.

Presence of Existing Tie-backs

Abandoned tie-backs could project into the planned tunnel excavation. Such situations are problematic because the TBMs cannot excavate through such tie-backs. In such cases, the tie-back cables must be cut and removed so the TBM cutter-head is not damaged. Tiebacks are anticipated at areas adjacent to deep basements and/or parking garages in buildings generally constructed after 1965.

Where the locations of tie-backs can be reasonably well established, it is possible to mine up to the tie-back and stop. The forward chamber of the TBM can then be pressurized with compressed air, and workers can enter ahead of the machine to cut and remove the tie-backs. A preferred procedure would be to excavate a small-diameter shaft from the ground surface and cut the tie-backs prior to tunneling.

Depending on the number of tie-backs intruding into the tunnel envelope and the depth of the tunnel, a short section of cut-and-cover excavation may be required in the tie-back zone. The TBM would “walk-through” the open excavation and erect the precast tunnel segments. Once the TBM had progressed completely through the area, backfill would be placed and compacted around the precast segments and up to the ground surface, which would then be restored.

In any of the situations above, the ground in the tie-back areas may need to be improved or strengthened by grouting prior to cutting the tie-back to minimize ground losses and associated settlement.

Tunneling in Gassy Ground

The primary measures used for safety in the event of encountering gas is having adequate ventilation, which dilutes and transports gases out of the tunnel. In addition, gas monitoring devices will be utilized to automatically shut down electric power to the TBM. TBMs and other equipment used in the tunnel will be sealed and be of explosion-proof design for use in a gassy environment. Tunneling in gassy and/or tar-laden ground Is discussed in section 4.9 of this Draft EIS/EIR.

Tunnel Safety Considerations

Worker Safety

All underground construction will require reviews and consents from the Metro Tunnel Advisory Panel and the Metro Fire Life Safety Committee, which includes members from the Los Angeles City and County Fire Departments, as well as Metro safety specialists. In California, tunnel construction safety is governed by the California Occupational Safety and Health Administration (Cal/OSHA) Tunnel Safety Orders and worker safety training. California Electrical Safety Orders will apply to use of electric equipment. Where methane and/or hydrogen sulfide gases could be encountered, the regulations are specific and begin with the tunnel classification. The classifications range from “non-Gassy,” where there is little likelihood of encountering gas, to “Gassy,” which is applied when gas in the tunnel is likely to exceed concentrations greater than 5 percent of the Lower Explosive Limit (LEL) of the gas.

Ventilation

The tunnel must have adequate ventilation to dilute gasses to safe levels. Methane is combustible when mixed with air in the range of between 5 percent and 15 percent by volume. Below the 5 percent LEL, methane is not explosive. Similarly, hydrogen sulfide levels must be maintained well below the safe worker exposure limit of 10 parts per million (ppm). Project tunneling specifications will require excess ventilation capacity. Gas levels will be monitored continuously to ensure maintenance of safe exposure levels. The main ventilation systems will exhaust flammable gas or vapors from the tunnel, be provided with explosion- relief mechanisms, and be constructed of fire-resistant materials.

In addition, special personal protective equipment, such as oxygen generating self rescuers and supplied-air respirators, will be readily available in key locations within the tunnel in potential hydrogen sulfide zones or when warranted by air monitoring.

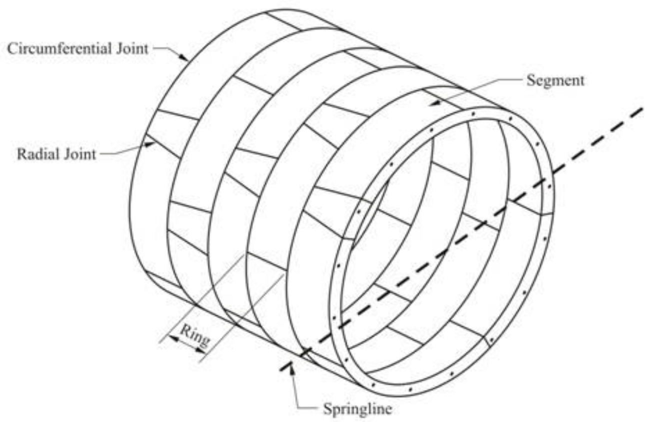

Figure E-12. Typical Precast Concrete Segmental Tunnel Lining

Tunnel Lining Construction

Precast concrete segments with gaskets will furnish the initial and final support of the tunnel. Single-pass, double-gasketed, precast concrete segments are the lining system of choice to limit infiltration of water and gas through the final lining (Figure E-12). These systems provide a high-quality tunnel lining close behind the TBM excavation. In areas of gassy ground, however, additional steps may be required to provide greater protection against gas leakage into the tunnel environment, either during or following tunnel excavation.

The precast concrete segments are fabricated off-site and delivered by truck. Several days or weeks of segments may be stored at the work site to ensure an uninterrupted supply to the tunnel excavation operations. A typical precast segment storage area is shown in Figure E-13. Care is required to ensure that the segment gaskets are not damaged during transport, shipment, or by prolonged exposure to sunlight. Depending on the gasket composition and the typical storage period, the segment gaskets may need to be installed at the site, rather than at an off-site pre-fabrication facility. If this is necessary, a small enclosure is required to install the gaskets under controlled conditions.

Figure E-13. Precast Concrete Segments Storage

E.1.12 Cross-passage Construction

Cross-passages between adjacent tunnels will be constructed at intervals within the tunnels. These openings will be almost entirely hand-excavated and concreted. Before exposing the ground, particularly where water or gas will be encountered, a tight seal of improved soils (using grout or other soil improvements) will be installed around the perimeter of the area to be excavated. Because excavation and construction of these structures is particularly sensitive to ground, water and gas conditions, locations will be determined based on ground conditions.

Individually, ground conditions will dictate the method and detail of preparing the cross-passage site for excavation. After ground treatment, a tight ring with grouted holes will be drilled from within the tunnel and then grouted with chemical or cement grout. Steel spiling bars (pre-Reinforceing) may also be employed, and would be drilled or driven from the tunnel above the cross-passage envelope.

Alternately, drilling and grouting might take place from above the tunnels. Although surface drilling is often more disruptive to surface activities, it may provide for greater control. In areas of weaker soils or higher groundwater, jet grouting from the surface may be utilized to provide a higher-strength and more consistent area of improved ground for cross-passage excavation. When below the water table, freezing the ground is another method that could be considered.

Cross-passages will be excavated by sequential excavation and support methods that require the ground to be excavated incrementally in small areas and stabilized or supported prior to advancing to the next area. The ground can be stabilized by different methods, including steel supports, spiling pre-Reinforceing, and shotcrete (sprayed concrete). Excavated soils would be removed through the TBM tunnels. The sequence of excavation would be predetermined and modified as needed during construction.

In areas with potential exposure to gas, special monitoring will be employed. At breakouts from the main tunnel, grouting and other aspects of the construction would not vary substantially from the normal procedure. Pre-treatment of the ground to reduce the potential for gas exposure is an option. Also, probe holes extending into the cross-passage area from the main tunnel will likely be drilled prior to cross-passage excavation. Such probe holes would be beneficial for detecting water and/or gas and can allow for excavation plans to be adjusted.

Pocket Tracks and Crossovers

The rail system will require crossovers and pocket tracks for proper operation. Crossovers allow trains to move from one track to the other. A pocket track is a third track set between the existing two running tracks for temporary storage of out-of-service trains and for use as an emergency crossover. Pocket tracks and crossovers will be constructed using cut-and-cover construction.

Each crossover will be approximately 450-ft long, 60-ft wide, and 60-ft below ground (depending upon the distances between track centers). Pocket tracks will be approximately 1100-ft long, 60-ft wide, and 60-ft below ground.

Vent Shafts and Emergency Exits

Construction of ventilation shafts, mid-line ventilation structures, emergency exits and cross-passages will generally occur after completion of tunnel excavation, with the potential for exposure to hydrocarbons and, therefore, ventilation and ground support requirements. Shafts and exits will connect to surface streets or surrounding areas. Cross-passages will occur solely below the surface.

In general, ventilation fans and noise-producing equipment will be housed in below-ground spaces. Ventilation shafts would be expected to be located between stations, approximately one mile from a given station. These shafts can be considered smaller versions of station structures in that the same structural support of excavation and concrete construction methods will be utilized. Where a station may extend some 600 feet or more in length, the vent structure will likely not exceed 100 feet in length, and construction will be proportionally easier.

E.1.13 Systems Installations and Facilities

Trackwork

Trackwork will be constructed below grade in the completed tunnels and station structures. Trackwork construction involves installation of trackbed components on the completed concrete structures, followed by the laying of rails. In general, third rail (traction power) and conduits for systems installations will be constructed at the same time as, or closely following, the trackwork. Rails, conduits and associated components will be brought into the tunnels at selected station locations with appropriate off-street access, and in some cases via the existing system.

Electrical Substations and Facilities

In general, electrical substation and facilities will be located within available spaces in the stations, cross-passages, ventilation shafts, and emergency exits. Some electric power equipment may be located within street-level spaces. Substations will include Traction Power Substations (TPSS) and smaller substations. The substations will be spaced along the alignment and may be located at or near to each station. These electrical facilities will be separated from public areas of the system and will include appropriate security.

Communications and Signaling

Communications and signaling systems will be accommodated within rooms and niches in the stations, tunnels, cross-passages, ventilation shafts, and emergency exits. These systems will be spaced along the alignment and positioned at or near each station. They will be separated from public areas and will include appropriate security.

Operations and control facilities will be housed within existing Metro facilities or may be incorporated into the above-ground ROC and/or maintenance yards.

E.1.14 Street/Site Restorations

This work restores the street or ground surface to its original condition, or better. Site restoration operations will closely follow completion of the station structures. To maintain traffic flow, one-half of a street will be restored at a time and/or restoration will occur over weekends to enable an entire street to be temporarily closed to through traffic.

Backfill material will be trucked in, placed, and compacted and, during backfilling over stations, utilities will be installed along with new sewer manholes and cable/duct vaults. Sidewalks would be restored, and the permanent street would be constructed, including paving, striping and signage. Streets, sidewalks and landscaping would be restored in accordance with City standards.