SECTION 10

Site Conditions for Zone 4

10.1 General

As depicted on Plates 2 and 8, Zone 4 extends northeasterly from the northern terminus of I-710 through the cities of Alhambra, San Gabriel, San Marino, Pasadena, and Arcadia to I-210. Zone 4 is approximately 6 to 7.5 miles long and 2 miles wide at its northeastern limit. The delineation of Zone 4 anticipates a connection between the northern terminus of I-710 and I-210 to the northeast. The general location of Zone 4 is shown in Figure 10-1.

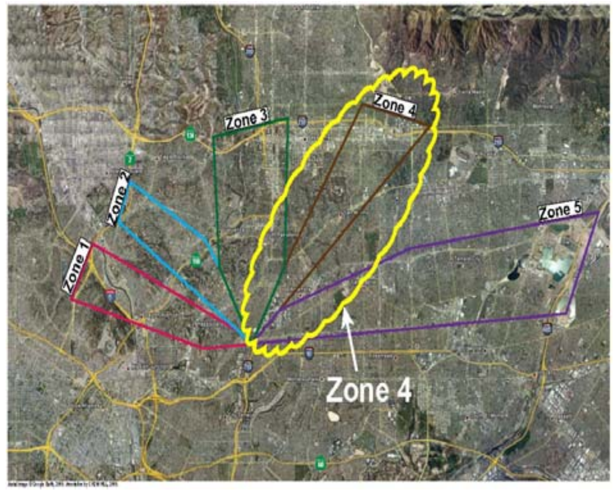

Figure 10-1. Zone 4 Location Map.

10.2 Existing Developments

Surface developments within the zone consist primarily of single-family residential structures with some apartment and condominium buildings and local businesses along some of the major arterial streets. Few multistory buildings are over 3 or 4 stories high. The tallest building is the Los Angeles County Department of Public Works offices in the Titemanson Building along Fremont Avenue.

I-210, a major southern California freeway, extends in an east-west direction and forms the northern terminus of the zone. Other important surface roads that cross through Zone 4 in a general east-west direction include, from south to north, Valley Boulevard, West Mission Road, Main Street, Huntington Drive, California Boulevard and Colorado Boulevard. Fremont Avenue, Sierra Madre Boulevard and San Gabriel Boulevard run in a north-south direction in the southern and northern portions of the zone. In addition, railroad tracks cross the southwestern part of the zone between Mission Road and Valley Boulevard.

Based on the densely urbanized nature of the San Gabriel Valley, it is anticipated that a large network of very shallow underground utilities is present underneath the surface streets. However, during our investigation we did not become aware of any major underground utility or other infrastructure that could potentially impact the excavation of a tunnel at an anticipated depth of 200 feet.

10.3 Zone Geology

10.3.1 Physiography

Zone 4 is located entirely within the San Gabriel Valley. The San Gabriel Valley is essentially a flat, gently south-sloping surface consisting of ancient (Pleistocene-age) alluvial fan, stream, and basin fill deposits. Elevations in the northern part of the San Gabriel Valley are in the 800- to 900-foot range; whereas in the south, elevations are in the 400- to 500-foot range. The gentle southward slope of the San Gabriel Valley is interrupted about halfway by the Raymond fault scarp, which crosses diagonally through the central part of Zone 4 (Plate 8). This scarp is a result of vertical fault displacement on the Raymond fault. Maximum relief across the scarp in Zone 4 is about 100 to 150 feet. In addition, a small knoll, representing an outlier of the Repetto Hills, occurs in the southwest part of the zone (Plate 2).

The intermittent Alhambra, San Pascual, Rubio, and Eaton Washes drain the zone in a southeasterly direction and flow into Rio Hondo south of Zone 5.

10.3.2 Stratigraphy

Geologic formations within Zone 4 consist of Tertiary-age marine sedimentary rocks, and Quaternary-age nonmarine alluvial sediments (Table 4-1). From oldest to youngest, these rock formations are Topanga Formation, Puente Formation, and Fernando Formation. Plate 2 shows the surface distribution of geologic units and Plate 8 illustrates the subsurface relationships of these various rock types along a northeast-southwest transect in the central part of Zone 4. However, it is important to realize that the geologic profile is idealized and simplified to represent the entire zone.

The tunnel is expected to be primarily within the alluvium as shown in Plates 2 and 8. The alluvial thickness ranges from about 0 to 50 feet at the southern end to over 600 feet at the northern end. A small portion of the tunnel will be in bedrock at the southern end. The alluvium is generally Old Alluvium (Pleistocene age), but local thin deposits of young alluvium exist in the uppermost levels of some intermittent gullies and washes. The alluvium in Zone 4 consists of clays, silts, sands, gravels, and cobbles. The sands and gravels are generally water-bearing and form the major aquifers of the basin. The finer-grained materials (clays and silts) are less permeable than the sands and gravels and thus form aquitards that impact the flow and distribution of subsurface water bodies.

The Fernando Formation comprises much of the southwestern portion of Zone 4 (Plate 8). The formation consists of massive (unbedded) soft, dark gray to black, marine claystone and siltstone.

A small area of the southwestern part of Zone 4 is composed of Puente Formation. The Puente Formation siltstone ranges from soft to moderately hard and is well-bedded with abundant partings along bedding planes. Although carbonate is common in the formation, only local zones are cemented into hard rocks. Such hard-cemented beds comprise no more than about 5 to 10 percent of the formation. Near the southwesternmost end of Zone 4, the Puente Formation might also include some white, soft, siliceous shale and thin-bedded mudstone. The Topanga Formation is at a depth well below a typical tunnel elevation and, as such, is not expected within the tunnel (Plate 8).

10.3.3 Structural Geology

As shown in Plate 8, the geologic strata are deformed into a series of folds and faults. Most of the folds and faults are continuations of geologic structures in the Repetto Hills to the west. These structures trend southeasterly and continue below the flat-lying Quaternary alluvium of the San Gabriel Valley. The major folds in this area are the Elysian Park Anticline and the South Pasadena Anticline.

The folds are offset by many faults, most of which are ancient features that are no longer active. The folding shown in Plate 8 is generalized and simplified. In reality, there are numerous small-scale folds within the larger fold trends. Frequent changes in bedding orientation should be expected during tunneling, due both to folding and faulting. Many of the faults are intraformational features, meaning that they offset rocks of the same type. If these faults are minor breaks, they may not significantly affect a TBM.

10.4 Faulting

The faults of most interest to proposed tunneling are the active faults that might result in displacement during an earthquake, and faults that might generate strong shaking of project facilities. For Zone 4, these are the Raymond fault and the Alhambra Wash fault. The surface scarp of the Alhambra Wash fault is short and does not extend into Zone 4 (Plate 2). However, seismic-reflection lines Z4-G2 and Z5-G2 (Appendix C.2) indicate deformation of Quaternary sediments along projections of the fault suggesting that it may continue through the zone in the subsurface.

Seismic-reflection data of line Z4-G1 indicate that the main branch of the Raymond fault is approximately several hundred feet wide. In addition, there appear to be several subparallel branches so the zone of faulting could be as wide as about 3,000 feet locally (Plate 8). This condition is confirmed by the S-wave velocity models obtained for surface wave soundings Z4-S2 through Z4-S4. These soundings were located in the northern, central and southern portions of seismic line Z4-G1, respectively. The S-wave velocity models for these soundings are quite variable, as may be expected because the Raymond fault bisects the seismic line.

As discussed in Section 4.2, the Raymond fault is capable of generating earthquakes in the 6 to 6.7 range. Fault rupture at the tunnel level can be expected to shift the ground in the 2- to 4-foot range. This displacement should be in a left lateral sense with the ground on the north side of the fault moving to the left and upward relative to the south side. The approximate magnitude of the maximum earthquake on the Alhambra Wash fault could be about 6.25 (see Section 4.2). Based on this, potential surface rupture displacement along the Alhambra Wash fault would be expected to be much less than those that would be expected along the Raymond fault.

Based on hydrostratigraphic evaluation of the San Gabriel Valley Area 3 Superfund Site Remedial Investigation, the potential presence of a northwest-trending structural bedrock discontinuity is inferred in the Alhambra and South Pasadena areas of the San Gabriel Basin (CH2M HILL, 2009c). The inferred bedrock discontinuity is shown from approximately the intersection of I-10 and Garfield Avenue in Alhambra on the south toward Raymond Hill and SR-110 in South Pasadena to the north. The existence of this structural bedrock discontinuity might explain a significant disparity in groundwater levels between the western and eastern portions (CH2M HILL, 2009c), and might correspond to an unnamed fault zone that extends across this area to the Raymond fault. On the other hand, the data that led to interpretation of the feature were not of high resolution and, thus, the feature may represent either the East Montebello fault or the Alhambra Wash fault (or both).

10.5 Groundwater and Surface Water Conditions

Groundwater occurs in the sand and gravel alluvial deposits of the San Gabriel Valley. The historically highest groundwater in the sand and gravel was shallowest on the north side of the Raymond fault where it was at the surface and formed small ponds and seeps. South of the Raymond fault, the historical high was at depth of about 100 feet, and it gradually deepens to about 200 feet bgs near the southwest end. The groundwater high north of the Raymond fault gradually deepened to about 100 feet at the northeast end of Zone 4.

Significant amounts of groundwater are expected only in alluvial deposits. The Tertiary sedimentary rocks are non-water-bearing and do not yield significant groundwater volumes.

Although there are no large surface water recharge areas within the zone, normal inflow of water from the ground surface will occur during periods of rainfall.

10.6 Hazardous Materials

The ISAs and ESA identified 14 open cases within Zone 4. The locations of these sites are shown in Figure 6-1.

The San Gabriel Valley NPL Site consists of four Operable Units (OUs) (Areas 1 through 4); however, only OU Area 3 (Alhambra) is located within the central and southern portions of Zone 4. Portions of the OU Area 3 (Alhambra) within Zone 4 are known to be contaminated with chlorinated VOCs including the following: tetrachloroethylene (PCE), and trichloroethylene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), 1,2,3-trichloropropane (1,2,3-TCP), carbon tetrachloride (CCl_4), perchlorate, and nitrate as NO_3 (CH2M HILL. 2009d). Well locations within OU Area 3 (Alhambra) that have detections of these contaminants above the maximum contaminant levels (MCLs) are shown in Figure 6-1.

In 1984, a study of the San Gabriel Valley groundwater was initiated by USEPA to determine the nature and extent of contamination. In 1999, a Remedial Investigation (RI) for Area 3 was initiated and later completed in June of 2009 (CH2M HILL, 2009c). The RI report assessed the nature and extent of groundwater contamination in Area 3 and the potential for harm to public health or the environment caused by the contamination. The EPA has not defined the lateral extent of contamination at this time. A Feasibility Study (FS) will be performed using the conclusions from the RI to identify and evaluate cleanup alternatives that will prevent and eliminate the release or the threat of release of contaminants in groundwater at the site (USEPA, 2009). A ROD, will be completed after the EPA evaluates the extent of contamination. After completion of the ROD, a containment system and remedial design will be developed.

Fourteen sites (including the San Gabriel Valley Area 3 [Alhambra] NPL Site) with localized groundwater or soil contamination are located within Zone 4. Six of these sites, summarized below, are located near (that is, less than 0.5 mile) to a portal zone for Zone 4:

- Chevron #9-7762, 233 Altadena Drive N., Pasadena, California (Map ID: 4/2). This site is located within 0.5 mile of the northern portal for Zone 4. The site has soil impacted with hydrocarbons. This site is considered to have a potential to impact the project because it is located within the northern portal zone for Zone 4 and has impacted the soil.
- 76 Products Station. #5917, 3678 Foothill Boulevard E., Pasadena, California (Map ID: 8/3). This site is located within 0.5 mile of the northern portal for Zone 4. The site has soil impacted with solvents and/or nonpetroleum hydrocarbons. This site is considered to have a potential to impact the project because it is located within the northern portal zone for Zone 4 and has impacted the soil.
- Naval Information Research Foundation, 3202 E. Foothill Boulevard Pasadena, California (Map ID: 13/2). This site is located within 0.5 mile of the northern portal for Zone 4. The site has soil impacted with arsenic, dioxins, petroleum, polychlorinated biphenyl (PCBs), polycyclic aromatic hydrocarbons (PAHs), and VOCS. This site is considered to have a potential to impact the project because it is located within the northern portal zone for Zone 4 and has impacted the soil.
- Abandoned Property, 2159 Foothill Boulevard E., Pasadena, California (Map ID: 24/1). This site is located within 0.5 mile of the northern portal for Zone 4. The site is suspected to have soil contamination. This site is considered to have a potential to impact the project because it is located within the northern portal zone for Zone 4 and has impacted the soil.
- Kinneloa Avenue Property, 175 S Kinneloa Avenue, Pasadena, California (Map ID: 101/6). This site is located within 0.5 mile of the northern portal for Zone 4. The site has soil impacted with asbestos, halogenated organic compounds, metals, and other inorganics. This site is considered to have a potential to impact the project because it is located within the northern portal zone for Zone 4 and has impacted the soil.
- ARCO Station No. 6109, 3201 West Valley Boulevard, Alhambra, California (Map ID: 254/14). This site is located within 0.5 mile of the southern portal for Zone 4. The site has soil impacted with gasoline-range organics (GRO), MTBE, and tertiary butyl alcohol (TBA). This site is considered to have a potential to impact the project because it is located within the southern portal zone for Zone 4 and has impacted the soil.

The remaining six sites (not including the NPL site) with localized soil or groundwater contamination are in the central portion of Zone 4 and are considered to have a low potential impact to the project because they are located greater than 0.5 mile from a portal zone, or are characterized with soil or groundwater contamination at a depth of less than 150 feet bgs. Additional details for each of these sites, including the corresponding soil and/or groundwater contaminants, their corresponding concentrations, and depths of maximum concentration are included in the ESA in Appendix F.

10.7 Potential for Naturally Occurring Gas

The alluvium making up the San Gabriel Basin is not a producer of hydrocarbons. However, there are rocks that serve as the source for hydrocarbons at the southern and western margin of the basin, and small oil fields are located around the southern margin. The basin represents an important groundwater aquifer and no incidents of naturally occurring hydrocarbons have been reported. Therefore, the potential for naturally occurring gas to be encountered within Zone 4 is considered low.

10.8 Geotechnical Considerations for Tunnel Design and Construction

10.8.1 Key Ground Characteristics

Based on the results of this evaluation, the key geologic factors for this zone in terms of tunnel design and construction considerations (along the generalized geologic profile shown in Plate 8) are:

- Subsurface conditions are fairly uniform in this zone at tunnel depth and consist mainly of Old Alluvium with a limited amount of sedimentary rocks (Fernando and Puente Formations) near the southern end of the zone. The majority of the tunnel is expected to be in the Old Alluvium. The Old Alluvium is generally expected to be uncemented coarse sand and gravel interbedded with sand, silt and clay. The Fernando Formation is expected to consist of siltstone and claystone. The Puente Formation is expected to be composed of clayey siltstone and silty claystone (commonly called mudstone), as well as some sandstone.
- The Old Alluvium exhibits the strength characteristics of a soil with low cohesion (i.e., low undrained shear strength). The Fernando and Puente Formations are expected to be moderately weak to weak rock. Cobbles and boulders can be expected in the Old Alluvium. Strong cemented layers and concretions may be encountered in the Puente Formation.
- The active Raymond fault and Alhambra Wash fault cross this zone, and could cause ground rupture during a large earthquake. Several inactive faults within the Tertiary-age rocks cross the southwestern portion of this zone.
- Most of the tunnel in this zone would be at or below the water table. Depth to groundwater varies; however, it could be as shallow as 100 feet below grade. The Raymond fault is a groundwater barrier; historically, groundwater is shallowest on the north side of this fault. Groundwater inflows could occur while tunneling below the groundwater table in the saturated alluvium.
- CDMG (1999d) identifies the alluvial materials within Zone 4 as potentially susceptible to liquefaction in areas where the groundwater location is in loose cohesionless soils.
- One Superfund site is located approximately at the southwest end of this zone. USEPA is currently evaluating the extent of the contamination and will subsequently complete a Record of Decision (ROD). Six other sites with various levels of soil contamination are

also present in this zone close enough to impact the tunnel. Most of these sites are located in the vicinity of the northern portal.

- There is a low potential for encountering naturally occurring gas in this zone due to the limited portion of the tunnel in the Puente Formation.

10.8.2 Preliminary Assessment of Tunneling Considerations

Information presented above and in previous sections of this report was used to perform a preliminary assessment of tunnel design and construction requirements, as summarized below.

Tunnel excavation in this zone would be mostly through alluvial materials consisting of silt, clay, sand and gravel. Cobbles and boulders are also expected throughout the alluvium. The remaining portion of the excavation will be through the Fernando Formation and Puente Formation.

The uncemented sands of the alluvium would likely have the tendency to run or flow during excavation, requiring specific tunneling methods and equipment to prevent this type of instability. Tunneling characteristics of the Puente Formation and Fernando Formation will be similar to those explained for Zones 2 and 3. Depending on the slope of the geologic contact between the alluvium and the Fernando Formation, there might be some length of tunnel excavated in mixed-face conditions, consisting of weak rock and alluvial soil. An excavation method capable of tunneling through both weak rock and alluvium under the groundwater table would need to be specified for this reach, such as a pressurized-face TBM.

The potentially running or flowing conditions in the alluvium could result in loss of ground and the potential for surface settlement. The amount of settlement would depend on a variety of factors including the tunnel excavation and support methods, ground characteristics, diameter of the tunnel, and cover above the tunnel (i.e., distance from the tunnel crown to the ground surface). Typically, a ground cover of at least two tunnel diameters is desirable for minimizing settlement magnitudes. The impacts can be mitigated as described previously (Section 7.8.2) in the discussion on Zone 1.

In the saturated alluvium, a watertight initial support system as well as final lining would be required such as a bolted and gasketed precast concrete segmental lining system. Support in the sedimentary rocks would be similar to those described for Zone 1.

This zone has active and inactive steeply dipping faults. Tunneling through these faults will be similar to that described in Zone 3. The active Raymond fault is a known major groundwater barrier; however, the inactive fault zones have the potential to act as groundwater barriers or conduits as well. Because the groundwater levels vary greatly over this zone, the excavation method and lining should be designed to be able to accommodate this wide range in hydrostatic pressures. Special considerations will need to be made for excavating through and lining the tunnel in an active fault zone as discussed in Zone 3. Additionally, because there is a potential for tunneling through contaminated soil and groundwater, precautions such as those described for Zone 1 should be taken with regard to excavation and the disposal of contaminated muck. Considerations similar to those outlined in Section 7.8 should be taken for excavating in a "gassy" environment if naturally occurring gas is present in the southern portion of this zone.

Based on the information collected and reviewed in Zone 4, tunneling is feasible in this zone from the geotechnical standpoint. Subsurface conditions and other tunneling considerations discussed for this zone should be further evaluated in more detailed tunnel design studies.