APPENDIX B

South Bay Geology

The Coast Ranges are dominated by northwest trending, folded and faulted sedimentary formations ranging from the Jurassic period (160 million years ago) to the Pleistocene epoch (about 2 million to 10,000 years ago). These ranges were formed by uplift and mountain-making processes as the North American plate collided with the Pacific Ocean plate. Many of the faults that exist in the area are no longer active. However, other significant and not so significant active faults do exist. The more prominent of the active, regional northwesterly trending faults include the San Andreas fault in the Santa Cruz Mountains and the Hayward and Calaveras faults in the Diablo Range. These major faults are strike-slip faults (lateral movement).

The major valley areas trend northwesterly, and continue northwesterly beneath San Francisco Bay. These are the result of an intermontane structural depression, formed by the block being downfaulted to create the depression. The valley areas are now being filled by alluvial deposits washing in from the Santa Cruz Mountains and the Diablo Range. These alluvial deposits comprise the groundwater basins of the study area. In the Santa Clara Valley, the maximum depth of the alluvial materials is in excess of 1,500 feet.

This complex structural regime, coupled with erosion when the Pleistocene sea level was low enough that the Pacific shoreline was close to the Farallon Islands, has resulted in a highly irregular bedrock contact under the alluvial fill. Some faults cross the groundwater basins, or parts of the groundwater basins, and can form barriers to, or pathways for, groundwater movement. Recent studies (Ikehara, et. al., 1998) indicate that a northern extension of the Silver Creek fault may be operating as a groundwater barrier. Current geologic investigations may provide information about the groundwater effects of other faults cutting through the water bearing alluvium.

The depth of the contact between the base of the alluvial valley fill and the underlying bedrock is highly variable and identified with certainty in only a few locations. Under parts of the San Mateo Plain, the bedrock elevation is as little as 100 feet below sea level; this increases to 880 feet below sea level at San Francisquito Creek which is the southern border of the San Mateo Plain and the border with Palo Alto. In Palo Alto, near Page Mill and El Camino, bedrock was not reached in a drill hole 1,147 feet deep (Pampeyan, 1993). In Sunnyvale and San Jose, the USGS installed compaction wells to a depth of 1,000 feet and did not encounter bedrock (Poland and Ireland, 1988; Meade, 1967 and 1968). In downtown San Jose, depth to bedrock is in excess of 1,300 feet. At Moffett Field, Franciscan Complex bedrock is encountered at 1,400 feet. There is geophysical evidence of deep alluvial-filled basins in the Evergreen area of San Jose, in Palo Alto, and beneath the alluvial fan in Cupertino. The clearest example of the steep buried bedrock surface is where the Alameda plain abuts the Coyote Hills (Atwater, Hedel, and Helley, 1977). These bedrock hills extend above the alluvium and bay mud adjacent to the shoreline. A deeper basin exists between the Coyote Hills and the Diablo Range mountain front. These deeper parts of the basin can hold substantial reserves of groundwater.

B.1 Stratigraphy

Similar formations form the Santa Cruz Mountains and the Diablo Range, and they underlay the valley fill areas of the groundwater basins. The discussion of the formations will start with the oldest formation and end with the youngest. These are divided into two broad groups:

1. Mesozoic formations that date back to about 160 million years ago to 70 million years ago
2. Younger Cenozoic formations that range from about 70 million years old to the present.

The Mesozoic members include the Franciscan Group and its serpentine member and Cretaceous sedimentary formations. The Cenozoic members include Tertiary volcanics, Tertiary sedimentary formations, Santa Clara Formation, old alluvium, and young alluvium. The Stratigraphy section is revised from Iwamura, 1999.

B.2 Mesozoic Formations

B.2.1 Franciscan Group

The Franciscan Group is a complex mixture of rock units that are sheared, contorted, and faulted by high pressure and relatively low temperature since burial. These impacts suggest a very active tectonic history since deposition. The Franciscan is composed largely of submarine-deposited volcanic rocks, serpentine, and silica carbonate (collectively often referred to as ophiolites). These are highly altered remnants of volcanic arc rock deposits that are the result of regional collision of tectonic plates. The group also consists of marine-deposited lithic sandstone, shale, and chert, some of which have metamorphosed to schists. Though most of the large bodies of serpentine within the Franciscan Group occur along the southeastern boundaries of the Santa Clara Valley in the Diablo Range, smaller but significant bodies of serpentine have pervasively intruded the Franciscan throughout (in small, unmappable units for small-scale maps). However, it is the serpentine unit that controls the mineral quality of waters that drain from the Franciscan Group terrain. Runoff water usually contains magnesium bicarbonate, as the serpentine has high magnesium content. Soils that have developed from weathered serpentine are toxic to most plants.

Because of the high magnesium content in serpentine-derived soils, plants have difficulty absorbing the calcium they need. However, there are a few characteristic plant species that have adapted and are the exceptions. One example is a type of ceanothus in the foothill areas referred to as ceanothus ferrisae, or more commonly known as Coyote ceanothus. Heavy metals such as mercury, chromium, and nickel are also present in soils and may present problems. Waters draining from serpentine often leave white evaporation lines along the pool edges that are the mineral magnesite, which is a magnesium carbonate. Thick veins of magnesite-filled fractures were formerly mined in the high area of the Diablo Range at the border with Stanislaus County.

Several significant mercury mines and numerous mercury prospects are located within the serpentine associated with silica carbonate rock throughout the coast ranges of California. Asbestos is formed from the recrystallization of sheared serpentine. Asbestos fibers have been detected in water samples collected from the Santa Clara Valley Water District. Limestone mining operation for portland cement occurs within the Calera Limestone member of the Franciscan Group in the Permanente Creek drainage. Small manganese deposits associated with Franciscan chert deposits (layered siliceous rock precipitated in a shallow marine setting, associated with ancient volcanic activities) have been noted in the Upper Penitencia Creek drainage area.

B.2.2 Cretaceous Sedimentary Formations

The Cretaceous sedimentary formations, also referred to as the Great Valley Sequence, consist of a regularly bedded series of micaceous sandstone, siltstone, and shale with locally thick layers of conglomerate. Today, only erosional remnants of the Cretaceous formations occur as a continuous northwesterly band in the south-central portion of Santa Clara County, east of Coyote Valley and the Llagas Basin. Discontinuous bands occur along the western foothills of the Diablo Range, east of Santa Clara Valley, and along the western edge of the county in the Santa Cruz Mountains. Individual Cretaceous formations include the Berryessa formation, Chico formation, Oakland conglomerate, and Del Valle formation.

The mineral quality of runoff water from the Cretaceous terrain can be variable, but would usually be a calcium-bicarbonate-containing water. Deep-seated connate water springs from this marine formation can be expected to be salty, but the concentration can be moderated by mixing with meteoric (surface) water as it rises to the surface.

B.3 Cenozoic Formations

B.3.1 Tertiary Sedimentary Formations

After the Franciscan Group and Cretaceous sedimentary formations had been accreted to the westward advancing North American continent, and as mountain-making processes continued, certain areas became depressed and became inland marine waterways and coastal embayments. Tertiary sedimentary formations were deposited in these depressed marine basins. These deposits consist of sandstone (often fossiliferous), shale, siliceous shales, chert, and some conglomerate and minor limestone deposits. These deposits have been divided into the San Lorenzo, Butano, Vaqueros, Temblor, Monterey, Briones, and Purisima formations.

Toward the end of the Tertiary period, the area began to rise due to acceleration of mountain-making processes, and the inland seas and embayments receded. Some of the late Tertiary formations, which were mostly marine deposits, have their upper portions deposited as subaerial (continental) fluvial deposits. These include the Purisima formation and, in adjacent counties, the Santa Margarita formation. The general distribution of Tertiary sedimentary formations occur as discontinuous, northwest-trending slivers of bedded formations along both east and west sides of the valley areas and along the upper crestline of the Santa Cruz Mountains.

Meager oil and gas deposits are hosted in the Tertiary sedimentary formations. The two defined oil fields are the Sargent, in a down-faulted block between the San Andreas and the Sargent faults in the southwestern portion of Santa Clara County, and Moody Gulch, above Lexington Reservoir. Though these oil fields are generally inactive today, they have the potential to produce brines for disposal if or when the fields become active again. The chert (siliceous bedded rock) in the Monterey formation is quarried for roadfill, as it can be hard and durable.

Runoff from Tertiary rocks is generally expected to be similar in mineral character as those from the Cretaceous sedimentary rocks, but in some rock units, particularly the organic, siliceous marine shales, a higher sulfate content would be expected. Sulfates may also be higher in some of the continental tertiary units should they contain secondary sulfate minerals, chiefly gypsum ($CaSO_4\ 2H_2O$). The presence of chert in the Monterey formation may contribute trace amounts of manganese to the runoffs.

B.3.2 Santa Clara Formation

The Santa Clara formation is a subaerially deposited fluvial, unconsolidated to lightly consolidated unit of bedded conglomerate, sandstone, siltstone, mudstone, and compacted siltstone and claystone. These sediments were deposited during the late Tertiary period through the Pleistocene epoch of the Quaternary period. This interval generally spans from about 2 million years to 10,000 years ago. This was a period of continued uplift and mountain building in the Coast Ranges. The uplift rejuvenated streams, and huge gravel deposits were laid down in the valleys. In Santa Clara and San Mateo Counties, these deposits are adjacent to the valley floor. Equivalent deposits in adjacent counties include the Livermore gravels and the San Benito gravels.

The Santa Clara formation can be distinguished from younger alluvial deposits by its being broadly folded, with dips of beds as high as 70^{o} east from the horizontal. The formations younger than the Santa Clara formation are undeformed. The Santa Clara formation is considered to be partly water bearing. The portion that outcrops above the edges of the valley is generally considered to be non-water-bearing. However, it may provide meager quantities of groundwater to domestic wells located in some of the canyon areas. Stevens Creek Dam and Reservoir are founded on the Santa Clara formation with no discernable leakage through the formation. The portion of the formation that is considered to be water bearing is that which dips beneath the younger alluvial deposits in the large valley areas.

Because of the general softness of the members of this formation, rock outcroppings are rare, except for some substantial outcropping of the conglomerate beds in some stream canyon areas. The gently-rounded Santa Clara formation terrain is covered by grassy sod and low-elevation trees and brushes. Where the surface grassy sod cover has been disturbed, significant erosion can occur, which may contribute substantial amounts of brown silts to the streams. Sometimes, erosional gashes will begin on hillsides if rainfall is intense and of long duration.

Gravel quarries for road fill and other fill materials have been operated in this formation. Due to the high clay content of the gravels in the foothills, extensive washing is needed to make the gravels suitable for aggregate.

The mineral character of the runoffs from this formation is expected to be a calcium-bicarbonate-type water. Significant turbidity can be expected during large storms.

B.3.3 Old Alluvium

Within the drainages, the Old Alluvium occurs in small mountain valleys. It more predominantly occurs along the elevated edges of the main valley floors as terrace deposits or older abandoned alluvial fans. These alluvial units are generally areas where the streams are presently downcutting because the sediment yields from the drainages today are far lower than in the most recent geologic past (Pleistocene) when the overall regional precipitation was much higher.

The Old Alluvium consists of unconsolidated gravel, sand, silt, and clay. The Qoa is considered to be water-bearing and can provide domestic-use groundwater to mountain valley residents and is an important water-bearing formation in the large valley areas. Surficially, it also has the appearance of the Santa Clara Formation, but because it is relatively young, the unit is undeformed. These deposits range in age from about 1 million years to 8,000 years before present.

Runoff from this formation is expected to be a calcium-bicarbonate-type water. As runoffs recharge this unit, they would tend to pick up calcium. The original runoffs from the drainages dominated by the Franciscan Group would be a magnesium-bicarbonate-type water. Infiltration and percolation through the old alluvium (and also through the young alluvium) would tend to be modified to a magnesium-calcium-bicarbonate- or to a calcium-magnesium-bicarbonate-type water through the process of base exchange.

B.3.4 Young Alluvium

Like the old alluvium, the young alluvium occurs as small, limited deposits within the mountain valley. However, it predominantly covers the large valley areas. The young alluvium consists of unconsolidated gravel, sand, silt, and clay, and occurs where it is actively being accumulated at present. This unit is considered to be water bearing and can be an important source of groundwater in the mountain valleys should it achieve a significant thickness, and is an important water-bearing unit of the major groundwater basins. The young alluvium ranges in age from about 10,000 years before present to the present.

The young alluvium deposits are the major source of aggregate materials. They can be quarried for other fill material and were used in the past for making bricks from the sandy clay unit. The surficial portions of this unit are generally fertile and have better subsurface drainage characteristics than the old alluvium and Santa Clara Formation. As a consequence, the young alluvium can support a variety of growth and crops.

Runoff waters from the young alluvium, like the old alluvium, are expected to be a calcium-bicarbonate-type water. Infiltrating waters would pick up calcium and, if groundwater percolates through this unit for miles, the groundwater would eventually become a calcium-bicarbonate type. In mountainous areas where organic materials have accumulated to form peat deposits in a swampland environment, effluent seepage into streams may contain higher levels of dissolved organic carbon, iron, and total phosphorus.

South Bay Geologic References

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