Guide to

HYDROGEOLOGY OF EAST BAY AREA AND NORTHERN SANTA CLARA VALLEY

By S. N. Davis

Field Trip D

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HYDROGEOLOGY FIELD TRIP
EAST BAY AREA AND NORTHERN SANTA CLARA VALLEY

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SAN FRANCISCO—UNIVERSITY OF CALIFORNIA ENGINEERING FIELD STATION—ALAMEDA CREEK ALLUVIAL FAN—NILES CANYON—SUNOL VALLEY—MISSION SAN JOSÉ—U.S.G.S. SUBSIDENCE RECORDER IN SAN JOSE—GUADALUPE-LOS ALAMITOS RECHARGE BASINS

Introduction

Most of the water used in the San Francisco Bay area comes from surface streams, and to satisfy the requirements of the metropolitan area much of this surface water must be imported from streams in the Sierra Nevada. Local ground water, nevertheless, still forms an important supplementary supply, particularly in Colma, Fremont, San Jose, Santa Clara, and surrounding suburban and rural areas. The lower cost of ground water has been its main advantage. Declining water levels in wells and the superior chemical quality of the imported water, however, have caused a relative decrease in the importance of ground water during the past 40 years.

The purpose of the hydrogeology trip is to obtain in a brief period an understanding of the ground-water geology of the area adjacent to the southern part of the San Francisco Bay (fig. 1). Although the area is fairly restricted in geographic extent, it presents a wide variety of special problems. Some of these are declining ground-water levels, land subsidence, sea-water intrusion, correlation of aquifers and aquicludes, location and design of recharge basins, and the barrier effects of active faults. All field-trip stops described in the road log are on private land, and permission for access for all except the Sunol stop should be obtained before going on the properties.

Aquifer materials in the region surrounding the San Francisco Bay include limestone, sandstone, fractured shale, basalt, serpentine, and alluvium. From the standpoint of both areal extent and total production, the alluvium is much more important than any of the other aquifer types. The alluvial aquifers are mostly irregular beds or lenses of gravel which are, in certain localities, permeable enough to yield more than 3,000 gallons per minute to wells. In contrast, the indurated aquifers rarely yield to wells more than 5 gallons per minute. These low-yield wells, nevertheless, have an importance far out of proportion with their production because they allow the development of otherwise useless land for livestock grazing and, in recent years, for country estates.

The distribution of major geologic units is controlled primarily by numerous faults and folds, most of which trend in a north-northwesterly direction (fig. 1). Although only lateral movement has been observed along the well-known San Andreas and Hayward faults during the past 70 years, offset beds and steep mountain fronts suggest that vertical movement along these and other major faults has been very important in forming San Francisco Bay and associated alluvial valleys.

The history of deposition within the alluvial val has been complicated by almost constant te

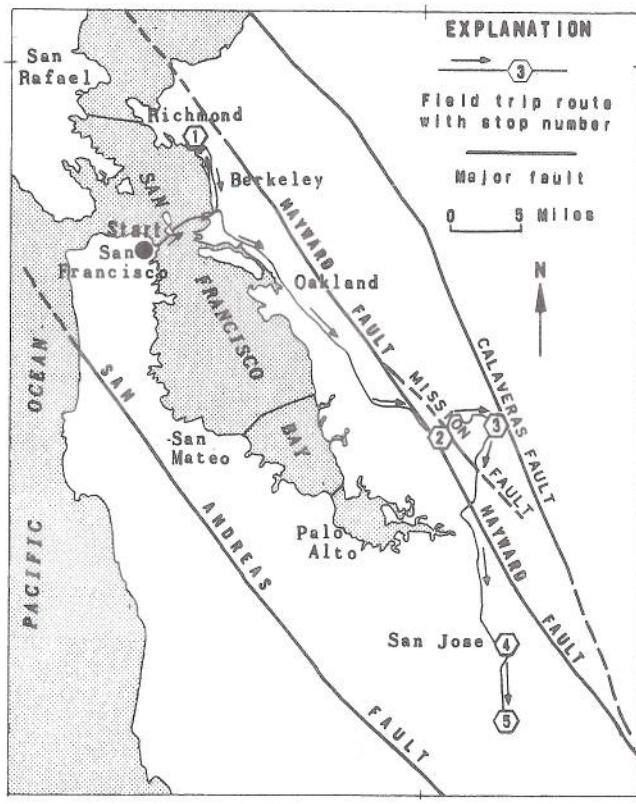

Figure 1. Map of southern San Francisco Bay area showing route of trip and location of major faults. Stops in road log indicated by numbers in hexagons.

activity superimposed on the effects of a fluctuating sea level. Evidence from stable coastal regions in other parts of the world indicates that the sea level has been as much as 100 feet higher and 300 feet lower than present levels, all within the past 150,000 years. Widespread gray clay, commonly called "blue clay" by well drillers, may indicate former marine deposits within alluvium adjacent to the present San Francisco Bay. Some of these clays may also be deltaic or lacustrine. Most wells near the present shoreline, however, appear to encounter alluvial silts, sands, and gravels, with less than half of the deposits having a possible marine or lagoonal origin. Inland from the shore the deposits appear to be mostly alluvial, with less than 10 percent gray clay in the deposits penetrated by wells along the basal slopes of the mountains.

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ROAD LOG

Mileage

00.0 *Onramp to west end of San Francisco-Oakland Bay Bridge.* (Interstate 80)

The western span of this bridge has its pier foundations on the highly indurated rocks of the Franciscan Formation, which are here chiefly graywacke. Recent and Pleistocene sands, silts, and clays overlying the Franciscan reach a maximum thickness of about 120 feet near the San Francisco side of the span. Water depth is generally between 80 and 110 feet beneath the western span.

02.2 Yerba Buena Island. This small island is composed entirely of Franciscan shale and sandstone (graywacke). Treasure Island, just to the north, is an artificial island constructed originally for the Golden Gate International Exposition in 1939.

02.5 The eastern segment of the bridge passes over Recent and Pleistocene sediments that have a combined thickness of more than 300 feet. Water depth, however, is only 10 to 20 feet through most of the distance to the eastern terminus of the bridge. Pier foundations for the bridge east of the island are within the compact Pleistocene sediments below the soft bay mud.

05.4 Toll plaza. Compaction and displacement of soft bay muds has caused continuing problems with settlement, particularly around the plaza buildings. Early subsidence was most rapid, being about 9 feet between 1935 and 1950.

06.3 Turn north-northeast (left) on Eastshore Freeway (Interstate Highway 80 to Sacramento).

10.7 Turn north (left) on Hoffman Boulevard (State Highway 17 to Richmond-San Rafael Bridge). El Cerrito, the hill east of the highway, is underlain by Franciscan sandstone. For many years a quarry was operated on the west side of the hill.

13.2 Turn southwest (left) on South 47th Street.

13.3 Turn north (right) into the University of California Engineering Field Station.

Stop 1. The Engineering Field Station was established after World War II as a locality where researchers in various branches of engineering could conduct projects that required more space than was available on the Berkeley campus. An extensive well field, constructed in 1951 and 1952, has served for numerous experiments in the study of subsurface travel of biological, chemical, and radiochemical contaminants.

The well field consists of about 26 observation wells distributed around a central pumped well. Most of the observation wells are 6 inches in diameter and are within 100 feet of the pumped well, although the most distant is 500 feet to the south. The pumped well is a 12-inch, gravel-packed well which has been grouted from the surface to a depth of 88 feet. This central well and the observation wells penetrate an aquifer of fine gravel and sand at an average depth of 95 feet. The aquifer ranges in thickness from 3 to 7 feet. Test results indicate a transmissivity of about 2,000 gals/day foot and a storage coefficient of roughly 2.5×10^{-4} (fig. 2).

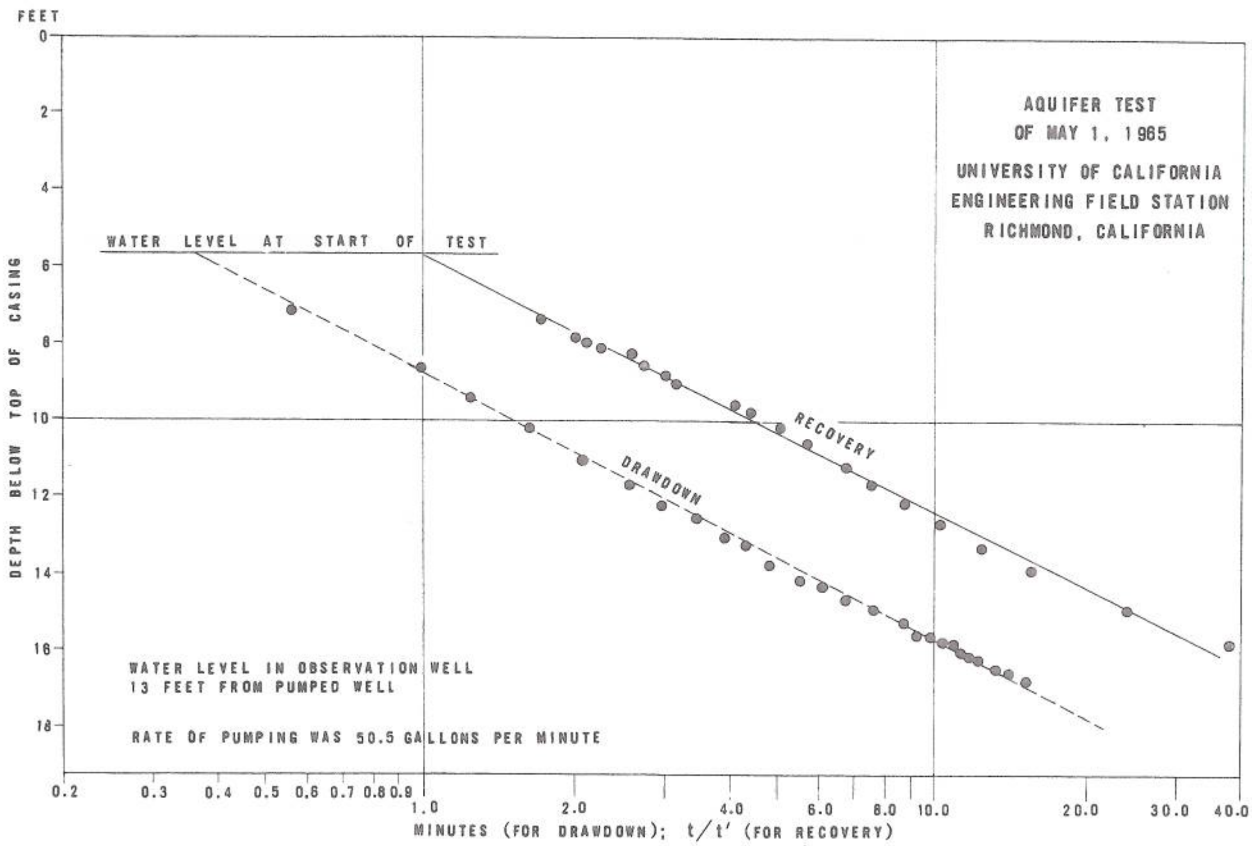

Figure. 2. Drawdown and recovery of pumped well at Richmond Field Station.

The aquifer is overlain by a continuous clay layer that ranges in thickness from 20 to 45 feet. A second aquifer, about 4 feet thick, is found at a depth of about 30 feet, but it is not connected with the test wells.

Both discharge and recharge tests have been made through the central well. In one series of tests sewage was injected at a rate of 37 gallons per minute. Even though the sewage had been allowed to settle and was screened, the well had to be redeveloped once a week to maintain the recharge rate. The water from the sewage traveled a total distance of more than 225 feet. Micro-organisms, however, were not found in wells beyond 100 feet down the hydraulic gradient or beyond 63 feet in other directions. Initial coliform concentrations in the sewage were roughly 2.4 x 10^6 per 100 ml, which was reduced to only 23 per 100 ml after the water traveled 100 feet downgradient.

13.5 Return to Hoffman Boulevard and retrace route southward via Eastshore Freeway.

19.9 Intersection with Bay Bridge approach. Continue south on C. W. Nimitz Freeway (State Highway 17).

The Merritt Formation of Pleistocene age is at the surface in this part of Oakland. Most of the formation is well-sorted sand and silt with the coarser material having eolianlike crossbedding.

23.2 Downtown Oakland to the east (left) and Oakland Inner Harbor to the west (right). Continue south on the Nimitz Freeway.

Recent and upper Pleistocene tidal flat deposits and artificial fill are at the surface for the next 6 miles. The fine-grained materials extend to the west under the water of the San Francisco Bay and serve to retard, and in some places prevent, the intrusion of saline bay water into the shallow aquifers.

27.6 Area office of the East Bay Municipal Utilities District west (right) of the freeway. The East Bay Municipal Utilities District is one of the organizations in the San Francisco Bay area which imports water for local distribution. This publicly owned system purchased local water companies in 1928 and soon thereafter had water delivered to the area from the Mokelumne River in the Sierra Nevada. Although the East Bay Municipal Utilities District services Richmond, Berkeley, Oakland, San Leandro, and many smaller communities, ground-water supplies are still used extensively for large industries. In general, yields of wells are greater in the southern part of the service area than in the northern part.

41.0 Leave the Nimitz Freeway and proceed east (left of the freeway) on Whipple Avenue.

The road climbs up the gentle slope of the alluvial fan of Alameda Creek. This fan is sometimes called the "Niles alluvial cone" after the old town of Niles that once stood at its apex. Low hills visible south (right) of the road in the near distance are the Coyote Hills, which are part of an elongate fault block that protrudes from the alluvium. The hills are composed of a variety of rocks of the Franciscan Formation, some of which are highly fractured and partly weathered. These make ideal land-fill material for construction on the soft bay muds, and quarrying has removed a large part of the southern section of the hills. Inasmuch as the hills form a local barrier to the movement of ground water within the Cenozoic aquifers, they are also important hydrogeologic features.

44.0 Turn south (right) on State Highway 238.

The steep mountain front to the east is caused by uplift along two prominent faults—the Mission fault and the Hayward fault. Rocks in the higher mountains are mostly Cretaceous conglomerates, sandstones, and shale, and in the nearby hills, they include intrusive Cretaceous rocks as well as extrusive rhyolite of possible Pliocene age.

The Hayward fault is about 400 feet east of the highway and parallel with the base of the mountains. Movement at the surface occurred along this part of the fault during the strong earthquakes of 1836 and 1868, and there is evidence that slow creep is taking place along it now. The Mission fault, about 1,500 feet east of the highway, has not been observed to be active within historical time.

46.5 Turn southwest (right) onto Nursery Road.

47.0 Turn into gravel-pit area. Access roads within this area are not fixed, so one should inquire about the best route when obtaining permission to enter.

Stop 2. Recharge operations have been conducted here for a number of years using Alameda Creek water which is discharged into the abandoned gravel pits. Walls of the pits expose typical coarse-grained sediments found in the apex area of the Alameda Creek alluvial fan. In the more distal parts of the fan the gravel is interstratified with finer grained sediments, which act as confining and partially confining beds. Initially, water levels in the wells within this region sloped toward the bay. By 1913

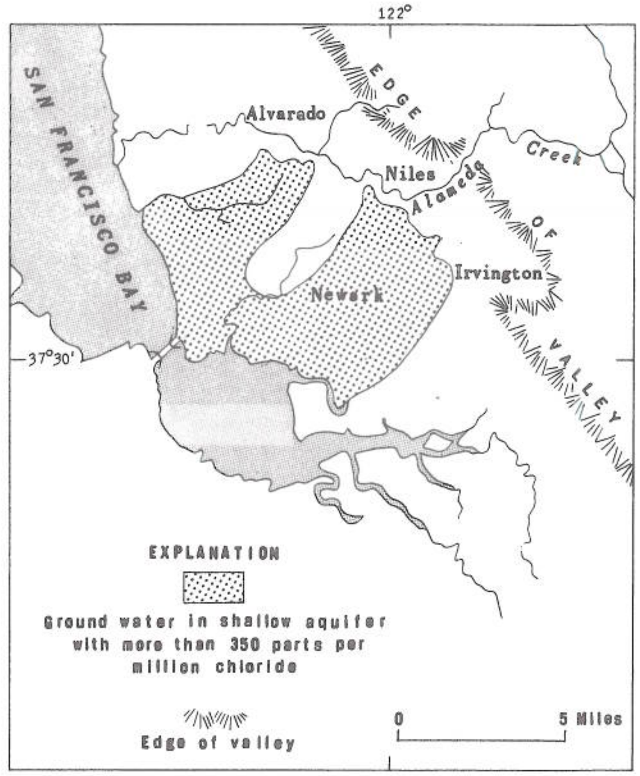

Figure 3. Map of a part of southern Alameda County showing extent of saline-water intrusion in 1958. *California Dept. Water Resources Div. Resources Plan, Bull. 81, 1960.*

water levels in many of the wells were below sea level, and by 1924 the intrusion of water from the bay became evident in the uppermost aquifer. By 1958 intrusion of saline water had advanced more than 4½ miles inland (fig. 3). Degradation of water quality in the upper aquifer forced water users to drill to a lower aquifer, locally called the "200-foot" aquifer. Subsequent pumping has reduced the head in the lower aquifer, and this in turn has induced a downward migration of saline water through abandoned wells and stratigraphic breaks in the confining layers (fig. 4).

The influence of the Hayward fault on ground-water migration in this area is of particular interest. As early as 1915 it was realized that the fault created a subsurface barrier which at that time produced a discontinuity in the water levels of the upper aquifer of as much as 25 feet. This barrier has been exposed from time to time in various excavations in the Niles area, where it appears as a crushed band which is more indurated than the surrounding sediments.

48.4 Turn southwest (right) on State Highway 238 after returning from the gravel pits.

50.2 Turn northeast (left) on State Highway 84. Bridge about 400 feet southwest of the intersection crosses over Alameda Creek. At this

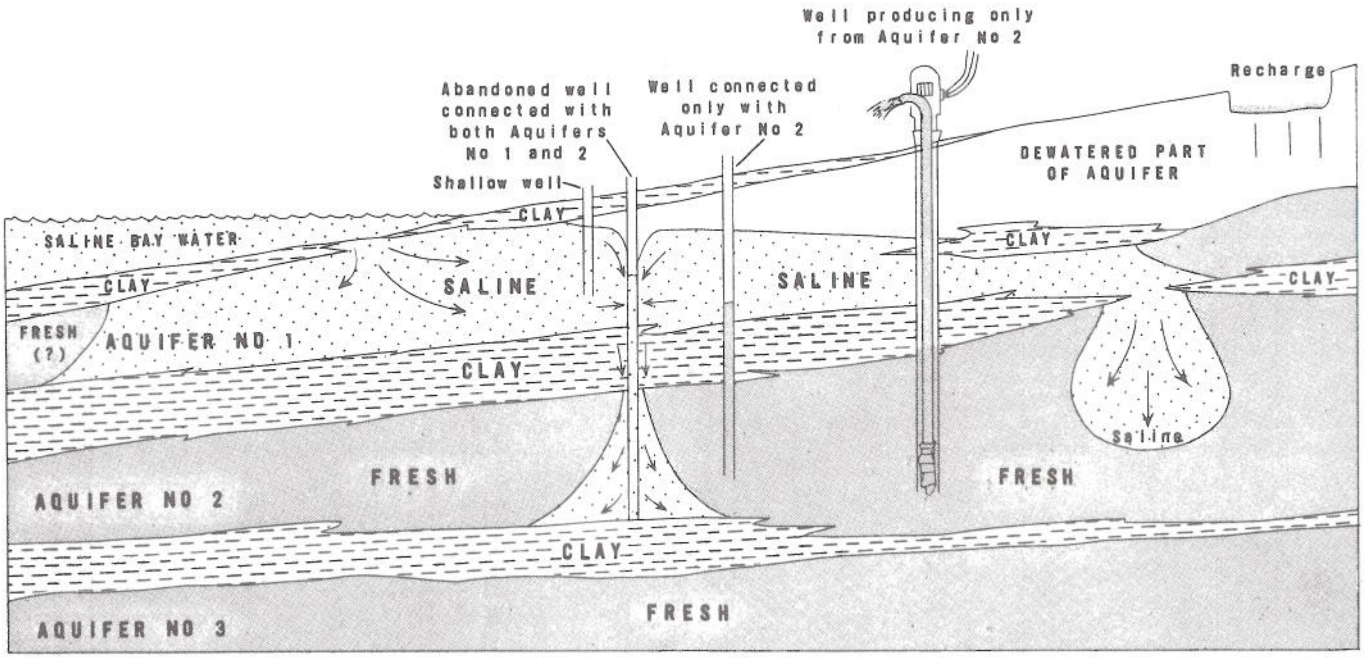

Figure 4. Schematic cross section showing probable migration of saline water in southern Alameda County, California.

point the channel is quite wide and serves as part of the recharge system for the underlying aquifers.

50.9 Note well-developed terraces east of the creek. The highest terraces are about 80 feet above flood level. The canyon ahead is known as Niles Canyon, and the road will follow this canyon for about 5 miles. All the outcrops exposed along the road are Lower Cretaceous sandstone and shale of the Niles Canyon Formation.

51.6 Railroad underpass.

A small landslide mass is exposed in the road-cut just beyond the underpass. In this area almost continuous highway maintenance is necessary to remove small rockfalls originating from the unstable hillside.

Although Alameda Creek is normally a very small stream, its extensive drainage basin to the west can contribute large amounts of runoff during winter storms. During the severe storms of the winter of 1955 the highway in this section was flooded.

53.6 Old concrete water conduit along the highway carries water from the Sunol area to reservoirs of the San Francisco Water Department on the San Francisco Peninsula.

The canyon is about 1,200 feet deep at this point. The steepness of the canyon walls, the recency of orogenic movements, and the presence of lower passes to the sea all strongly suggest that Alameda Creek has maintained its ancient course across the slowly rising Mount Hamilton Range.

54.9 Shale deposit is being developed north (left) of the highway. The shale will be expanded by heating and will be used for lightweight concrete aggregate.

57.0 Turn south (right) through large gateway to the "water temple."

57.6 *Stop 3.* Picnic grounds. The "water temple" is in Sunol Valley, one of many broad but isolated valleys that are typical of the Coast Ranges in California. Most of these valleys owe their origin to Pleistocene folding and faulting. The major fault that passes through Sunol Valley is the Calaveras fault. Because some earthquake centers seem to plot along it, the fault may be active, but it has not shown any surface offset within historic time.

The Sunol infiltration galleries discharge their water into the "water temple," which in turn feeds the water into the cross-bay conduit. The infiltration works were originally designed to filter surface water through the natural gravels. They were completed in 1900, and consist of rectangular concrete tunnels with thousands of 1½-inch pipes driven into the gravel on either side of the tunnels. Most of the water is recovered in the tunnels after winter rains have brought runoff into the adjacent creek. Ground-water levels during the dry part of the year are normally below most of the intake pipes.

The Sunol operation originally included the importation of water from a well field near Pleasanton, 4 miles to the north of Sunol. Since the City of San Francisco purchased the system from the Spring Valley Water Company in 1932, the well field has been gradually abandoned, and in 1965 only a very small amount of water was being pumped for local users.

58.2 Return to the highway and continue southeast (right) on State Highway 21.

The Calaveras fault borders the northeast side of the valley and is about 200 feet northeast (left) of the road. Hills beyond the fault are underlain by upper Pliocene to lower Pleistocene Livermore gravels.

58.9 Turn southwest (right) on Interstate Highway 680.

59.7 Cross Alameda Creek. Well-developed terraces flank the stream on both sides.

60.2 The road at this point starts to cross the Mission Pass syncline. The lower Cretaceous Niles Canyon Formation forms the outer part of the syncline, and Miocene sandstone and shale that rests unconformably on the Cretaceous rock fills the axial part. Poor exposures prevent the structure from being seen from the highway.

62.2 The road crosses the Vargas anticline at this point. The poorly exposed rocks along the road are Miocene sandstone and shale.

63.5 Cross the Mission fault.

63.6 Turn southeast (left) on State Highway 238.

64.2 Mission San José founded in 1797 by Padre Lasuen. This was one of the largest and most successful of the California missions founded by the Spanish padres.

The Irvington gravel pits, about 2 miles east of the mission, have yielded a rich vertebrate fauna of early to middle Pleistocene age.

65.1 Pleistocene silt, sand, and gravel exposed in roadcuts.

67.2 Cross Hayward fault.

68.6 Turn south (left) on Interstate Highway 680.

76.2 Turn southeast (to downtown San Jose) onto First Street, and continue southeast through the center of the city.

78.8 Turn northeast (left) on East Reed Street.

79.6 Turn southeast (right) on 12th Street.

80.0 *Stop 4.* Subsidence recorder of the U.S. Geological Survey at the San Jose Water Works pumping station near the intersection of Martha and 12th Streets.

The compaction-recorder installation is in the central part of the subsidence area in the Santa Clara Valley (fig. 5), and has been operating since May 1960. It was installed by the U.S. Geological Survey in an unused municipal well 907 feet deep. A stainless steel cable ⅛-inch in diameter leads from an anchor bench mark at well bottom over sheaves at the land surface and is counterweighted to produce tension. Another

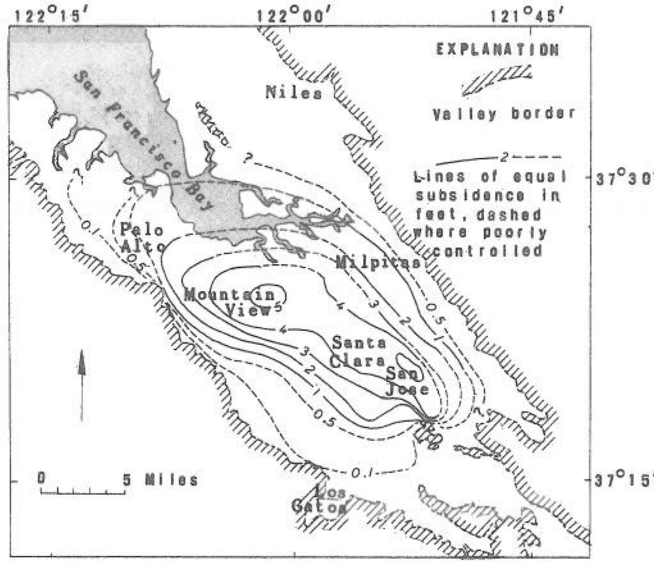

Figure 5. Map of Santa Clara Valley showing lines of equal land subsidence from 1934 to 1960. *Simplified from an unpublished map by J. F. Poland.*

cable firmly fastened to the anchor cable at land surface actuates a recorder to supply a 1:1 continuous record of any change in the distance between the anchor bench mark and the land surface due to compaction of the deposits. A second recorder driven by the first supplies a 24:1 record of compaction. A third recorder furnishes a continuous record of water-level fluctuation in the same well. Figure 6 shows as an example the record of the compaction and water level obtained in September and October 1963.

This well taps several sand and gravel beds (aquifers) separated by beds of silty clay of low permeability. The water in the aquifers is confined and under artesian pressure and wells flowed here initially. About 11 feet of land subsidence and about 250 feet of water-level decline have occurred at this site since 1915.

The compaction recorder shows 2.86 feet of compaction (to 900 feet) from August 1960 to September 1965. The rate of compaction varies in accord with the water-level trend, increasing during the summer drawdown and decreasing during the winter recovery of water levels.

80.0 Continue southeast for two blocks on 12th Street.

80.2 Turn southwest (right) on Keyes Street, continue on Keyes Street to its end, angle right on Graham Street, and angle left on Willow Street. Continue on Willow for only 1½ blocks.

81.1 Turn southeast (left) on Vine Street. Continue on Vine Street until it merges with Almaden Road. Continue south on Almaden Road and Almaden Expressway to 15420 Almaden Road.

87.3 *Stop 5*. Headquarters of the Santa Clara Valley Water Conservation District and the Guadalupe-Los Alamitos recharge basins. The Santa Clara Valley Water Conservation District started operation in 1934 and is the earliest large-scale, ground-water recharge operation in northern California. The Conservation District obtains its recharge water from the South Bay Aqueduct of the State of California and from the storage of local stream water. The total reservoir capacity is 174,400 acre-feet, spread among ten separate reservoirs. Future importation of water through a tunnel near Pacheco Pass is planned for the southern part of the Santa Clara Valley. This water will come from the large Central Valley Project reservoir near Los Banos.

Ground-water recharge here is accomplished through the release of stored water into natural stream beds and into about 12 percolation pond systems. A recent expansion of the percolation pond systems required extensive exploration for areas underlain by permeable gravel. This exploration work has been accomplished by surface resistivity geophysical measurements combined with test drilling.

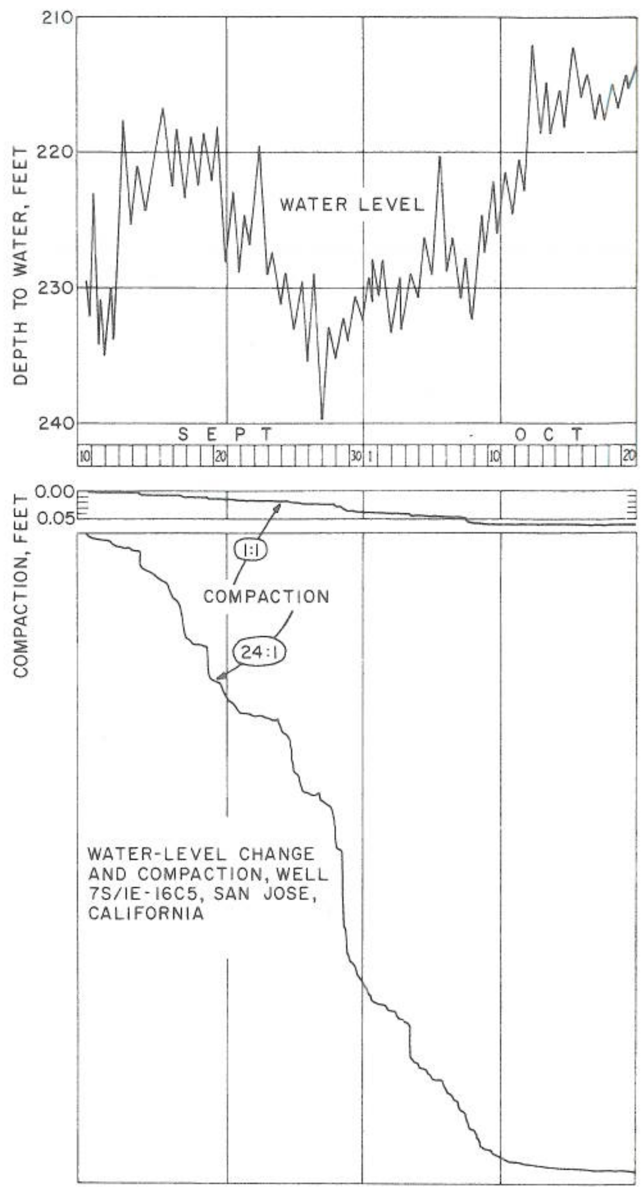

Figure 6 (opposite). Sample of graph from the 12th and Martha Street compaction recorder. *J. F. Poland, unpublished data.*