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GEOLOGY AND GROUND WATER IN WESTERN SANTA CRUZ COUNTY, CALIFORNIA, WITH PARTICULAR EMPHASIS ON THE SANTA MARGARITA SANDSTONE

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SUMMARY

This study was made to assess the water-bearing potential of the geologic formations in the western part of Santa Cruz County. Most of the sedimentary formations in this area are fine-grained rocks of Tertiary age that have been folded and faulted. These rocks, in general, yield supplies of water sufficient only for individual domestic supplies. The Lompico and Santa Margarita Sandstones, however, are coarser grained and have the potential to yield moderate quantities of water (50-100 gallons per minute or 3.2-6.3 liters per second). Areas where the Lompico Sandstone might warrant exploration are (1) near and on the west side of the Ben Lomond fault, (2) near and south of the outcrop of the Lompico Sandstone between Ben Lomond and Felton, and (3) in the area near Bald Mountain School. The Santa Margarita Sandstone should be explored by test drilling in the area between Davenport and Bonnie Doon.

The Lambert Shale in the area near Skyline Boulevard and Highway 9 has the potential to yield enough water for small housing subdivisions; however, the quality of water from these formations may not be suitable for domestic use. Marble of pre-Cretaceous age near the western boundary of the University of California at Santa Cruz has the potential to yield moderate quantities of water, but the occurrence of water in this formation is erratic, and the marble is of limited extent.

Granitic rock of Cretaceous age on the northeast flank of Ben Lomond Mountain is deeply weathered and fractured in places and has the potential to yield moderate quantities of water. A favorable site for exploring this potential is about 1 mile (2 kilometers) west of Brookdale.

The direction of ground-water movement in western Santa Cruz County is controlled by topography and geologic structure. In general, the water moves under the influence of gravity through fractures or permeable sandstone from recharge areas at higher altitudes to the lower areas where it emerges as springs or seeps,to become base flow of perennial streams.

The quality of ground water is generally good, although saline water occurs in the San Lorenzo Formation near Redwood Grove and Riverside Grove. The cause of the saline water in this area may be upward leakage through abandoned oil-test wells. Heavy pumping from wells in the Santa Margarita Sandstone along the coast has not yet caused seawater intrusion, but some wells in alluvium along streams have been abandoned because of seawater intrusion.

INTRODUCTION

This report presents results of one study in a series on the occurrence of ground water in Santa Cruz County published by the U.S. Geological Survey. Previous studies include the Soquel-Aptos area (Hickey, 1968); Scotts Valley area (Akers, 1969); and Pajaro Valley area (Muir, 1972, 1974). A brief earlier study was made of the entire county by the California Water Resources Board (1953).

This study was made in cooperation with the Santa Cruz County Flood Control and Water Conservation District. The purpose of the investigation is to assess the water-bearing potential of the various geological formations in western Santa Cruz County. The projected population growth of the area indicates that new sources of water for municipal supply will soon be needed. The area covered in this study (fig. 1) is the part of Santa Cruz County lying generally west of the San Lorenzo River and Zayante Creek, exclusive of the city of Santa Cruz and the Scotts Valley area described by Akers (1969). The formations are discussed in this report in order from oldest to youngest, as shown in the explanation of figure 2.

Some sampled wells or springs described in this report are designated by the numbering system used by the U.S. Geological Survey in California. For example, in the number 10S/3W-25A, the number and letter preceding the slash indicates the township (T. 10 S.); the number and letter between the slash and the hyphen indicates the range (R. 3 W.); the number following the hyphen indicates the section (sec. 25); and the last letter indicates the 40-acre subdivision (A) of the section as shown in the diagram below.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

The authors thank the well-drilling firms, water-company managers, and private consultants who furnished data from their files and who contributed from their knowledge of the area. G. D. Glysson, U.S. Geological Survey, collected much of the field information on which this report is based.

Conversion factors used are listed below. In the text the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

Multiply English	*By*	*To obtain metric*
acre-feet (acre-ft)	1.233×10^{-3}	cubic hectometers (hm^3)
feet (ft)	3.048×10^{-1}	meters (m)
cubic feet per second (ft^3/s)	2.832×10^{-2}	cubic meters per second (m^3/s)
gallons per minute (gal/min)	6.308×10^{-2}	liters per second (L/s)
inches (in)	2.540×10	millimeters (mm)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)

GEOGRAPHY

Western Santa Cruz County is largely a forested, mountainous area incised by deep V-shaped canyons. The western and southern margins are composed of partly dissected marine terraces that are relatively flat. The central part of the area is dominated by Ben Lomond Mountain, an elongated mass of granitic rock trending northwest that has been uplifted and partly exposed by erosion.

Altitudes range from sea level to 3,231 ft (984.8 m) at Mt. Bielawski in the northern part of the area. The average annual precipitation ranges from a minimum of about 20 in (500 mm) along the coast to about 60 in (1,500 mm) on top of Ben Lomond Mountain.

The San Lorenzo River drains most of the area east of Ben Lomond Mountain. Several streams, of which Scott and Waddell Creeks are largest, drain the area west of the mountain.

The area along the San Lorenzo River north of Santa Cruz contains numerous small towns and communities which thrive mainly on the tourist trade and as bedroom communities for Santa Cruz and the southern San Francisco peninsula. Most of the residents are served by one of the numerous small water companies that obtain water from wells and springs. Other homes in these communities and in the surrounding mountains are summer homes that have individual water supplies developed from wells or springs. Two communities, Bonnie Doon and Davenport, outside the San Lorenzo River drainage area on the south and west slope of Ben Lomond Mountain, obtain water from wells.

GENERAL STRATIGRAPHY AND GEOLOGIC STRUCTURE

The discussion of geology is summarized in table 1 and is based mainly on interpretation of the map compiled by Brabb (1970). Description of the lithology and general character of the various geologic units are based in part on Brabb (1970) and in part on field observations. A detailed description of the Santa Margarita Sandstone is included in this text.

Most of the area is underlain by marine sedimentary rock of Tertiary age. A few interbeds of Tertiary volcanic rock occur in the area north of the Butano fault (fig. 2). Several levels of marine terraces occur along the coast, and there are appreciable thicknesses of alluvium along the larger streams such as the San Lorenzo River and Waddell Creek. Ben Lomond Mountain consists mostly of granitic and metamorphic rocks of Paleozoic and Mesozoic age.

Three major faults--Butano, Zayante, and Ben Lomond--cross the area. All three trend generally northwest (fig. 2) in accord with the regional structure. The San Andreas fault lies north of the study area and also trends generally northwest. Rocks in the area between the San Andreas and Ben Lomond-Zayante faults are complexly folded. Folding and faulting have fractured these rocks and, although most are nearly impermeable, fine-grained sedimentary rock, they commonly transmit enough ground water in the fractures for small domestic supplies.

The granitic and metamorphic basement rocks that form the core of Ben Lomond Mountain have been elevated and partly exposed by erosion along the southwest side of the Ben Lomond fault. Faulted wedges of deformed Tertiary sedimentary rock discontinuously flank the exposed granitic rock of the mountain on the northeast side; the southwest side is covered by a westward-dipping blanket of sedimentary rock of Tertiary and Quaternary age.

Exploratory drilling for oil between Ben Lomond Mountain and the ocean has revealed that the granitic basement complex forms a steep, northwest-trending escarpment that is buried in the subsurface (fig. 3). This subsurface feature is referred to as the Davenport Escarpment (Martin and Emery, 1967). The Texaco Poletti No. 1 oil-test well north of Davenport intercepted basement rock at a depth of 9,135 ft (2,784 m) (9,005 ft or 2,744 m below sea level). About 2 mi (3 km) to the northeast the basement rocks are exposed at an altitude of about 560 ft (170 m) above sea level. In the area defined by Santa Cruz, Davenport, and Ben Lomond Mountain on the shallowly buried east side of the escarpment, the basement complex crops out in several discontinuous exposures. The Monterey Bay Oil Co. exploratory well near Terrace Point (fig. 2) was abandoned at a depth of 5,450 ft (1,660 m) without penetrating the basement rock (California Division of Oil and Gas, 1964). This buried escarpment has had considerable influence on the depositional history and water-bearing character of the sedimentary rock. In general, the sedimentary units thicken westward considerably, and drill cuttings and logs of wells indicate that the deeply buried units west of the escarpment are finer grained and more firmly cemented than those on the east side.

Elevated marine-terrace deposits of Pleistocene age and continuing seismic activity along the faults indicate that the structural geology of this study area is still actively evolving.

DETAILED GEOLOGIC AND HYDROLOGIC CHARACTER OF THE SANTA MARGARITA SANDSTONE

Because the Santa Margarita Sandstone is the most important water-bearing unit in the study area, it is described here in detail. The other units are described briefly in table 1. The Santa Margarita Sandstone crops out in a narrow band almost continuously between the coast and Ben Lomond Mountain from the vicinity of the city of Santa Cruz northward into San Mateo County. Fairly extensive exposures occur near Bonnie Doon and east of the Ben Lomond fault in the Ben Lomond-Felton area.

According to Ellen and others (1972) the Santa Margarita Sandstone is:

"...unbedded to indistinctly bedded in very thick beds, locally internally cross-bedded in thick beds. The sandstone is soft and friable on ridgecrests and slopes, firm in stream bottoms; light gray to grayish orange where fresh, white where weathered; generally well sorted; and generally arkosic in composition. The sandstone ranges from very fine to very coarse grained, though much is coarse to very coarse grained. The fine-grained sandstone commonly contains silt or glauconite. A quartz and feldspar pebble conglomerate occurs locally at the base. Where the rock is firm, fracture spacing is unknown; where soft, the rock is probably unfractured."

The Santa Margarita Sandstone is locally bituminous in parts of the Laguna, Majors, and Baldwin Creek basins near the city of Santa Cruz. Lesser amounts of bitumen in the Santa Margarita Sandstone also occur in the southwestern Big Basin area (Brabb, 1960). The Santa Margarita overlies the granitic and metamorphic basement rock along most of the west flank of Ben Lomond Mountain; but north of Scott Creek and south of Laguna Creek, it overlies older Tertiary sedimentary rocks.

Maximum thickness of the Santa Margarita Sandstone is about 280 ft (85 m); it averages about 150 ft (45 m) in thickness along its outcrop (Earth Science Associates, 1971, sec. III, p. 8). It is not present where truncated by erosion or pinched out over buried basement highs.

Subsurface information from exploratory oil wells in the Davenport area indicates that the Santa Margarita Sandstone dips steeply westward and is below sea level in much of the area west of its area of outcrop. A break in dip coincides approximately with, and is probably controlled by, the underlying Davenport Escarpment. Exploratory oil wells west of Ben Lomond Mountain indicate that the escarpment continues both north and south of Davenport, but the trend of this buried escarpment is not known. The dip of the Santa Margarita Sandstone changes from approximately 100 to 200 vertical feet (30 to 60 m) of drop per 1,000 horizontal feet (300 m) to approximately 400 vertical feet (120 m) per 1,000 horizontal feet (300 m) along this subsurface feature. The log of the Texaco Poletti well (fig.2) indicates that the Santa Margarita Sandstone pinches out in the subsurface northwest of the Davenport area.

Cores taken from exploratory oil wells in the Davenport area indicate the Santa Margarita Sandstone is more indurated in the subsurface than where it is exposed, owing to the presence of calcareous cement. This cement probably lowers the permeability of the formation and may result in low water yields.

The potential of the Santa Margarita Sandstone as an aquifer can most easily be described by subdividing the Santa Margarita Sandstone into five areas. Differences in the degree of erosional dissection and structural deformation of this formation and the overlying Santa Cruz Mudstone of Clark (1966) have imparted varying potentials to the Santa Margarita Sandstone as a ground-water producer.

Area 1 Southeast of Laguna Creek.--Southeast of Laguna Creek, the gently west-dipping Santa Cruz Mudstone-Santa Margarita Sandstone sequence is deeply dissected by numerous steep-sided canyons. Where this sequence is eroded in this manner or where the Santa Margarita Sandstone is exposed by erosion along its outcrop, it is mostly an unconfined aquifer. It has proven to be a productive aquifer several miles to the east in the Scotts Valley area (Akers, 1969).

The statement quoted below summarizes percolation tests that were made in the Santa Margarita Sandstone north of Santa Cruz by Earth Science Associates (1971, section III, p. 9) to compare its permeability west of Ben Lomond Mountain with established values in the Scotts Valley area.

"A rough check on the transmissibility of the formation in the coastal region was carried out during the current investigation in the quarry which was located adjacent to Highway 1 about 7 miles southwest of Davenport. A total of six small percolation pits were excavated in various parts of the formation, and rates of infiltration observed. Infiltration rates varying between 3 and 17 minutes per inch were observed, from which it has been inferred that the permeability of the formation is on the order of 30 gpd/ft². While this is much below the 900 gpd/ft² determined at Scotts Valley, it is nonetheless sufficient to support wells of moderate yield. It can be demonstrated, moreover, that estimates based on the average results of these simple field tests generally underestimate the transmissibility of the entire formation."

Without further evidence, it is concluded that where the Santa Margarita Sandstone is present in an area of considerable extent and contains unconfined water, it will probably be adequate as a source for individual domestic and light-industrial water supplies. It may not, however, be adequate as a heavy agricultural or municipal water-supply source.

The Santa Margarita Sandstone occurs at depth along the coast in this area. Wells started in the lowest terrace deposits commonly penetrate a green mudstone unit--the lower part of the Santa Cruz Mudstone or a mudstone at the top of, and in, the Santa Margarita--before entering the Santa Margarita Sandstone. Water in the Santa Margarita Sandstone is confined by this mudstone and commonly rises in wells to a level above the confining mudstone.

The yields of wells in this area reportedly range from 200 to 700 gal/min (13 to 44 L/s). The quality of the water is suitable for most purposes. Although several of these wells are within a few hundred yards of the ocean and are pumped regularly in the dry season, none to date are reported to show a substantial increase in chloride concentration. Table 3 shows the

chloride concentration in four of these wells that are heavily pumped.

Area 2 Between Laguna and Waddell Creeks.--Between Laguna and Waddell Creeks, erosional dissection of the westward-dipping Santa Cruz Mudstone-Santa Margarita Sandstone sequence is far less extensive than in area 1. The impermeable Santa Cruz Mudstone continuously caps the Santa Margarita Sandstone over much of this area. As a result, the Santa Margarita may contain water under pressure and might be tapped as a water source. Only exploratory oil wells have penetrated the formation in this area, however, and no drill-stem tests were made. The potential of the Santa Margarita Sandstone as a confined aquifer in this area is unknown.

Area 3 North of Waddell Creek to the San Mateo County boundary.--In this area, as in the area between Laguna and Waddell Creeks, water in the Santa Margarita Sandstone probably is confined. The surficial geology and data from one exploratory oil well indicate that several large folds are present in this area. As a result, the subsurface geometry of the Santa Margarita Sandstone is unknown. Any water entering the formation at exposures along the flank of Ben Lomond Mountain moves down dip toward the ocean. The hydraulic conductivity in this area is unknown, and therefore the potential yield of wells is not predictable. The possible effect the structure may have on the quality of water within the Santa Margarita Sandstone is uncertain. On the basis of surficial geology, wells drilled into the Santa Margarita within 1,000 ft (305 m) of its outcrop may obtain fresh water under pressure.

Area 4 Bonnie Doon area.--Well logs indicate that the Santa Margarita Sandstone in the vicinity of Bonnie Doon (fig. 2) is mostly less than 50 ft (15 m) thick, but it may be as much as 140 ft (43 m) thick. In this area, it consists mostly of gray to yellow, medium-grained sandstone that is friable to semi-consolidated. Most wells in this area also penetrate the underlying granitic rock and obtain water from both formations. The water occurs under unconfined conditions, commonly near the base of the Santa Margarita.

Because the Santa Margarita is not distributed extensively and is fairly thin in this area, it does not have much capacity to store ground water. It absorbs and transmits water readily, however, and thus is recharged annually during the rainy season.

The Santa Margarita and the underlying weathered granitic rock in the Bonnie Doon area probably have the potential to furnish small municipal supplies--perhaps a combined total of about 100 gal/min (6 L/s)--if the water is withdrawn from several strategically located wells. A favorable site for a test-well location in this area is about 3/4 mi (1 km) south-southeast of Bonnie Doon School (fig. 2).

Area 5 Ben Lomond-Zayante-Olympia area.--The Santa Margarita Sandstone occurs in most of the area in the triangle described by the towns of Ben Lomond, Zayante, and Olympia. In this area it consists mostly of friable, light gray, medium- to coarse-grained sandstone and interbeds of granule-to-small pebble-sized material.

Several fairly productive wells (200-400 gal/min or 13-25 L/s) have been developed in the Santa Margarita Sandstone near the axis of a syncline that extends from Ben Lomond to Scotts Valley (fig. 2). An analysis of water from one of these wells (Quail Hollow Ranch, main well) is given in table 2. Two fairly large springs also discharge from the Santa Margarita Sandstone near the axis of this syncline just north of Olympia.

The Santa Margarita in this area receives recharge as rainfall. The recharged water moves through the formation to be discharged as pumpage, spring flow near the east end of Quail Hollow Road just west of Zayante Creek, and as base flow of Newell Creek and the San Lorenzo River just south of Ben Lomond.

Although wells tapping the Santa Margarita Sandstone in this area have good yields, storage within the aquifer and recharge to it are meager. The quantity of ground water that could be pumped annually without seriously lowering ground-water levels would be somewhat less than the average annual recharge. Data on the quantity of water recharged to the Santa Margarita Sandstone in this area are not available. If it is assumed that as much as 25 percent of the average annual precipitation of 40 in (1,000 mm) becomes recharge in the outcrop area of about 2 mi² (5 km²), the annual recharge would be about 1,000 acre-ft (1.2 hm³), or about 600 gal/min (38 L/s).

The general direction of ground-water movement as determined by water levels in wells in May and June 1975 is shown in figure 4. These water-level data are not sufficient for contouring the water table, but they do indicate that ground water moves toward both Newell and Zayante Creeks from the approximate center of the outcrop area. The ground water in the Santa Margarita is unconfined in this area.

GROUND-WATER MOVEMENT

Most water that enters the ground in western Santa Cruz County moves through fractures toward discharge points at lower altitudes. These discharge points may be at spring orifices or seeps along the banks of streams.

In the area southwest of Ben Lomond Mountain the ground water moves through fractures in all the formations except the weathered granitic rock, Lompico Sandstone of Clark (1966), Santa Margarita Sandstone, and alluvium. Rainwater absorbed by the weathered granitic rock on Ben Lomond Mountain

moves downward into fractures in the unweathered rock and moves through these fractures into adjacent formations and to spring orifices or stream banks where it emerges. Water that enters the Santa Margarita Sandstone in the Bonnie Doon area moves downward into the underlying weathered granitic rock and generally southward through fractures in unweathered granitic rock toward springs and streams. Water that enters the Santa Margarita Sandstone lapping the southwest flank of the mountain moves through the interstices toward the ocean. Some moves to lower altitudes to emerge as base flow of the streams; some probably discharges under the ocean or as upward leakage through the Santa Cruz Mudstone.

Rainwater that enters the rock or overlying soil northeast of the Ben Lomond-Zayante fault complex moves mostly into fractures in the rock and thence to lower points of discharge at spring orifices or seeps along streams. In some areas northwest of the fault in the synclinal area, the ground water probably is stagnant. The deeply buried formations in some of these areas contain saline water. One such area is near Brookdale where the Lompico Sandstone, and possibly the Butano Sandstone, yield water containing a chloride concentration of 4,200 mg/L (milligrams per liter). The extent of this occurrence of saline water is unknown.

Rainwater that enters the weathered and fractured granitic rock between the crest of Ben Lomond Mountain and the Ben Lomond-Zayante fault complex moves generally toward the San Lorenzo River. A considerable part emerges as springs which contribute to the base flow of tributaries of the San Lorenzo River between Felton and Boulder Creek.

Water levels in the few wells developed in the Santa Margarita Sandstone in the Ben Lomond-Zayante-Olympia area indicate that ground water moves from the central part of this area toward Zayante Creek on the east and toward Newell Creek on the west (fig. 4). Measurements made in September 1975 indicate that Newell Creek gained 0.55 ft^3/s (0.016 m^3/s)--about 40 percent of its flow--where it crosses the exposure of the Santa Margarita Sandstone near Ben Lomond.

GEOLOGIC UNITS HAVING POTENTIAL FOR GROUND-WATER DEVELOPMENT

The geologic formations in several areas may have the potential to yield substantial quantities of ground water. These include (1) marble on the southern flank of Ben Lomond Mountain, (2) the granitic rock on the northeast flank of Ben Lomond Mountain, (3) the Lambert Shale in the area along Skyline Boulevard near Highway 9, (4) the Lompico Sandstone in the Felton-Boulder Creek-Lompico area and on the southern flank of Ben Lomond Mountain, and (5) the Santa Margarita Sandstone on the western flank of Ben Lomond Mountain. None of the units has been adequately tested to establish its water-supply potential.

Marble on Southeast Flank of Ben Lomond Mountain

Several extensive, fractured bodies of marble occur between Bonnie Doon and the University of California at Santa Cruz campus. Percolating ground water has dissolved some of the marble along fractures to create a system of caves in the vicinity of Peasley and Cave Gulches just west of the campus. A well drilled into this formation for the university near Cave Gulch is reported to have yielded 40 gal/min (2.5 L/s). The well was not developed, however, because it was too far from the campus.

Fairly large yields, perhaps as much as 100 gal/min (6.3 L/s), might be obtained from the system of caves in this limestone. The occurrence of water in cavernous limestone is erratic, however, and several test wells may be necessary to locate water--and, of course, none may be found.

Granitic Rock on Ben Lomond Mountain

The granitic rock on Ben Lomond Mountain has been the source of small domestic water supplies for years; some wells in extensively fractured and deeply weathered granite are reported to yield several tens of gallons per minute. This quantity of water from each of several such wells could significantly augment existing small municipal supplies.

Numerous springs emerge from this granitic rock on the northeast side of Ben Lomond Mountain where fracturing and weathering associated with the Ben Lomond fault are prevalent. One area of numerous springs is north of Alba Road and east of Empire Grade in the headwaters area of Clear Creek. These springs and seepage from the granitic rock furnish the base flow of Clear Creek.

A well drilled just west of the junction of the two main forks of Clear Creek west of Brookdale (fig. 2) would test the potential of the weathered and fractured granitic rock in this area.

Lambert Shale

Drillers' logs and records indicate that the Lambert Shale near the junction of Skyline Boulevard and Highway 9 yields several tens of gallons of water per minute to domestic wells. This is an area where considerable development is taking place and where small municipal supplies of water may be needed.

A favorable site for testing the Lambert Shale is near the point where the synclinal axis, shown in figure 2, intersects Highway 9. This is an area of fairly high rainfall where considerable recharge may occur.

Lompico Sandstone

The Lompico Sandstone of Clark (1966) crops out in an irregular band between Boulder Creek and Felton and between Boulder Creek and Lompico. It also crops out along Smith Grade Road in the general area of Bald Mountain School.

Test wells recently drilled in this formation near Brookdale and Boulder Creek for the San Lorenzo Valley County Water District obtained saline water from the Lompico Sandstone. This saline water may be connate, or it may derive from other formations. The saline water has been flushed out of the formation to some extent at several sites where recharge takes place. Areas where this may have taken place and favorable sites for test wells are indicated in figure 2. These sites are located where the formation is present west of the Ben Lomond fault and south of the outcrop of the Lompico Sandstone between Ben Lomond and Lompico.

Santa Margarita Sandstone

The degree of cementation of the Santa Margarita Sandstone and textural characteristics which affect porosity and permeability cannot be predicted for unexplored areas. Spatial variations of these factors and the degree to which they affect the Santa Margarita Sandstone as an aquifer can be determined only through exploratory drilling.

Five suggested test sites in the Santa Margarita Sandstone are shown in figure 2. The sites are suggested on the basis of the following factors.

1. Probable confined conditions in the underlying aquifer. All sites are down dip from outcrops of the Santa Margarita Sandstone where confined conditions should occur.

2. Good water quality.

3. Minimum thickness of overlying Santa Cruz Mudstone. The exploratory well sites were chosen along stream bottoms wherever possible. This minimizes the thickness of Santa Cruz Mudstone to be penetrated and consequently the cost of the well.

4. Proximity to existing roads and water systems. Drilling sites are located close to existing roads, that is, roads shown on the 1968 photographically revised edition of the U.S. Geological Survey 7 1/2-minute topographic coverage of the area. Where possible, the sites are close to existing water-supply lines.

Only indirect evidence is available to indicate what the quality of water might be in the Santa Margarita Sandstone north of Laguna Creek. Possible sources of highly mineralized water include:

1. Saline formation water in structurally low areas near sea level. Calculations of water resistivities in the Santa Margarita Sandstone were made from electric logs run on Shell Davenport core holes 1 and 3 (fig. 2). No logs were available for core hole 2. Porous sand beds, which are required for the calculations, were not recognized on the electric log for core hole 4; the Santa Margarita may not be present at this site. Salinities in the brackish range were indicated for apparently clean porous sands within the Santa Margarita Sandstone of core holes 1 and 3. A fresh water-saline water interface apparently exists at depth in the Santa Margarita Sandstone; however, the depth of this interface is unknown. Although the Santa Margarita is breached by erosion near sea level along Laguna Creek, no saline water contamination of this stream has been reported. On this basis, it seems that the Santa Margarita Sandstone, at least locally, is flushed by fresh water at least to sea level. Drilling where this formation lies below sea level will run the risk of encountering saline water. All the recommended test sites are located where the base of the Santa Margarita Sandstone is thought to be above sea level.

2. Local structural entrapments of sulfurous or saline formation water associated with bituminous deposits. The only indication that this may be a problem is an abandoned well on Yellow Bank Creek. This well may penetrate the Santa Margarita Sandstone. The driller's memory provided the only log (Earth Science Associates, 1971). This report states:

"The uncontrolled artesian flow of about 10 to 15 gpm from this well fouls and mineralizes the lower portion of Yellow Bank Creek. If the source of this poor quality water is the Santa Margarita Formation, and if that water were representative of the quality of water contained in the formation throughout this reach of the coast, then there would be no hope of developing a useful water supply. However, the area in which the well is located has been subject to massive landsliding, so that subsurface geologic conditions are unclear in the vicinity of the well. Moreover, the well is located on the limb of an atypical local feature, an anticline, which appears to have created special conditions in the sedimentary rocks

south of Yellow Bank Creek. For example Santa Margarita Sandstone exposures in Laguna and Majors Creeks, especially the latter, have a high asphalt content, a condition peculiar to this area and perhaps associated with a local entrapment of both hydrocarbons and mineralized water."

Another possibility is that mineralized water from this abandoned well originates in either the Santa Cruz Mudstone or the Monterey Formation. Both these units are known to yield mineralized water elsewhere in the Santa Cruz Mountains area. As a precaution against encountering sulfurous water in the Santa Margarita Sandstone, no exploratory sites were suggested in either the Yellow Bank Creek area or north of Waddell Creek where the formation is structurally deformed. If water wells developed in the Santa Margarita Sandstone in the lower Yellow Bank Creek area penetrate the Santa Cruz Mudstone and Monterey Formations, these formations should be cased off.

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