

REPORT OF INVESTIGATION

AN EVALUATION OF GROUND WATER QUALITY

In Deep Aquifers Beneath Pleasant Valley

Fresno County, California

PREPARED FOR

STANDARD OIL COMPANY OF CALIFORNIA

PREPARED BY

HYDRODEVELOPMENT, INC.

OJAI • BAKERSFIELD



Report of Investigation

AN EVALUATION OF GROUND WATER QUALITY
IN DEEP AQUIFERS BENEATH PLEASANT VALLEY
FRESNO COUNTY, CALIFORNIA

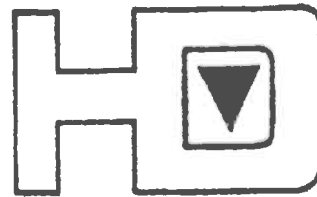
Prepared for

Standard Oil Company of California

by

HydroDevelopment, Inc.
Bakersfield, California

May 1969



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May 9, 1969

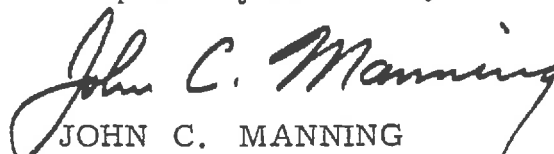
Standard Oil Company of California
225 Bush Street
San Francisco, California

Gentlemen:

Enclosed is our report entitled "An Evaluation of Ground Water Quality in Deep Aquifers Beneath Pleasant Valley, Fresno County, California." The report is based on studies made during the drilling of a deep test hole and includes chemical analyses of ground water as well as estimates of productive capacities from the deep aquifers. Also included are suggestions for future ground water development in Pleasant Valley.

We wish to acknowledge the cooperation and assistance of officials and employees of the Standard Oil Company and their land tenants in Pleasant Valley. We are particularly indebted to Mr. S. O. Hutchison of the Standard Oil Company and Mr. W. W. Weeth, Jr. of the Weeth Ranch.

Respectfully submitted,


JOHN C. MANNING
President

JCM:jam
Enclosure

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SUMMARY

HydroDevelopment was retained by the Standard Oil Company of California to investigate the deep aquifers beneath Pleasant Valley to determine suitability of the waters for irrigation. This investigation is a follow-up to a previous study of total water reserves that was entitled "An Evaluation of Water Sources for Agricultural Supply in Pleasant Valley, Fresno County, California." The reader is referred to this earlier report for a more detailed treatment of geology and ground water hydrology of the basin. The present investigation, which was confined mainly to a study of water quality in deep aquifers, is summarized in the following paragraphs.

The focus of this investigation was a test hole, drilled in what was thought to be the deepest part of the ground water basin. This hole, called the Standard Oil Company Test Hole 1-17H, was drilled to a total depth of 3,300 feet. It penetrated more than a thousand feet of good aquifers below the depth of present ground water development. A lithologic log was made from drill cuttings taken while the hole was being drilled; and after drilling was completed, electrical logs were run and 40 sidewall cores were taken from formations in the hole. The suite of electrical logs included a dual induction-laterolog, a proximity log-microlog, a compensated formation density log, a sidewall neutron porosity log, and a caliper log. Finally the newly-developed Standard Oil formation water sampler was run into the hole and four water samples were taken from the underground formations.

Analyses of water samples from the deep aquifers show that these deep waters, from about 1,700 to 2,800 feet, are suitable for irrigation and are in fact comparable to waters presently being used in the developed aquifers above 1,000 feet. Water below 2,800 feet appears to be too poor for use as irrigation water, and a zone of relatively poor water was also discovered between about 1,000 feet and 1,700 feet.

Interpretation of the electrical logs, supported by production data from operating wells and laboratory tests on the sidewall cores, indicate that the deep sands are about $1/6$ to $1/7$ as permeable as sands in the presently productive zone above 1,000 feet. However, there is about twice the amount of permeable sand in the lower zone as compared with the presently productive zone; and this lower zone probably would add about $1/3$ to $1/4$ of the present production to a deep well. At the site of the test hole, a well completed to about 1,000 feet and presently producing 3,000 gpm would produce about 4,000 gpm if it were deepened to about 2,800 feet.

One important result of this investigation, in addition to data on the deep aquifers, is the establishment of practical methods for economically testing deep formations anywhere in the valley. By drilling a pilot hole and running a few electrical logs and taking water samples with the Standard Oil Company sampler, one can now design an irrigation well that will produce a maximum quantity of the best available water at any given location. If programmed immediately in advance of the finished well construction, the testing program can be done for a cost well within the reach of most farmers in the valley.

REPORT OF INVESTIGATION

INTRODUCTION

HydroDevelopment was retained by the Standard Oil Company in 1967 to investigate water supplies presently or potentially available for irrigation in Pleasant Valley. The resulting report summarized ground water conditions in the valley and included an estimate of future reserves.* The reader is referred to this earlier report for a discussion of the geology and ground water hydrology of the Pleasant Valley basin. The investigation reported on here, following recommendations contained in the previous study, was made to ascertain the chemical quality of water in the deeper aquifers.

Most water wells in Pleasant Valley draw from aquifers that extend to depths of about 1,000 feet, and analyses of well waters have determined ground water quality to this depth. In the previous investigation it was postulated that usable aquifers might be found at depths as great as 3,000 feet. Although this deeper water appeared from indirect data to be usable, its true character was unknown. It was the purpose of the present investigation to determine the chemical quality of the deeper water and to determine the physical characteristics of the aquifers beneath a depth of 1,000 feet.

The scope of the present investigation included drilling a test hole to penetrate all potential aquifers in the deepest part of the basin. The subsurface formations were studied by logging drill cuttings, taking sidewall core samples, and by running several kinds of electrical logs in the hole. A special sampling device was run in the hole to extract formation water samples from potential aquifers, and these samples were sent to a commercial laboratory for chemical analysis. Finally a report was prepared summarizing the testing program and presenting conclusions on the nature of the deeper aquifers.

THE TEST HOLE

The focus of this investigation was a test hole, drilled in what was thought to be the deepest part of the ground water basin (see Fig. 1). The hole, called the Standard Oil Company Test Hole 1-17H, was drilled to a depth of 3,300 feet; and it penetrated more than a thousand feet of good aquifers below the depth of present ground water development. Earlier studies had suggested the presence of this new water zone, but until the test hole was drilled, no one knew for certain what lay beneath the deepest producing wells. Results from this test hole have proved up large reserves of irrigation water and have added important new information on the geology and hydrology of the Pleasant Valley basin.

* An Evaluation of Water Sources for Agricultural Supply in Pleasant Valley, Fresno County, California; Prepared for Standard Oil Company of California by HydroDevelopment, Inc. (1967).

Previous studies of the deeper, untested water zones had been based on interpretations made from electrical logs of wild-cat oil wells.* These kinds of indirect data are suggestive of subsurface conditions but are not at all conclusive, particularly in the upper fresh-water zones. Electrical logs are used mainly to infer conditions in deeper salt-water zones associated with oil-bearing formations. Where formation water salinity is more than about 3,000 to 3,500 parts per million (ppm) Total Dissolved Solids (TDS), the electrical logs indicate not only the approximate total salinity of the water but the general character of the formations as well, e.g., sand, silt, shale, etc. Where formation water salinity is less than 3,000 ppm TDS, the electrical logs provide less reliable information on salinity and formation character, and in these cases it is necessary to sample the formations and the formation waters to get a clear idea of their true character and to find out how best to interpret the electrical logs between sampling points.

The test hole was the subject of intensive study, both during and after the time drilling was going on. While the hole was being drilled, samples of the drill cuttings were collected and studied to provide a continuous lithologic log of the hole (see Plate I). After the hole was drilled to total depth, the drilling tools were removed and several kinds of logging and sampling tools were run into the hole to obtain more information on the rock formations and their contained fluids. Several kinds of electrical logs were made in the hole, and numerous small cores of the formations were taken with a sidewall coring device (see Appendix for descriptions of cores). Finally, a sampling tool was run to take actual samples of the formation waters at places where the earlier testing and logging indicated potential new productive aquifers might exist.

A chronologic record, or "history", of the drilling and testing operations is included in the Appendix. Brief descriptions of the various electrical logging and sidewall coring operations are presented below together with a description of the formation-water testing program.

Electrical Logging

Introduction: Electrical logs of subsurface rock formations are made by running various kinds of instruments, or logging tools, into a drill hole and recording data at the surface on a specially calibrated chart. The hole is usually logged right after completion of drilling, while it is uncased and still full of drilling mud. The logging tools are suspended from a steel cable and are run to bottom before making a logging run. The log is made at the surface by a recorder that automatically plots data transmitted by the logging tool as it is pulled slowly up the hole. The cable winch is calibrated so that the depth of the tool can be recorded on the log as the electrical data is being plotted.

* Ibid.

An electrical log is a continuous record of data transmitted by the tool as it traverses the various rock formations exposed in the drill hole. The data makes a continuous line on the calibrated chart that forms the base for the log. Thus the particular property of the rocks being measured by the tool can be determined quantitatively at any depth, and the overall variation of this rock property throughout the depth of the hole is readily apparent on the completed log.

Variations in electrical (or other) properties, as recorded on the log, are related to variations in characteristics of the subsurface rock formations and their contained fluids. Interpretations of rock or fluid characteristics based on electrical logs have been improved over the years by empirical studies that compared logged values with values obtained from measurements made on actual rock or fluid samples taken from the hole. In general the log interpretations are fairly accurate where the logs are run through formations saturated with salty waters. Where the formation waters are relatively fresh (less than 3,000 ppm TDS), electrical log interpretations are not nearly so accurate and it is usually necessary to seek more definitive information on rock and fluid properties; often the only sure method being to take samples of the rocks and the fluids. A few selected samples of rocks and fluids from a drill hole often provide enough supplementary information to permit reasonably accurate interpretation of the logs for the entire depth of the hole. This was the case in the present investigation, and a combination of log and sample results gave a picture of the subsurface that seems to be sufficiently accurate for the purpose at hand. The logs run in the test hole are shown on Plate I in the pocket at the back of this report.

In order to discuss the log interpretations as they relate to the overall purpose of evaluating water quality in the deep aquifers, it might be helpful to briefly discuss the various types of logs used during the investigation. As will be seen in the following paragraphs, each trace on the logs measures a specific property of the rocks, and it takes a suite of several logs to fully characterize the subsurface formations.

Dual Induction - Laterolog: This log measures two things: the natural electrical potential set up at the contact between two rock formations, and the electrical resistivity of these formations.

The natural potential, called spontaneous potential in logging parlance, is the result of an electrical cell that is set up at the contact between two rock formations and the intersection of that contact by the wall of the drill hole. The spontaneous potential logging tool measures an electrical current that is generated in the borehole due to differences in salinity of drilling mud and formation water. This current flows at the bed boundaries between sands and shales, and the spontaneous potential log can be used to differentiate between these kinds of subsurface formations penetrated by the borehole. However, it should be noted that the log is designed for conditions where there is a marked contrast in salinity between

formation fluid and fluid in the borehole; and the amplitude of the line on the log is dependent upon these differences in salinity. Since the water used to mix drilling mud for the test hole was very similar to formation water in the deeper zones under investigation, the spontaneous potential log is "suppressed" and registers the differences between sand and shale by small and rather subtle changes in the line on the log. This was one reason to take so many sidewall cores: to aid in interpretation of the spontaneous potential log.

Electrical resistivity of rock formations, as measured by the logging tool, is really the resistivity of the fluid contained in the pores of the formation and not resistivity of the mineral particles making up the solid body of the rock itself. Thus in two sand formations of identical mineral composition and similar grain size, the difference in resistivity can be substantial if one sand is saturated with fresh water and the other with salt water. Likewise the resistivity may differ markedly in two formations of similar mineral composition and similar water composition but with greatly differing grain sizes, and hence differing amounts of pore space. The fine-grained sand, having more pore space and more water, will have the lower resistivity. For this reason the resistivity side of the log is of particular interest when we are making comparative studies of subsurface formations that may be potential aquifers. The resistivity lines on the log tell us in a general way how salty or how fresh the formation waters are in a particular sand (which we have previously identified in the subsurface by studying the spontaneous potential line on the log).

There are three resistance-measuring instruments on the Dual Induction-Laterolog tool. One measures the formation near the borehole, a second measures resistivity at an intermediate distance from the hole, and the third measures resistivity at a distance of several feet out in the formation away from the borehole. The reason we need all of these measurements is to be sure that we measure the true formation resistivity. The water that is mixed with clay to make drilling mud used in rotary drilling nearly always "invades" the permeable formations for a short distance from the borehole. It is necessary to reach beyond the mud-filtrate invasion zone to measure true formation resistivity, hence the need for several measuring instruments in the logging tool.

Proximity Log - Microlog: The proximity log measures resistivity out in the formation about 12 inches from the borehole wall. When used in conjunction with the Dual Induction-Laterolog, the proximity log is designed to determine the type and depth of invasion of mud filtrate out into the formation. The microlog consists of two resistivity curves for the zone immediately adjacent to the borehole wall (about 1-1/2 to 2 inches out). Its primary function is to detect the presence of mudcake on the borehole wall, which in turn is an indication of permeable zones in the formation. Mudcake is the solid residue left behind at the borehole wall when water from the drilling mud invades the formation.

Compensated Formation Density Log: The logging tool contains a generator that bombards the formation with high-energy gamma rays. These rays are reduced in energy as they collide with electrons in atoms of solid formation material, and the returning low-energy gamma rays are counted by a recorder in the tool. The rate at which the rays return (the counter rate) is proportional to the number of electrons in the formation and hence proportional to the density of material making up the formation. The curve printed on the log reads in grams of matter per cubic centimeter and is a measure of the bulk density of the formation, which in turn is proportional to porosity in granular sediments such as sand, silt and shale. This is probably the most accurate electrical logging method for determining porosity of granular formation.

Sidewall Neutron Porosity Log: This tool has a generator that bombards the formation adjacent to the drill hole with high-energy neutrons. A recorder in the tool measures returning low-energy, or epithermal, neutrons that result from the bombardment. When the high-energy neutrons enter the formation they collide with certain atoms and are reduced in energy, returning as epithermal neutrons to be measured by the logging tool. The chief energy reducer is the hydrogen atom, and the tool is therefore hydrogen-sensitive. Since nearly all of the hydrogen in the formation occurs in the water, the tool measures the water content, which is in turn a function of the amount of pore space in the formation. The log is calibrated to read in percent porosity, and this is a measure of the reservoir space in the formation available for storing water.

Caliper Log: Most tools that make contact with the borehole wall (e.g., the proximity log, microlog, etc.) may also be instrumented to record hole size, which is recorded as a caliper log along with whatever other quantity the tool is measuring. The bit size is recorded on the log along with actual hole size, and the log is used (along with the microlog) to show zones of permeability where mudcake results in an undersized hole. It also shows zones of washout where the hole is oversized, and thus it is an aid in telling where to set or avoid setting packers in the hole.

Sidewall Coring Tool: The tool has a number of small coring devices that can be inserted into the formation at the borehole wall to take samples of the formation for examination and study at the surface. The cores, which are 2 inches long and 1 inch in diameter, are taken by firing an explosive charge and driving the coring tube into the formation to be sampled. During the coring operation, the tool is located opposite the spot to be sampled and the charge is fired by pressing a button at the surface. The locations to be sampled are chosen by examining the Induction Log and Microlog and selecting the formation intervals where samples are desired.

Water Sampling

Introduction: Although the electrical logs may give a general idea of formation water quality at various depths, there is no substitute for an actual sample that can be analyzed in the laboratory. The electrical log tells us that formation water is relatively fresh or salty, but it does not give any indication of the specific constituents dissolved in the water. And these can be either helpful or harmful when the ground water is finally pumped from a well and put to use. For example, even fairly fresh water that doesn't look too bad on the electrical log may contain enough boron to make it harmful (or even lethal) to plants. To really know, we have to take an actual water sample for laboratory analysis.

Until recently it was difficult and expensive to get a true formation water sample without completing a water well and pumping it. If the water was not usable, the cost of the well was lost. Now it is possible to take a formation water sample from an uncased test hole, and this has greatly reduced the cost of investigating the quality of water in underground formations. The Standard Oil Company has developed a sampling tool that will take ground water samples from formations in uncased test holes at a reasonable cost. This sampler was used in the present investigation with excellent results.

The sampling tool consists of two inflatable packers separated by a pre-determined length of perforated tubing, with the whole assembly attached to the bottom of the drilling rig's string of hollow drill pipe. After the intervals to be tested have been selected from studying the logs and core samples, the tool is made up with the appropriate length of perforated tubing between the packers, and the whole assembly is run into the hole on the drill pipe (see Fig. 3). The perforated interval is placed opposite the sand to be tested, and the packers are then inflated to fill the hole both above and below the perforated tubing and isolate the formation in this interval from the rest of the drill hole. Next an air line is run down the drill pipe, usually to a depth of several hundred feet below the static water level, and air is pumped down and allowed to bubble out and up inside the drill pipe. This causes the fluid column in the drill pipe to froth and move up to the surface along with the larger air bubbles. By means of "air-lift" pumping, the formation to be tested is drawn on; and water begins to come into the perforated tubing between the packers and move toward the surface. In this way it is possible to pump from the formation at rates of from 2 to 3 gpm up to rates of about 20 to 30 gpm. It usually takes several hours for the water to clear up, but in time nearly all of the drilling water is pumped out of the formation near the drill hole and true formation water is produced at the surface by the air-lift system. At that time a sample is taken. The packers are then deflated and the tool moved up the hole to the next interval to be tested. The testing procedure is repeated and the tool is moved upward higher and higher in the hole until all zones have been tested.

It was mentioned earlier in the discussion of resistivity logging that some drilling water, or mud filtrate, flows out into the permeable formations during drilling. When the formation is produced by air-lift pumping during the sampling procedure, the first water to come out is mostly mud filtrate. Later, as the discharge begins to clear up and more and more of the pumped water is formation water, we try to gauge the change from filtrate to formation water by frequently checking electrical conductivity (the reciprocal of resistivity) of the effluent stream at the surface. After one or two hours of fairly constant readings on the conductivity meter, we assume that most mud filtrate has been displaced and that mainly formation water is being produced. This method works well and we can be confident in most cases that most, if not all, of the effluent stream at the surface is coming from the formation being tested. In this investigation we had an additional check through the courtesy of the Standard Oil Company in the use of a newly patented method in which a tracer is put into the drilling water and used to detect the presence of drilling water during test pumping from a formation of unknown water quality. This method, employing the addition of sodium nitrate to the drilling water, allowed us to establish a reasonably accurate value for the proportion of mud filtrate still flowing into the test stream at the time of sampling. The results showed that the samples taken for analysis were about 90% formation water and 10% filtrate.

Sampling Program in Test Hole 1-17H: The test hole was spudded on February 11, 1969, and was drilled to a depth of 890 feet by 3:00 a.m. on February 12. At this time heavy rains forced cessation of drilling, and the rig stood idle until March 14, when drilling was resumed. The hole was drilled to a total depth of 3,300 feet by March 18 and electrical logs were run and 40 sidewall cores were taken. Examination of the electrical logs showed the position of the sands making up the deeper aquifers, and also showed that the drill hole was washed out, or oversized, in several places. Drilling fluid was changed over from mud to clear water in order to reduce its weight and thus lessen the differential pressure across the packers of the sampling tool. The sampling tool was run into the hole, but it could not be lowered below a depth of 1,846 feet. It appeared that the hole was caving at the wash-out zones indicated on the logs, and it was obvious the hole would not stand open when filled with water alone. The hole was again filled with mud to prevent further washing out and was reamed to total depth to clean it out preparatory to again running the sampler.

Below a depth of about 2,800 feet the electrical logs indicated the presence of thin sands containing formation water of poorer quality than water above 2,800 feet. A bottom-hole sampler (with a single packing element) was run to a depth of 2,984 feet to sample this lowermost zone in the hole. Unfortunately the hole was so oversized in the lower part that the packer would not seat, and we were unable to obtain a water sample. Although it was not necessary to sample this zone to accomplish the purpose of the

investigation, it would have completed the water-quality profile in this test hole and was desirable from that standpoint.

The next interval chosen for sampling was the sandy interval shown on the logs from about 2,565 to 2,690 feet. This interval was bounded by deep washouts both above and below the sand. The sampling tool, with the two packers separated by 95 feet of tubing (including several perforated lengths), was run into the hole and the top packer was set at 2,574 feet. Air-lift pumping began, but after about 1-3/4 hours, drilling mud began to bypass around the top packer. It appeared that the formation was caving, probably starting from the washout above the packer. At any rate, the packer failure caused termination of the test before a formation water sample could be taken.

After deflating the packing tool, the whole assembly was moved up the hole, and the first successful test was made in the sand from 2,290 feet to 2,440 feet, with the top packer set at 2,327 feet. The zone was pumped by air-lift for four hours at a rate of about 5 gpm. The discharge cleared up after about three hours, and after pumping clear water for an hour, three one-gallon water samples were taken. The low pumping rate appears to have been caused by plugging of some perforations in the sampling tool. This required a longer pumping time to get clear formation water but otherwise did not appear to affect sampling results.

The packer was deflated and moved up to the next sand to be tested. This was from 2,045 to 2,165 feet, with the top packer at 2,049 feet. After pumping for 6 hours at a rate of about 2 to 3 gpm, three one-gallon water samples were taken. Again, sampling was done after the discharge had been running clear for about an hour.

The next sand to be sampled was from 1,860 to 1,920 feet, with the top packer set at 1,874 feet. This time, after pumping between 5 and 6 hours at 3 to 4 gpm, and just as the water was beginning to clear up, one of the packers began to leak. The last samples taken were mainly drilling mud, and pumping was stopped at the end of 6 hours. During the pumping period, it was customary to take one-gallon samples every 15 minutes as soon as the water began to clear; and in this case the samples used for analysis were the last two samples taken prior to packer failure. After pumping about 5 hours at a rate of 3 to 4 gpm, more than 1,000 gallons had been produced from the formation before the packer failed. Therefore this sample, although partly contaminated with drilling mud, was probably mostly formation water. This interval contains the uppermost sand in the deep, previously unexplored water zone.

Moving on up the hole to the lowermost zone presently developed by wells, a sample was taken for comparison with previous analyses from nearby wells tapping this zone and for comparison also with waters in the deep undeveloped zone. The interval tested was a massive sand zone from about 795 to 990 feet. The top packer was set at 852 feet, but the packers

failed to hold. The assembly was moved down the hole again and the top packer was set at 938 feet. Three one-gallon samples were taken after pumping for 3 hours at a rate of about 8 gpm. This concluded the water sampling program.

QUALITY OF WATER IN DEEP AQUIFERS

In the previous investigation, ground water reserves were classified on the basis of chemical quality and were categorized as "good" (TDS $\leq 1,800$ ppm), "fair to poor" (TDS 1,800 to 2,800 ppm), and "very poor" (TDS $> 2,800$ ppm). * These categories were selected after studying chemical analyses of waters from wells down to about 1,000 feet and from interpretations of electrical logs of wildcat oil wells below 1,000 feet. A test hole was recommended to allow sampling of formation waters below 1,000 feet and to provide a check on the accuracy of previous electrical log interpretations. Now that the test hole has been drilled and sampled, we are in a position to discuss quality of waters in the deeper aquifers as based on analyses of actual water samples taken from these formations.

Chemical analyses of water samples from the test hole and from nearby wells are tabulated in Table I. All of the waters are relatively high in sulfate, and the upper waters (above 1,000 feet) could be classified as calcium-magnesium-sodium sulfate waters. The deeper waters are mainly sodium sulfate waters. Boron content is low in all the waters, and chloride and bicarbonate are also relatively low for waters of this type. Although the sodium percentage is fairly high in the deeper zones, the chemical balance is such that these waters should be as well suited to irrigation requirements as the upper waters.

The water in the deep aquifers appears to be better in quality than predicted in the previous report. * At the location of the test hole the upper zone presently developed by wells is about as expected. But below this zone some of the water (from 1,700 to 2,800 feet) that was previously designated "fair to poor" appears to be within the range of salinities found in the upper "good" water zone. The sampled interval from 1,874 to 1,982 feet shows a little higher salinity than other samples from the deep zones, but it was in this interval that packer failure occurred before a clear sample of formation water could be obtained. The salinity found in other samples from the deep zone (2,049 to 2,157 feet and 2,321 to 2,429 feet) is probably representative of most of the aquifers from 1,700 to 2,800 feet. These salinities (1,007 ppm and 1,029 ppm TDS, respectively) are lower than the salinity of the water sampled in the interval 937 to 1,034 feet (1,290 ppm TDS). The deeper waters are comparable in TDS to water from well 9H (Table I), which is completed to 493 feet in the upper "good" water zone.

* Ibid.

Interval Sampled →	Standard Oil Co. Test Hole 1-17H**			Standard Oil Co. Water Well 9H** (drilling water source)			W. Weeth Water Well 18***		
	2327-2427	2049-2149	1874-1984	200 - 493	200 - 493	200 - 493	200 - 1020	200 - 1020	200 - 1020
	2327-2427	2049-2149	1874-1984	200 - 493	200 - 493	200 - 493	200 - 1020	200 - 1020	200 - 1020
Specific conductance micro mhos/cm x 10 ⁵ @ 25° C.	269	238	269	199	150	-	-	-	-
pH	7.8	8.4	8.1	7.9	8.0	7.4	7.4	7.4	7.4
Hardness as Ca CO ₃	87.1	120.0	135.0	258.0	425.0	499.9	499.9	499.9	499.9
Sodium %	87.7	86.1	86.7	70.7	45.4	43.1	43.1	43.1	43.1
Constituents in parts per million (ppm)									
Total solids @ 105° C	1007	1029	1629	1290	1014	1170	1170	1170	1170
Calcium (Ca)	28.6	37.0	43.4	52.6	80.4	91.5	91.5	91.5	91.5
Magnesium (Mg)	3.8	6.7	6.4	30.8	54.7	65.1	65.1	65.1	65.1
Sodium (Na)	301	356	427	300	164	173.0	173.0	173.0	173.0
Potassium (K)	3.4	4.0	5.3	5.5	2.5	-	-	-	-
Iron (Fe)	0.13	0.16	1.98	< 0.05	< 0.05	-	-	-	-
Manganese (Mn)	0.04	0.07	0.05	0.05	< 0.01	-	-	-	-
Fluorides (F)	0.10	0.15	0.34	0.30	0.17	-	-	-	-
Carbonates (CO ₃)	0	9.6	4.8	0	0	0	0	0	0
Bicarbonates (HCO ₃)	84.2	133.6	261.7	137.9	168.4	158.6	158.6	158.6	158.6
Chlorides (Cl)	114.3	134.5	118.6	90.3	49.6	63.8	63.8	63.8	63.8
Boron (B)	0.72	0.60	0.84	0.86	0.54	0.2	0.2	0.2	0.2
Sulfates (SO ₄)	495	561	652	655	551	626.4	626.4	626.4	626.4
*Nitrates (NO ₃)	-	-	-	-	3.5	-	-	-	-
Silica (SiO ₂)	18.0	11.0	16.0	33.0	24.0	36.8	36.8	36.8	36.8

* Nitrates reported in these ground waters are generally low. Sodium Nitrate was used as a tracer in the drilling fluid of test hole 1-17H in order to estimate the proportion of drilling fluid in the formation water samples obtained in the tests. Therefore, in this table, nitrates, and the sodium that combined with the nitrates, are not reported for the test hole.

** Analysis by B.C. Laboratories, Bakersfield, California.

*** Analysis by the Twining Laboratories, Inc., Fresno, California

Even though the waters in the upper and deep "good" zones are similar in TDS content, there is enough difference in their chemical constituents to make them dissimilar electrically. On the electrical log the lower water does not appear to be as good as actual samples proved it to be, and it was for this reason that we had previously classified it as "fair to poor". On the other hand, formation water resistivity as calculated from the electrical logs checked closely with laboratory measurements of resistivity made on water samples from the test hole. It appears that in the relatively fresh ground waters of Pleasant Valley, even slight differences in chemical character (e. g., higher chlorides in water of essentially the same TDS) may produce distinct differences in resistivity of water from the various subsurface formations. With this fact in mind, we were able to use electrical logs from wells at other locations along with results from the test hole to modify the subsurface picture presented in the previous report.*

Conditions prevailing at the test hole have been extended along a line of section (shown in Fig. 1) to show in a general way the geology and hydrology of aquifers in the central part of the basin. The crude picture presented on a cross section in the previous report on Pleasant Valley has been considerably refined by results from the test hole. Subsurface conditions, as inferred from test-hole results, are shown diagrammatically on cross section A-A' (see Fig. 2), and the following discussion refers generally to this line of section.

Chemical stratification of ground waters within the basin has been demonstrated during this investigation. Water in the uppermost massive sands and gravels is generally "good" quality water, but there appears to be a downward gradation in quality, with water in the lower part of the zone having a somewhat higher salt content than the top water. This shows up in the electrical logs and was confirmed by sampling in the test hole. Analyses of water from the Standard Oil Company 9H well (depth 493 feet) and the test hole sample at 937 feet show that although both are "good" water, the 9H water is distinctly better (see Table I). No analysis for water from the Lovelace well was available, but here the electrical log shows a distinct break in water quality at about 615 feet; and we can infer a situation similar to that found in the test hole.

Below the base of the upper massive sands (about 1,000 feet in the test hole) there is an interval several hundred feet thick where thin silty sands and silts appear to contain "fair to poor" quality water. No tests were made in this zone in the test hole because there appeared to be so many thin, lenticular silty sands with fine silt interbeds that it was felt no worthwhile aquifer could be developed in this zone. Also on the electrical logs these thin silty sands appear to contain water of much lower quality than the zone above. Water in the lower part of this zone appears to be even poorer than water in the upper part.

* Ibid.

The next interval, appearing at about 1,700 feet in the test hole, is composed of about 1,100 feet of fine-grained massive sands with a few interbeds of silt and clay. Here the water is of "good" quality and is similar to water in the upper zone above 1,000 feet.

Below a depth of about 2,800 feet the water appears to be decidedly more saline and the formations contain fewer sand bodies than in the "good" water zone just above, from 1,700 to 2,800 feet. Studies of electrical logs from wildcat oil wells indicate that this lowest zone in the test hole extends on downward for several thousand feet and gives way finally to the zone of saline connate water in the underlying oil-bearing formations.

If we look at other areas in the valley, we see considerable variation in ground water quality. For example, in the vicinity of the Conn Ranch where there is very little near-surface, "good" quality water (see Figs. 1 and 2), most wells produce poorer quality water than that found in the test hole. The deep Conn well shown on the cross section appears to have penetrated about 300 feet into the deep "good" water zone. Based on electrical log data it appears that this is the only well in the vicinity of Conn Ranch that goes deep enough to enter the lower "good" water zone. It is interesting to speculate on the water quality that this well might have produced if the well had been drilled to the base of this zone and if the casing had been perforated opposite only the upper "good" zone and the deep "good" zone. It is our feeling that had this been done, the well would have produced water of considerably better quality than other Conn Ranch wells.

The general geologic and hydrologic conditions shown on the cross section may prevail in other parts of the valley as well. In that case, would deeper drilling develop aquifers with water comparable in quality to the deeper water found by this test hole? Probably so. But only a test hole, with water samples taken for analyses, can definitely answer that question at any given locality.

One important result of this investigation, in addition to data on the deep aquifers, is the establishment of practical methods for economically testing deep formations anywhere in the valley. It is no longer necessary to commit oneself to drilling and completing a deep well in order to learn about water quality in subsurface formations. The drilling and testing program carried on here could be adapted to a preliminary exploration program in advance of completing a deep irrigation well. The only extra expense would be for drilling a pilot hole to some predetermined depth (say 3,000 feet), running one or more electrical logs, and running the Standard Oil sampling tool for obtaining water samples. Results of logging and sampling should then be adequate to make a decision on how deep to complete the well. The extra depth of pilot hole below completed well depth can be easily and cheaply plugged before the rest of the hole is reamed and sized for the finished well. This procedure would take most of the guesswork out of future water well development programs in the valley and could be done for a cost that would represent only a small proportion of the finished well cost.

PRODUCTIVITY OF DEEP AQUIFERS

Productive capacity of the aquifers beneath a given area can be defined only by pump testing. This requires the drilling of a well which must be properly cased and completed, carefully developed, and then pumped at maximum or near maximum rate. This investigation did not encompass such an ambitious program. Nothing other than information pertaining to ground water quality and aquifer lithology was obtained directly from the test program. However, the lithologic samples, together with the electrical logs, did provide some information on expected production rates from the deeper fresh water aquifers beneath the test site.

Estimates of productive capacity from aquifers penetrated by the test hole can be made on a comparative basis. If sand thickness and permeability of the deeper aquifers (1,700 to 2,800 feet) can be related to sand thickness and permeability of the presently productive aquifers lying above 1,000 feet, then we have a basis for estimating the total potential productivity. There is considerable information on production rates from nearby wells, which are perforated through the entire sequence of aquifers down to about 1,000 feet. What we have attempted to do is to compare the total thickness and permeability of the zones lying between 1,700 and 2,800 feet with productive sands above 1,000 feet. On this basis we have derived a productivity rating that expresses the potential production rate from the deep sands as a percentage of the known production rate from the upper sands.

Electrical log data supplemented with data from the sidewall cores have provided us with information on the nature of the aquifer sands penetrated by the test hole. Production rates are dependent primarily on sand thickness and permeability. Sand thickness can be determined from electrical logs. At present there is no way of directly measuring permeability from the electrical logs. However, with sufficient supplementary permeability data from cores, it is possible to make general estimates of permeability by using electrical logs.

In the test hole, aquifer sands from the water table to a depth of 1,000 feet have a net thickness of about 325 feet. Nine sidewall cores were taken in this interval and their average permeability was 2,810 millidarcys (see Appendix). However, the sands of these aquifers are not uniform in grain size, and laboratory-derived permeabilities varied over a wide range. When the sidewall core permeabilities are adjusted using electrical log data, the overall average permeability appears to be closer to 2,000 millidarcys. To check adjusted permeability of the sands above 1,000 feet, a value of 2,000 millidarcys, used in a common hydrologic equation for well producibility, resulted in a theoretical maximum production rate of 3,500 gpm for a 1,000 foot deep well. Nearby wells produce at rates of 1,000 gpm to 3,000 gpm from this interval. Thus our value of 2,000 millidarcys for the zone above 1,000 feet is probably realistic though possibly a little high.

The deeper aquifers explored by the test hole extending from about 1,700 to 2,800 feet have a net sand thickness of about 566 feet. This sand is quite uniform in grain size and permeability, and an average permeability of about 300 millidarcys obtained from measurements on the 17 sidewall cores in this zone is probably quite representative. Thus these sands are about $1/6$ to $1/7$ as permeable as the sands above 1,000 feet. However, with almost twice the net sand thickness, the lower aquifers can be expected to produce at a rate of about $1/3$ to $1/4$ that of the upper aquifers. A well in the vicinity of the test hole, presently capable of producing 3,000 gpm from the upper aquifers would be expected to produce about 4,000 gpm if deepened to include the entire thickness of the lower aquifers.

The additional water produced from deeper wells should be of "good" quality and in much of the valley it would noticeably upgrade irrigation water quality. Pumping levels would probably be about the same in new deep wells as in the present shallower wells. Even with deeper wells, the long-time decline in water levels experienced in Pleasant Valley during recent decades would probably continue at about the same rate, around 5-1/2 feet per year.

CONCLUSIONS

At the beginning of this investigation we had a pretty good idea of the general geology and hydrology of the Pleasant Valley basin. We knew in a general way, from studies of electrical logs, what kind of water the deeper aquifers held. However, as was proved conclusively during the investigation, slight differences in chemical character of waters can make distinct differences in electrical resistivity patterns shown on the logs. This was the reason the test hole was needed: to bring up actual samples of deep waters for analysis. Having done this in one place and having run a complete suite of electrical logs in the same hole, we can now make better interpretations of electrical-log data throughout the valley. Therefore, results of this study, while referring specifically to the test hole, do lead to conclusions that would seem to apply in a general way throughout the valley.

1. Although electrical logs are useful as guides to ground water quality and subsurface lithology, actual water samples are necessary to determine usability of water for irrigation.
2. Results of this investigation show that some of the water previously labeled "fair to poor" is actually of "good" quality.
3. In at least part of the valley there are two major zones of "good" water, an upper zone beneath the water table and a lower zone lying above the deep, "very poor" water, the upper surface of which was shown on the map in Figure 3 in the previous report.* These two "good" water zones are separated by a variable thickness of sediments containing "fair to poor" water.

* Ibid.

4. As could be seen on maps included in the report on the previous investigation, the water quality zones thicken and thin in various parts of the valley; and thicknesses of zones found in the test hole may vary considerably at other locations. Many wells in the valley go through the upper "good" water zone and appear to be completed in the "fair to poor" zone beneath. If some of these wells had been drilled deeper they probably would have penetrated aquifer sands containing relatively "good" quality water.
5. Future exploration for the deeper "good" water zone should be preceded by test drilling followed by electrical logging and water sampling.

RECOMMENDATIONS

The results of the present investigation along with those of the previous investigation provide a fairly complete picture of ground water reserves in Pleasant Valley. Data summarized on maps in the first report give a generalized picture of the ground water reservoir, and refinements added during this investigation further enhance reliability of the water quality data shown on these maps. * The test hole has convinced us that, while the generalized data previously presented may be correct in its gross aspects, actual conditions at a given locality may be somewhat different from those shown on the generalized maps. Therefore we would like to offer the following recommendations as guides to further water development in the valley.

1. It would seem fruitless to explore below the base of the "fair to poor" water zone (top of the "very poor" water zone) as shown on the map in Figure 3 of the previous report. *
2. Future exploration for additional water supplies should be carried on somewhat as follows:
 - a. Drill pilot hole to a depth slightly below the postulated base of the "fair to poor" water zone, as given on map in Figure 3 of previous report. *
 - b. Run induction electrical log and microlog-caliper log.
 - c. Use Standard Oil Company formation water sampler to take water samples from a few zones selected after a study of the electrical logs.
 - d. Plug pilot hole back to base of "good" water zone as indicated by logs and sampling tool.
 - e. Ream pilot hole to desired size for finished well.
 - f. Run casing with perforated intervals opposite "good" water sands as indicated by logs and water samples. Leave blank casing opposite zones indicated as having poorer quality water.

* Ibid.

APPENDIX

APPENDIX

HISTORY - STANDARD OIL COMPANY TEST HOLE 1-17H

Section 17, T 16 E, R 21 S, Pleasant Valley, Fresno County, California

1/13/69-
2/7/69 Move in from January 13 through February 8. Rain caused delay.
2/7/69 Rig up. Elev. 585' GL (topo) DF above GL = 10'.
2/10/69 Rig up - 30' 10-3/4" conductor cmt in place.
2/11/69 Finish rigging up. Spud 1:10 p.m., Tuesday, February 11. Drill to 220' (7-7/8" bit). Condition mud @ 220' at 67#, vis. 36, w.l. 6.2 cc. sd 1%, salinity 684 ppm, type-cypan. Added 100# sodium nitrate tracer. Drill ahead to 890'. Pull out of hole 3:00 a.m. 2/12/69 - Wet loc.
3/14/69 Repair conductor. Start bit in hole @ 12:30 p.m. Ream out hole to 890'. On bottom at 5:45 p.m. Circ. clean. Drilling ahead at 6:15 p.m. Mud 67#, 36 vis., w.l. 5 cc., salinity 2100 ppm, 1/2% sd.
3/15/69 Drilled to 1531' (8:00 a.m.). Mud 67# vis. 37, w.l. 7.2 cc., 1910 ppm, sand 1/2%. Survey 1317'-0°30'. Drilled ahead to 1897' (8:00 p.m. 3/15/69). Surveys: 1592'-0°55', 1897'-1°. Mud pump gear box noisy. Worked on gear box from 8:00 to 10:00 p.m. Pulled several stands out of hole - circ. Wait on mechanic.
3/16/69 Waiting on mechanic to return with parts. Repair mud pump. Start back in hole at 2:40 p.m., circ. clean, resume drilling at 3:45 p.m. Mud: 67#, 36 vis., w.l. 7.1 cc., 1910 ppm, 1/2% sd. Added 2nd sack of Na₂NO₃.
3/17/69 Drilling - 2743'. Survey 2203'-1°, 2521'-1°45'. Mud 70#, 39 vis., w.l. 8.9 cc., pH 8.0, 1910 ppm, 1% sd. Survey 2834'-1°30'. Add 3rd sack Na₂NO₃.
3/18/69 Drilled - TD 3300' @ 1:00 a.m. Wipe out of hole from 3300' to 1800'. Return to bottom. Circ. clean for log. Pull out of hole. Run dual induction, proximity micro, sidewall neutron and density log. Mud prior to logging 70#, 38 vis., pH = 8, w.l. 7.1 cc., 2110 ppm, 1% sd. Took 40 sidewall samples. Recovered 40 samples. Run bit back in hole. Wipe from 700' to 1000' and from 1700' to 2100'. (midnight)
3/19/69 Wipe hole 2100' to 3000'. Ream tight hole to 3270'. Circ. hole clean (1 hour). Pull 60' off bottom and clean mud pit. Fill pit with water. Add 1 sack NaNO₃. Run to bottom and change system over to NaNO₃ water. Strip out tight hole from 3300' to 2820' (some running shale over shaker). Pull out (measure out) slowly, check fluid loss rate in hole @ 9:40 - very low rate. Make up straddle packers. Run packers in hole. Separation between packers 282'. Lower packers to 1846', packers would not go below this. Packers probably started dragging at about 1000'. Pull packers. Go in with bit (water still in hole). Run in to 980'. Hole caving. Ream to 1000'. Mix mud. Ream from 1000' - 1498' with mud.

- 3/20/69 Ream tight hole- Mix mud. Mud 75#, vis. 45, w.l. 7.3 cc., 1500 ppm, 1% sd. Ream ahead and circ. Ream to 3300' TD. Circ. and cond. mud. Circ. 4-1/2 hours. Pull out to collars. Let set 2 hours. Run in w/bit. Ream 2562' to 2613'. Mud 72#, 42 vis., w.l. 5.6 cc., 1820 ppm, 1% sd.
- 3/21/69 Circ. bottom up. Ream 2613-1/2 to 3200'. Circ. and cond. mud - 1 hour. Ream 3200' to 3300' TD. Circ. and cond. mud (2 hours). Pull up to 2400'. Work pipe 1 hour. Run in to 3290' (10' fill). Ream 3290' to 3300'. Circ. and cond. mud (1 hour). Mud as above but w.l. down to 3.6. Pull out bit. Run in H-D packer - top packer set at 2984', bottom at 2988'. Tail to TD, 1 blank - rest perf. Run 1-1/4" tbg. to 1060', displace mud in annulus between tbg and drill pipe. Packer began to leak. Pulled up on packer and reset. Still leaked. Pull 1-1/4" tbg. Pull packer (chain tong out). Run in to 3015'.
- 3/22/69 Circ. and cond. mud (3 hours). Pull out. Mud 72#, vis. 47, w.l. 3.3 cc., 1800 ppm, 1/4% sd. Make up inflatable packers. 1 blank below top packer and then 2 perf. Distance between packers 95.55'. Set top of top packer rubber @ 2574' and top of bottom packer rubber @ 2673.5'. Run 1-1/4" tbg and displace mud in tbg with water. Make-up water 6.78 ohm/m @ 77°. Inflate packers with water. Inflation pressure 133 psi. Displace mud in drill pipe with water. Pull 1-1/4" tbg and remove inflation stinger. Rerun 1-1/4" tbg to 531'. Pressure 1-1/4" tbg w/air to begin air lift pumping. Start pumping at 8:05 p.m. Sample @ 9:00. Resistivity 5.94 ohm/m. Mud began to leak around packers at 9:45 p.m. Shut down test at 12:00 ±.
- 3/23/69 Pull out 1-1/4". Run in and deflate packers. Pull drill pipe and 1-1/4" up to next test int. Top of top packer @ 2327' and top of bottom packer 2427'. Displace mud in 1-1/4" tbg with water and inflate packers. Displace mud in drill pipe. Pull 1-1/4" and remove stinger. Run 1-1/4" open end to 540'. Start air lift @ 11:00 a.m. - 100 psi pumping pressure. Pumping rate 5 gpm ± (plugged perfs?). End test at 3:00 p.m. - collect 3 one-gal. samples. Deflate packers. Pull 1-1/4" and drill pipe up to set packer at next zone. Top of top packer at 2049.4' and top of bottom packer at 2149'. Displace mud from 1-1/4" and attempt to inflate packer. Held 300# but packer failed to set. Pulled 1-1/4" tbg and setting tool. Rerun setting tool and displaced mud. Inflate packer. Packer seated. Displace mud in drill pipe.
- 3/24/69 Run 1-1/4" to 548' and start air lift at 1:45 a.m. Shut off air at 7:30 a.m. (pump rate 2 gpm ±). Obtained 3 one-gallon samples of fluid just prior to shutting off air. Pull 1-1/4". Pull drill pipe - place top of top packer 1874' bottom 1974'. Displace mud in 1-1/4", inflate packer at 275 psi. Wash perfs w/655 gal. (370 theoretical displacement). Pull 1-1/4". Remove inflat. tool. Run 9 stands 1-1/4" air line to 540' ±. Start air lifting at 2:30 p.m. Pumping rate 3 gpm ±. Air pressure 100 psi. Packer failed between 7:30 and 8:30 p.m. Samples taken at 7:45 (1 gallon) 8:00 (1 gallon), and 8:30 (1 gallon). 8:30 sample was drilling mud. Other two samples muddy formation water - possibly slightly contaminated by drilling mud. Pull 1-1/4". Run setting tool on 1-1/4" and deflate packer.

3/25/69

Pull 1-1/4". Pull packers up to next zone. Run setting tool on 1-1/4" and displaced mud. Attempt to set packers - top of top packer 852' and top of bottom packer at 952'. Inflated packers. Displaced mud in drill pipe. Pulled 1-1/4" and removed setting tool. Rerun 1-1/4" to 540'. Start air lift at 4:10 a.m. Packers failed to hold. Deflated packers. Lowered packers - top of top packer 937.66', top of bottom packer 1038'. Run 1-1/4" and displaced mud. Attempted to inflate. Could not hold pressure. Pulled 1-1/4" and setting tool. "O" rings stripped off. Replace "O" rings and run tool on 1-1/4". Displace mud from 1-1/4" tbg. Attempt to inflate. Packers appear to have inflated. Displace mud in drill pipe. Pull 1-1/4" (tool still on) to 330' +. Start air lift to blow off hydrostatic head above water table at 11:00. 5 gpm +. Shut down at 11:20 a.m. Add 90' 1-1/4" (bottom at 420'). Start air-lift again at 11:40 a.m. 8 gpm rate. Shut off air at 2:00 p.m. Collect 3 one-gallon samples just prior to shut-off. Deflate and pull packers. Set heavy mud plug and abandoned hole.

SIDEWALL SAMPLES - STANDARD OIL COMPANY TEST HOLE 1-17H

Section 17, T 16 E, R 21 S, MDBM, Fresno County, California

- 278' Recovered 1/2". Sand; buff, fine grained, silty, poorly sorted, low permeability.
- 329' Recovered 1/4". Sand; buff, medium to coarse grained, predominantly coarse, poorly sorted, slightly silty, fair permeability.
- 385' Recovered 1-1/2". Sand; buff, medium to coarse grained, predominantly medium, fair sorting, slightly silty, good permeability.
- 486' Recovered 1-1/4". Sand; as above.
- 643' Recovered 1-3/4". Sand; buff, fine to coarse grained with frequent granules and a few small pebbles, slightly silty, poorly sorted, fair to good permeability.
- 680' Recovered 1-3/4". Sand; as above, few pebbles to 1/4" diameter.
- 719' Recovered 1". Gravel; pebble gravel in matrix of fine to medium grained silty sand. Abundant chert and sandstone pebbles. Fair to low permeability.
- 782' Recovered 1-1/2". Sand; light brown, fine to coarse grained with scattered granules, predominantly medium, poorly sorted, slightly silty, fair permeability.
- 832' Recovered 1-1/2". Granule Gravel; matrix of light brown fine to coarse grained, silty sand. Poorly sorted, fair to low permeability.
- 895' Recovered 1-3/4". Sand; light brown, coarse grained with abundant granules, good permeability.
- 955' Recovered 1-1/2". Sand; as above.
- 1283' Recovered 1-3/4". Sand; light brown, fine grained, silty, fair to low permeability.
- 1782' Recovered 1-3/4". Sand; dark bluish-gray, fine grained, silty, fair sorting, fair to low permeability.
- 1812' Recovered 1-3/4". Sand; as above.
- 1854' Recovered 1-3/4". Sand; as at 1782'.
- 1882' Recovered 1-3/4". Sand; as at 1782'.
- 1933' Recovered 1-3/4". Sand; as at 1782'.
- 1968' Recovered 1-3/4". Sand; as at 1782'.
- 2049' Recovered 1-3/4". Sand; as at 1782'.
- 2111' Recovered 1-3/4". Sand; as at 1782'.
- 2152' Recovered 1-3/4". Sand; as at 1782'.

- 2235' Recovered 1-3/4". Sand; as at 1782'.
- 2267' Recovered 1-1/2". Sand; dark bluish-gray, fine to medium grained, silty, fair to low permeability.
- 2337' Recovered 1-3/4". Sand; as above.
- 2370' Recovered 1-3/4". Sand; as at 1782'.
- 2433' Recovered 1-1/2". Sand; dark bluish-gray, fine grained, very silty, locally clayey, low permeability. Few irregularly shaped claystone masses scattered throughout sample.
- 2515' Recovered 1-3/4". Sand; dark bluish-gray, fine to medium grained, poorly sorted, silty, low permeability.
- 2580' Recovered 1-3/4". Sand; as above but dark gray.
- 2646' Recovered 1-3/4". Sand; dark gray, fine to coarse grained, silty, poorly sorted, fair to low permeability.
- 2736' Recovered 1-3/4". Sand; as above.
- 2785' Recovered 1-3/4". Sand; dark gray, fine to coarse grained with abundant granules and pebbles, silty, poorly sorted, fair to low permeability.
- 2890' Recovered 1-3/4". Sand; dark gray, fine to medium grained, silty, fair to poor sorting, fair to low permeability.
- 2942' Recovered 1-3/4". Sand; dark gray, fine to coarse grained, silty, poorly sorted, fair to low permeability.
- 2999' Recovered 1-3/4". Sand; as above.
- 3060' Recovered 1-3/4". Sand; as above.
- 3092' Recovered 1-3/4". Sand; dark bluish-gray, fine grained, silty, fair to low permeability.
- 3149' Recovered 1-3/4". Sand and Silt, interlaminated; silt is dark gray, clayey. Sand is dark gray, fine grained, very silty and has low permeability.
- 3181' Recovered 1-3/4". Sand; dark gray, fine grained, silty, fair to low permeability.
- 3219' Recovered 1-3/4". Sand; dark gray, fine to coarse grained with abundant granules and small pebbles, silty, poorly sorted, fair to low permeability.
- 3262' Recovered 1-1/2". Silt and Sand, interlaminated; silt is dark gray, sandy. Sand is light gray, fine grained, silty and has low permeability.

NOTE: All sands below 1782' are graywackes and have abundant serpentine and chert. All sands are unconsolidated or poorly consolidated.

SIDEWALL CORE ANALYSES FOR TEST HOLE 1-17H

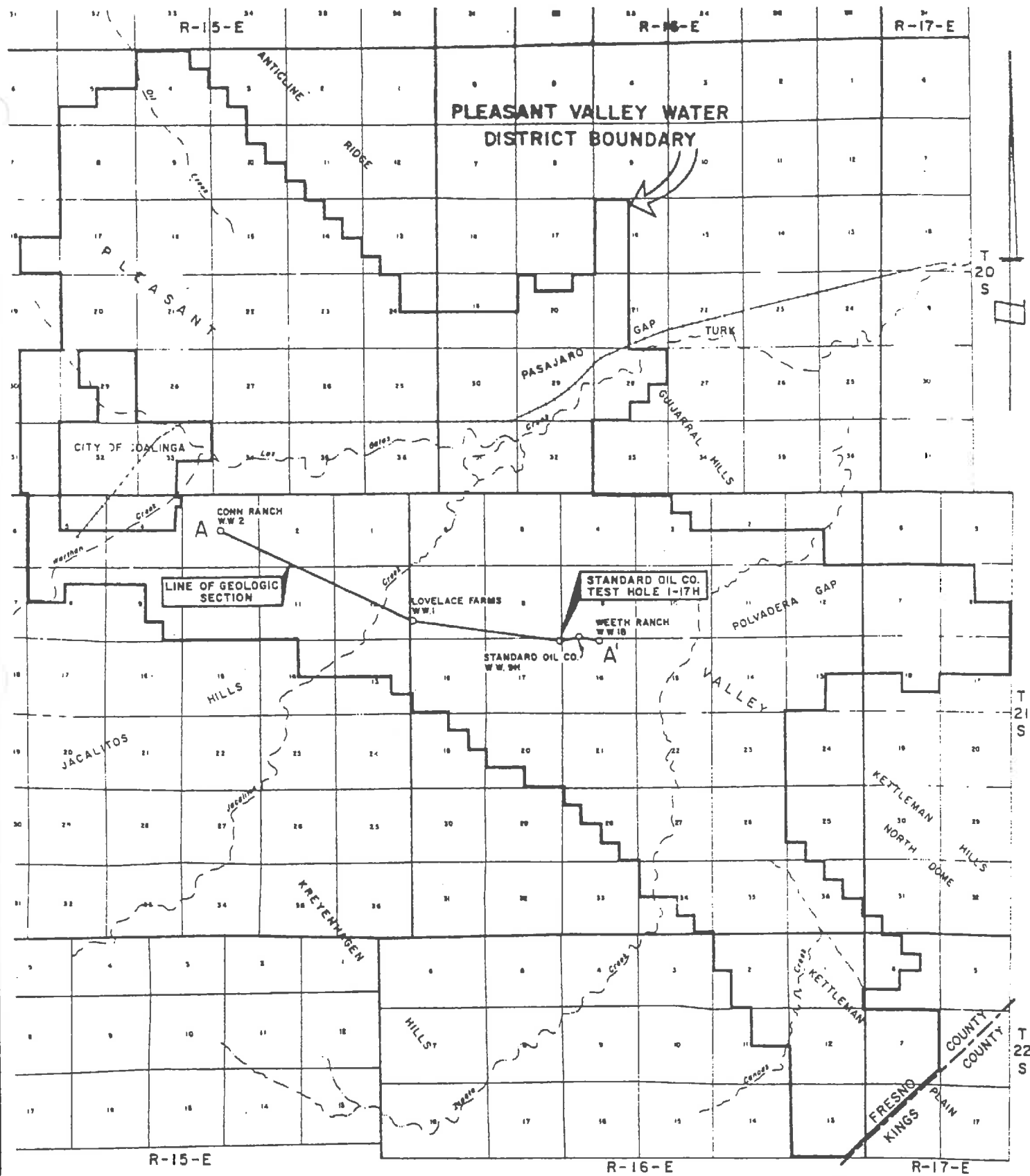
Analyzed in the Standard Oil Company Laboratory

Camp 1C, Taft, California

April 3, 1969

<u>Sample #</u>	<u>Depth (feet)</u>	<u>Air Permeability in millidarcys</u>	<u>Porosity %</u>
1	278	292	32.0
2	329	-	-
3	385	4870	29.0
4	486	4690	28.9
5	643	2940	26.6
6	680	1580	34.6
7	719	1440	23.6
8	782	1580	22.4
9	832	989	22.0
10	895	3520	28.5
11	955	3700	29.8
12	1283	272	32.6
13	1782	118	32.0
14	1812	269	39.3
15	1854	186	36.4
16	1882	178	37.2
17	1933	562	34.7
18	1968	297	31.4
19	2049-1/2	555	28.3
20	2111	282	27.8
21	2152	257	31.4
22	2235	6.9	34.0
23	2267	199	30.0
24	2337	217	32.0
25	2370	64.7	32.8
26	2433	379	33.1
27	2515	266	30.0
28	2580	116	30.0
29	2646	616	35.9
30	2736	216	30.9
31	2785	418	28.2
32	2890	265	36.6
33	2942	921	32.5
34	2999	1720	30.8
35	3060	949	30.6
36	3092	119	34.4
37	3149	6.6	33.3
38	3181	100	32.5
39	3219	274	28.3
40	3262	2.9	32.5

ILLUSTRATIONS



INDEX MAP



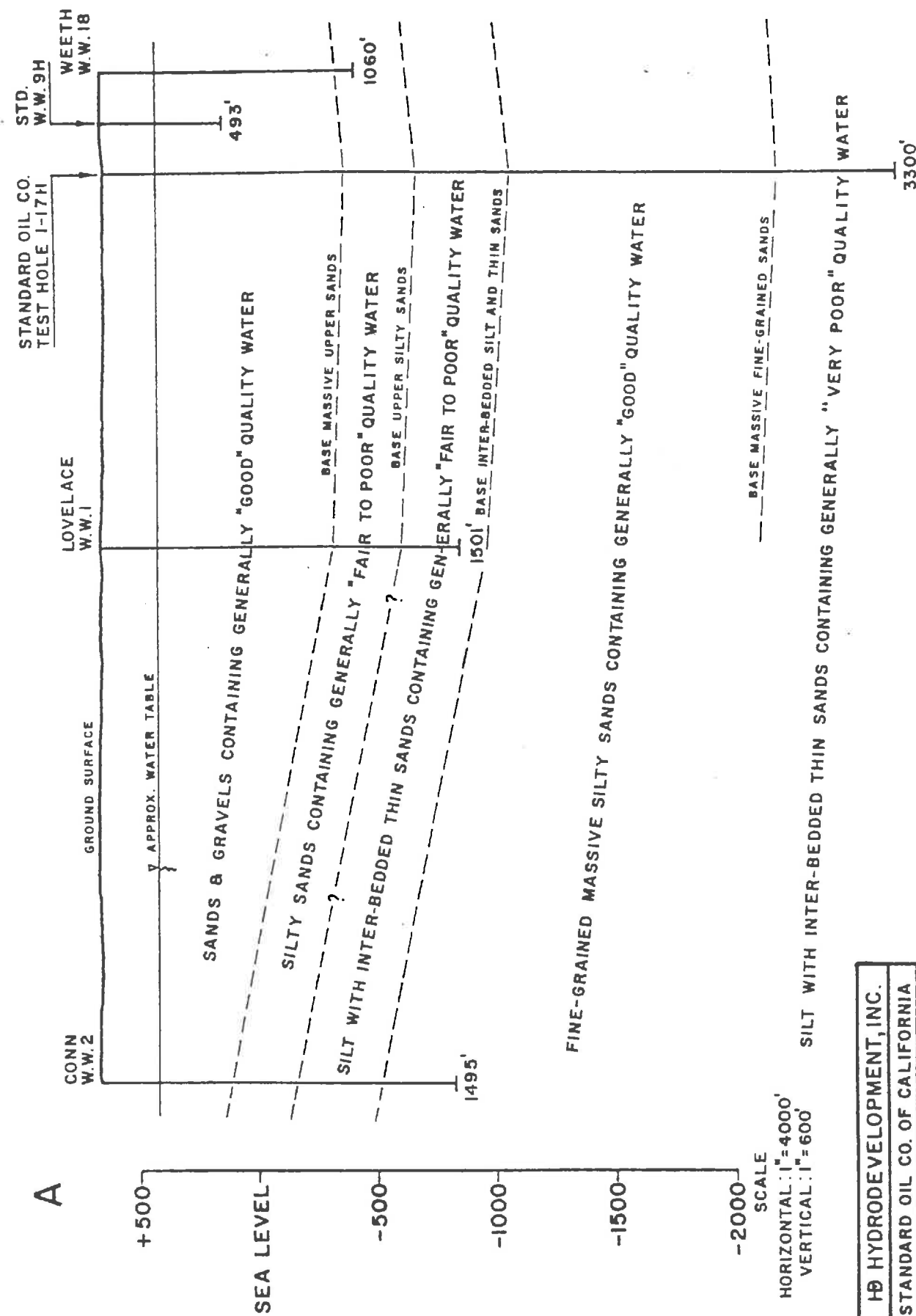
HD HYDRODEVELOPMENT, INC.

STANDARD OIL COMPANY OF CALIFORNIA

AN EVALUATION
OF
GROUND WATER QUALITY IN DEEP AQUIFERS
BENEATH PLEASANT VALLEY
FRESNO COUNTY CALIFORNIA

DATE: MAY, 1969

A'



GENERALIZED GEOLOGIC CROSS-SECTION A-A'

SHOWING FRESH WATER AQUIFERS BENEATH PLEASANT VALLEY

H&B HYDRODEVELOPMENT, INC.

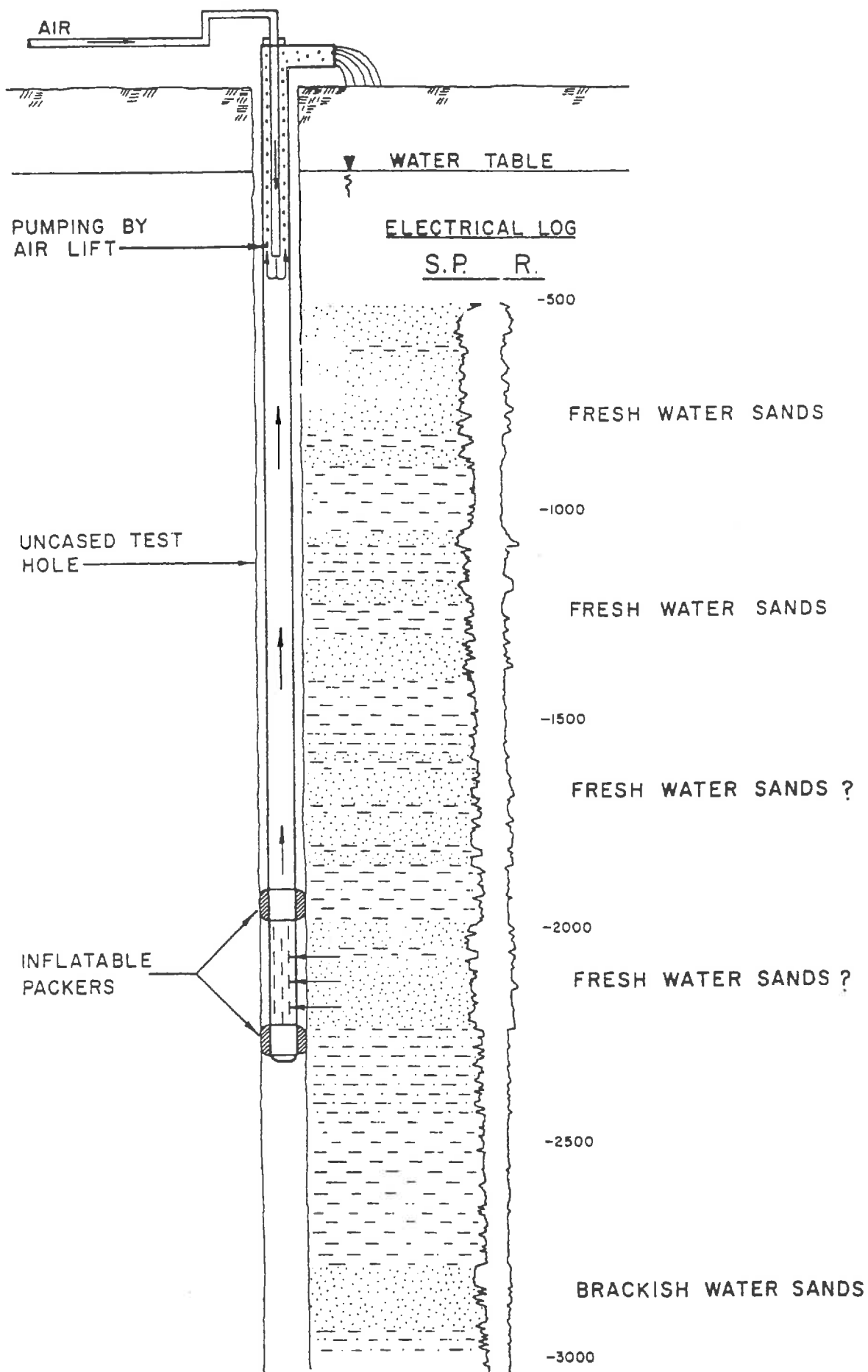
STANDARD OIL CO. OF CALIFORNIA

AN EVALUATION OF

GROUND WATER QUALITY IN DEEP
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OPEN-HOLE FORMATION WATER SAMPLER