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Santa
Monica
Area

REVISED GROUND WATER GEOLOGY
AND
NEW WATER WELL SITES
FOR
THE CITY OF SANTA MONICA

By

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CONCLUSIONS AND RECOMMENDATIONS

Recent subsurface information indicates that a large quantity of potable fresh water generally of better quality than Colorado River water has been wasting into the ocean since 1962 both via a stream in Santa Monica Canyon and by unseen underground seepage. Much of this water can be recovered and used by the City of Santa Monica by drilling several new wells in addition to the recently completed wells, Arcadia 3 and 4 and San Vicente #1 (19th and San Vicente). This well drilling program should result in a very considerable reduction in the cost of the City's water supply over the next 10 years or longer.

Most of this ground water is obtained from porous and permeable gravel and sand beds, or aquifers, that aggregate 50 to 100 feet in thickness, in the surficial Terrace Deposits (Qt) of Upper Pleistocene age. These water bearing strata are nearly horizontal and underlie the entire City. The base of these shallow Qt aquifers is generally 200 to 300 feet below the ground surface and wells producing from them have yields of 300 to 500 g.p.m. Some of the new wells might have capacities as high as 800 g.p.m.

Under the eastern or northeastern third of the City of Santa Monica recent test holes reveal that deeper water bearing sands and gravels in the San Pedro formation of Lower Pleistocene age are present at depths of 200 to 500 feet and below the Qt strata. These deeper aquifers have an aggregate thickness as great as 225 feet and are cleaner and less silty than Qt and, therefore, some wells in them should be capable of pumping as much as 1000 g.p.m. The Charnock wells located about a mile east of the City Limits

commonly pump 2,000 gallons per minute on production tests; they derive their water from about 230 feet of the same San Pedro sands and gravels at depths of 140 to 500 feet.

As requested, I am recommending four new wells as follows:

Well Site A. - A well about 450 feet deep to be located near the northeast corner of the Public Works Yard. The water will come from the San Pedro aquifers between depths 200 and 500 feet. A 26-inch gravel pack well is suggested and such a well will probably produce 1,000 g.p.m. of potable fresh water initially.

Well Site B. - This site is in the center parkway of Olympic Boulevard and should be located within a few hundred feet of Centinella. The estimated depth is about 500 feet and the San Pedro sand below 200 feet is the objective. A well here is over 2,000 feet from Site A and should not interfere with any wells at the Public Works Yard; the yield should be similar, probably at least 1,000 g.p.m.

Well Site C. - This location for a 250 feet deep Qt well is in San Vicente parkway near 11th. It is along the easterly projection of the Potrero Canyon fault where possible fracturing bordering the fault zone may increase the water yield beyond the normal 350 g.p.m. capacity. The base of Qt is just above sea level, so that there should never be any danger of future sea water intrusion at Well Site C.

Well Site D. - This location in Lincoln Park is the most promising site for a large volume Qt well found to date. The well here would be 300 feet deep and a probable water yield of 600 to 800 g.p.m. is indicated. The static water level should be watched carefully and not allowed to fall below sea level more than a few feet because the aquifers are mostly below sea level and subject to sea water intrusion if overpumped for a protracted

period.

Observation Well. - An observation well about 300 feet deep is suggested at Marine Street Park, where sea water invasion occurred about 1940 and would be apt to occur in the future. A small diameter well here would give a warning if sea water should begin to invade the aquifers again.

Although four new well sites are given above and will probably remain valid, your drilling program should be flexible and might be revised because of new information obtained in the drilling or pumping of each new well as it is completed.

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REVISED GROUND WATER GEOLOGY AND
NEW WATER WELL SITES FOR CITY OF SANTA MONICA

August, 1968

This report is prepared for the purpose of (1) bringing up to date the ground water geology of the City as revealed by the drilling of a few new water wells and eleven test holes with electric logs since my original report in 1962 and supplementary report of February 15, 1965, and (2) recommending the most promising sites for four new water wells together with the justification therefor.

Sources of New Information

In May, 1965, United Geophysical Company drilled six test holes, three (Nos. 1, 2 and 3) in or near San Vicente Boulevard, No. 4 in the circle of Palisades Avenue near 7th Street, No. 6 at Cloverfield and Olympic, and No. 5 (near the City's abandoned Marine Street wells) Marine and 16th Streets. These test holes all appear on the enclosed map together with some of the significant information obtained in each hole. Electric logs were run but those from No. 5 (at Marine and 16th) and No. 6 (Cloverfield and Olympic) show no character and are practically useless, suggesting either poor recording or, possibly, the presence of brackish to salty water in No. 5, the poorest log. However the water sample recovered from No. 5 was fresh. These holes were blown with compressed air and water samples were collected for partial analysis except in No. 1 (19th and San Vicente) from which no sample of water or cuttings were obtained, and No. 3 (7th and San Vicente) where only mud was recovered, possibly because of caving conditions. A

report by Paul Prestholt, geologist for United Geophysical Corporation, dated May, 1965, included copies of the electric logs and also water analyses showing Ph, Iron and "hardness in parts per million" (p.p.m.) (possibly Total Dissolved Solids) from Test Holes Nos. 2, 4, 5 and 6. The "hardness" varied from 240 in No. 4 to 514 in No. 2 and the water in all these holes is usable, although Iron with a concentration of 0.17 p.p.m. in No. 4 (at Palisades near 7th) is much higher than in the other holes and might increase enough eventually to require some treatment.

On June 30, 1965, I submitted to the City a memo entitled "Review of United Geophysical Corporation Report and Recommendations on New Well Sites." In this I called attention to the poor quality of the electric logs and recommended three new well sites, No. 1 at 19th and San Vicente, No. 2 at 26th and La Mesa and (tentatively) the site of No. 5 Test Hole at Marina and 16th Streets.

In April, 1966, a new water well (which I shall call San Vicente #1) located in San Vicente parkway at 19th Street, was completed at a plugged depth of 276 feet. This well pumped a maximum of 603 gallons per minute of good quality fresh water with an 86 foot draw down and a sustained yield of 463 g.p.m. with a 64' draw down. This is considered to be a satisfactory well in view of its shallow depth and about 60 feet of aquifers. As the bottom of this well is 44 feet above sea level there is no danger of future sea water intrusion here. The yield of this well was somewhat higher than that in the two recently completed Arcadia wells (Nos. 3 and 4) that pump 360 to 450 g.p.m. sustained flow each with a drawdown of 61 to 108 feet.

In March, 1968, Geo-Dats drilled five test holes to an average depth of 400 feet and obtained electric logs of good quality from all five holes. These electric logs together with Ken Kemp's interpretation furnish a much

more reliable guide for locating new water wells than previous information and my present well site recommendations, therefore, supersede previous recommended well sites that have not been drilled.

Mr. F. J. Schroeder has kindly supplied me with additional subsurface information from Mobil Oil Co. in the Venice area adjacent to Santa Monica, and an Occidental Petroleum Co. core hole with a good electric log in Santa Monica Canyon, as well as additional well information from Los Angeles Flood Control District, the State Division of Water Resources and the published "Report of Referee" by State Dept. of Public Works; California Water Service Company vs. City of Compton and Alexander Abercrombie, June 1952. All the wells from which significant information was obtained, including Geo-Data and United Geophysical Corp. test holes, oil wells, and deeper water wells are shown on the enclosed large topographic Contour Map of Santa Monica. The more important or essential information such as total depth, Base of Qt (Upper Pleistocene Terrace Deposits, the shallow water zone), aggregate thickness of aquifers and the most recent static water level appear on the map alongside each test hole or well.

Section A-A' of my 1962 report, through the Arcadia plant, has been revised to show geological conditions as they were found in the two new wells and the 600-foot test hole that found no deep water sands; it is included herewith also.

NEW GEOLOGICAL INFORMATION

As my original report to the City of Santa Monica, dated April 23, 1962, describes the ground water geology and aquifers that underlie the City, the present report will discuss new geologic information that has been obtained from the 11 test holes mentioned above as well as from Mobil Oil Company's Venice wells, Occidental Oil Company's Marquez E. H. Core Hole in Santa

Monica Canyon, and the new City wells, San Vicente #1 (19th and San Vicente) and Arcadia Nos. 3 and 4. The City's two latest Charnock wells, Nos. 13 and 14, were also studied and the San Pedro aquifers in them were compared with the probable San Pedro in the lower part of Geo-Data test holes Nos. 2 and 4. Unfortunately no electric logs were taken in the Charnock wells so the driller's logs were used.

Summary of Ground Water Geology

In the City of Santa Monica the fresh ground water occurs in two formations as follows:

1. Upper Pleistocene Terrace Deposits (Qt). - These consist of flat lying more or less silty but generally porous and permeable, brown to tan-gray, massive bedded, poorly sorted gravels and pebbly sands containing lenses or interbeds of sandy silt and silty clay. The less silty, permeable gravel and sand strata below the water table constitute the shallow aquifer zone (Qt). The silt and clay bodies, that comprise locally from 10 to 65 per cent of the Qt, have low permeability and contribute little or no ground water. The upper part of these Terrace Deposits is well exposed in the cliffs of the Palisades and those bordering Santa Monica Canyon. The deeper strata are similar to these outcrops.

The thickness of the Terrace Deposits (Qt upper aquifer zone) ranges from 0 at Brentwood Knoll at the north edge of the City (where Pico Pliocene outcrops) to 300' at Lincoln Park. The aggregate thickness of water bearing gravels and sands (aquifers) generally ranges from 40 feet in the northern part of Santa Monica to 110 feet at Lincoln Park (7th and Wilshire in Geo-Data Test Hole No. 3) and 115 feet at Memorial Park (14th and Olympic) in the central part of the City. The thickest more permeable section of Qt aquifers was found in Geo-Data No. 3 at the center of Lincoln Park. Although these

shallow aquifers are slightly thicker (115') in Geo-Data No. 5, at the main entrance to Memorial Park, the electric log indicates they are less permeable than at Lincoln Park. The Qt aquifers tend to become more silty and contain more silt interbeds east of Colorado Avenue; hence they are less promising to the east.

2. San Pedro Formation (Qsp-Lower Pleistocene). - This formation is mainly of marine origin but the original sea water has been flushed out of the aquifers for thousands of years and it now contains large volumes of good fresh water. It consists of 50 to 75 per cent generally well stratified and persistent, light gray to tan, soft and generally clean and permeable sands, pebbly sands and gravels interbedded with 25 to 50 per cent blue gray silt and clay. On account of their cleaner character and higher permeability the San Pedro sands and gravels generally yield larger volumes of good quality fresh water than the shallower Qt aquifers above.

The San Pedro aquifers, which are gently folded, unconformably underlie only the eastern third of Santa Monica, east of the heavy line marked "West Edge of San Pedro Sand" on the enclosed maps. These deeper aquifers have been removed from the central and western parts of the City by pre-Qt (post Qsp) erosion. In Geo-Data No. 4 (see Cross Sections B-B' and D-D') the San Pedro is 258 feet thick and 145 feet of it and possibly more below the bottom of this test hole, is water bearing. The bottom of the San Pedro water sand may not have been reached at 430 feet, the bottom of Geo-Data No. 4. The Charnock wells located about 6,000 feet east of the eastern corner of Santa Monica, obtain their water exclusively from the San Pedro formation. Recently Charnock No. 13, with its aquifer from depth 142 to 390 (see the northeast end of Cross Section B-B'), pumped a maximum of 2,100 g.p.m. from about 240 feet of San Pedro sand and gravel (perforations 200-390); Charnock

No. 14 nearby pumped 2,200 g.p.m. maximum. Therefore it is reasonable to expect that wells located at or near Geo-Data Test Holes 2 and 4 in the northeastern part of the City, will yield 1,000 gallons per minute or more of usable fresh water per well. As the water level in the unconfined Qt aquifers may be different from that in the confined San Pedro aquifers the two aquifers should not be perforated in the same well.

Pico Formation. - The steeply folded Pico formation lies unconformably beneath the Qt and San Pedro formations under Santa Monica but it outcrops at the surface in a small area north of Brentwood Knoll and in Potrero Canyon. The Pico consists of blue-gray silty clay shale or mudstone. The electric log of Mobil Oil Company's Brentwood No. 1 on the northwest side of Brentwood Knoll (Montana near Centinella) indicated that the upper 300 feet of the Pico formation from 110 to 410 feet consisted of silty sand and sandy silt. However this sandy zone has evidently changed into impervious silt or clay eastward because, in the 596-foot test hole located at the southern corner of the Arcadia Pumping Plant property no sand was encountered. Hence no aquifers are expected in the Pico formation beneath Santa Monica. To date all test holes or wells drilled into this formation have found only blue gray mudstone or silty clay shale that will not produce water in significant quantity.

Oil well data indicate that aquifers in the still deeper Miocene Monterey (Modelo) or Topanga formations beneath the Pico mudstone contain only a little salt water in the Santa Monica-Venice area.

STRUCTURAL GEOLOGY

The Pico and older (Miocene) formations in this area have been rather intensely folded and faulted; they commonly have dips of 50 degrees to vertical in Potrero Canyon and northwestward where they are exposed at the surface. The San Pedro formation is gently folded (dips generally less than

15°) and is cut by a few faults that are shown on the map.

Faults

Potrero Canyon Fault. - This fault, that is clearly exposed at the mouth of Potrero Canyon at the extreme west edge of the map is recent enough to cut the Upper Pleistocene Terrace Gravels (Qt). On page 154 Yerkes and Wentworth (U.S.G.S. Special Publ. for Atomic Energy Commission, 1965) describe the Potrero Canyon fault as follows: "Locality 6: The base of the Upper Pleistocene coastal terrace deposits is cut by two branches of a fault with aggregate vertical separation of about 120 feet (mapping by J. T. McGill); - - -. One fault at this locality is vertical and the other dips about 55° north; at the level of the Pacific Coast Highway the faults juxtapose marine Pliocene (Pico) strata on the north with marine and non-marine upper Pleistocene deposits (Qt) on the south; these faults may represent an eastward extension of the Malibu Coast fault." Hoots in U. S. Geological Survey Prof. Paper 165-C showed a N 75° E strike for this Potrero Canyon fault zone; I measured a N 80° E strike for it and on the map both are shown. This fault probably effects the ground water level and may fracture the Qt deposits so as to increase their yield of ground water at Well Site C.

Brentwood Fault. - This fault is discussed in my original (1962) report to the City and appears to be an en echelon easterly continuation of the Potrero Canyon fault zone. It was found at 2,625' in Mobil's Brentwood No. 1 oil test and at about 3,445' (-3,200 subsea) in Santa Monica-Sawtelle Oil Co.'s Birch No. 1 oil test. It appears to cut off the San Pedro sand a short distance southeast of the Arcadia Pumping Plant as shown on the map and Cross Section B-B'. It acts as a ground water barrier.

Santa Monica Fault. - This doubtful fault is based on water well evidence and may act as a barrier against sea water intrusion at new Well Sites A and

B, at least to some extent. In Cross Section E-E' the Santa Monica fault is shown as dropping the base of Qt gravel and sand south of this fault, thus accounting for a greater thickness of Qt aquifers in Geo-Data No. 3 and No. 5 test holes. The east end of the Santa Monica fault may extend farther east than shown on the map.

Charnock fault. - The northwest-trending Charnock fault lies off the enclosed map and between the City's Charnock wells and the east corner of Santa Monica. It is shown at the east end of Section B-B'. It drops the San Pedro aquifer on the northeast side so that it has been preserved from pre-Qt erosion, thus accounting for the 200 feet of aquifer or more in the Charnock wells. This fault constitutes the southwest boundary of the Charnock ground water sub-basin and forms the northeast boundary of the shallow Santa Monica ground water basin, over which the City is situated.

PRESSENT GROUND WATER SITUATION

Since 1941 when the City of Santa Monica abandoned its Marine Plant wells because of sea water intrusion and began to obtain most of its water from Metropolitan Water District, the aquifers beneath the City have been recharged with fresh water derived from local rainfall. During the last several years a considerable quantity of potable fresh water has been wasting into the ocean via Santa Monica Canyon and shallow underground seepages along the shore line. Much of this escaping fresh water is superior in quality to that from the Colorado River (Metropolitan Water District) as well as being a lot less expensive. It is probable that a new wet cycle has begun in southern California, possibly starting in 1965-66, thus ending the abnormally long 20 year dry cycle that began in 1945-46. During a new wet cycle with above average rainfall for ten or twelve years (the usual length of a local wet cycle), it should be possible to obtain most of the City's water supply at much lower

cost from local wells that would otherwise waste into the Pacific Ocean.

Area Free of Sea Water Intrusion Hazard. - In the northern and north-western parts of Santa Monica, where the base of the shallow Qt aquifer is above sea level, there should never be any danger of salt water intrusion. Therefore it is possible to pump as much water as can be economically obtained from the Arcadia wells and from San Vicente No. 1 at 19th and San Vicente as well as from future wells at formerly recommended Well Site 2 at or near 26th and La Mesa (see Memo of June 30, 1965) or at Well Location C near 11th and San Vicente (this report) where the base of Qt is near or above sea level (see Section C-C') without danger of future sea water invasion. In other words the base of the only aquifers here (Qt gravel and sand) lies above sea level and the area is free from the threat of future sea water intrusion northwest of a line running from San Vicente and 11th (Well Site C) northward to the intersection of Centinella and Santa Monica Boulevard. Although wells in this triangular area north of the Potrero Canyon and Brentwood faults may go dry during future droughts of long duration they should never produce salt water. However, only moderate sized wells pumping from 300 to 500 g.p.m. each at present can be expected in this area and the thickness of the aquifers is 50 or 60 feet. It may be possible to obtain 600 or 700 g.p.m. wells along San Vicente Boulevard by drilling 26-inch diameter holes with 14-inch casing surrounded by a well washed gravel envelope 6 inches thick.

San Vicente No. 1 well at 19th and San Vicente has been standing so long without being pumped that it may be silted up. Although it had a sustained yield of nearly 500 g.p.m. when completed in 1966 it should be test pumped, and possibly swabbed again also, before installing a new pump. It may not come back after standing so long without pumping.

NEW WATER WELL SITES

As I have been requested to recommend sites for four new municipal water wells after carefully evaluating the latest information from recent test holes and wells, I shall discuss below these and other well sites previously considered. On account of the thicker aquifers, a new well at Site A or B producing from the San Pedro formation in the inland eastern part of the City, will probably have a larger water yield; therefore it rates No. 1 in my recommendations.

In view of the fact that the 200-foot wells at the former Marine Street pumping plant became intruded with salt water even during the wet year of 1941 it might be advisable to drill a 200-foot observation well near Marine and 16th before pumping a new San Pedro aquifer well, such as Well Site A, too heavily. Unfortunately the electric log of United Geophysical Corporation's No. 5 test hole at Marine and 16th drilled in 1965 showed no character; both the S. P. and Resistivity curves are nearly straight lines. This indicates either that the recording instruments were not functioning properly or that salt water is still present in the aquifers here. A water sample from 120 feet in United Geophysical's Test Hole No. 5 was fresh, therefore it appears that the recording equipment was out of order. In Mobil Oil Company's Venice No. 1, about a mile farther southwest and only a few blocks from the coast line, the electric log shows excellent detail and clearly indicates that the San Pedro sands below 260 feet contained fresh water. However the low resistivity and high S. P. curve (on left) shows that the Qt aquifers above 245 feet all contained salt water at the time the Venice No. 1 log was run in 1960. This salt water may have been flushed out by fresh water since 1960 but this emphasizes the fact that the Venice-southern Santa Monica area is vulnerable to sea water intrusion. An observation well about 300 feet deep

at the former Marine Street pumping plant in order to detect future salt water intrusion is highly desirable in my opinion.

The locations for new water wells in the City of Santa Monica that are recommended herewith or have been considered in the past few years are discussed in the following paragraphs. These well sites are arranged in their order of probable water yield, the most favorable location being discussed first.

Well Site A (Public Works Yard). - On the basis of known geological evidence the most promising site for a large capacity water well is in the vicinity of Geo-Data No. 4 which logged 145 to 165 feet of water bearing sand and gravel in the San Pedro formation between depths 186 and 425 feet. These aquifers are cleaner and much more permeable than those in the shallow Qt aquifer. The electric log of this Geo-Data No. 4 (near Stewart and Olympic) shows a puzzling increase in Spontaneous Potential (S.P.), the curve on the left side of the log, below 370 feet; this might indicate brackish water between depths 370 and the bottom of the test hole at 430 feet. However the resistivity (right side of log) remains high so that saline water is unlikely above 405 feet. On account of its convenience as a drill site and the possibility that two or three wells as much as 1,400 feet apart, (so that they should not interfere with each other), can be drilled on this large tract, the northeastern part of the Public Works Yard is designated Site A. As it lies slightly farther east from the "West Edge of San Pedro Sand" (see map) this aquifer might be somewhat thicker than in Geo-Data #4 test hole, 800 feet to the northwest. The 500-foot offset of the West Edge of the San Pedro Sand by the Santa Monica fault shown on the map is merely a possible interpretation as is the northward bend in the east end of the Santa Monica fault so as to throw United Geophysical No. 6 test hole on the south side.

Actually there is no proof that the somewhat questionable Santa Monica fault extends this far east. If it does it might act as a barrier against possible sea water intrusion from the south. It is probable that a gravel pack well at Site A will yield 1,000 g.p.m. of water similar to the City's Charnock wells and that water like Charnock will be found.

The pilot hole for a new well at Site A should be drilled to a depth of about 500 feet and a regular electric log run so as to determine the proper depth for the well and the exact intervals to be perforated in addition to the probable quality of the water and thickness of aquifers. As the San Pedro aquifers are confined (separated by impermeable clay and silt from the Qt aquifers above in Geo-Data No. 4 and No. 2) and under some hydraulic pressure only the San Pedro aquifers should be open to perforations, the water in the Qt above being blanked off with unperforated casing. This should help prevent any contamination during future droughts by salt water, such as that shown by the 1960 electric log of Mobil Oil Company's Venice No. 1 above 245 feet (in Qt). The San Pedro aquifer below Qt in this Mobil well contained only fresh water in 1960.

Alternate Well Site A. - This alternate location at or close to Geo-Data No. 4 is a little less of a gamble than a site near the northeast end of the Public Works Yard (Site A) because a test hole has already been completed here. However, Site A is about on strike with Alternate A and these two sites may be considered as equal in view of the more easily controlled drilling conditions at this yard.

Well Site B. - This site is spotted in the center parkway of Olympic near Centinella but may be moved as much as 500 feet southwest if this presents too much of a traffic hazard. This site is shown on Section B-B'-B" and it appears to fall in a small syncline or basin in the San Pedro aquifers, a

desirable feature. A depth of 520 feet for the pilot hole, in which an electric log should be run, is estimated but it might be carried as deep as 550' or to the base of the San Pedro sand (top of Pico) if still in sand or gravel at 520 feet. A site close to Geo-Data No. 2 test hole is slightly less of a gamble and can be substituted for Site B if desired. A new well at Site B or one near Geo-Data No. 2 is just as good as at Site A or a well near Geo-Data No. 4 except for the favorable land situation and accessibility at Site A; otherwise B might be rated first.

Alternate Site B. - A little used (?) corner near the north end of the Santa Monica airport has been picked as Alternate Well Site B on the map. This would require an exploratory pilot hole to 400 feet or so in which an electric log would be run and the log may be unfavorable. The base of San Pedro sand might be too shallow to justify a well here, even if permitted from the standpoint of air traffic, but promising aquifers might be found. It is too much of a gamble to be recommended now but it could be a good site for a San Pedro water well several years hence.

Well Site C. - This new well location is in the center parkway of San Vicente near 11th Street. It lies just north of the easterly projection of the Potrero Canyon fault where fractured Qt aquifers may be more prolific than where unfractured by faulting. A big spring comes out in Santa Monica Canyon a short distance west of this well site probably from such a fracture zone. Although the base of the Upper Pleistocene gravel and sand (Qt) is expected at about 250 feet (see Section C-C') and is somewhat shallower than on the downthrown side of the fault, this Site C is recommended because (1) the fault should act as a barrier against future sea water invasion (2) the base of Qt is close to sea level so that no salt water invasion can take place unless the base of Qt is deeper than shown. A well about 275 feet

deep is recommended at this Well Site C and a maximum yield of 500 to 700 g.p.m. is not unreasonable.

Well Site D. - This site is in Lincoln Park near Geo-Data No. 3, in which 110 feet of unusually permeable Qt aquifers are indicated by the electric log. As shown in Cross Section E-E' the base of the Qt aquifers is at 305 feet so that a 325-foot well is recommended here. The present water level is about 67 feet above sea level so that there is no present danger of sea water intrusion. As long as the static water level here remains above sea level there can be no chance for salt water invasion. However this recommended well site lies south of the Santa Monica fault barrier and is subject to sea water intrusion if a well here is pumped for several months with the static water level below sea level (depth 130 feet or deeper). Therefore the standing water level should be watched carefully if it gets below 120 feet and pumping should be reduced or discontinued if the level should fall below 130 feet. By holding this static level near sea level or above there should be no hazard from sea water intrusion in the future. A gravel pack well 26 inches in diameter at this location will probably yield 600 to 800 g.p.m. from the 110 feet or so of aquifers between the static water level estimated at 60 feet and the bottom of Qt at 305 feet.

Alternate Well Site D. - This well location is near the southern corner of Memorial Park at 14th and Olympic at or near Geo-Data No. 5. Although the base of Qt gravel and sand was found here at 253', about 50 feet shallower than at Well Site D in Lincoln Park, it has about the same thickness of aquifers. If the static water level is not allowed to fall below depth of 110 feet (close to sea level) no salt water invasion should occur. The aquifers appear to be more silty than at Site D; hence a well 275 feet deep at Alternate D (Memorial Park) will probably yield 500 to 700 g.p.m. from about 115 feet of

aquifers. However satisfactory wells can probably be obtained at both Lincoln and Memorial Parks.

Well Site No. 2 (26th and La Mesa or San Vicente). - This well site was recommended in my memo of June 30, 1965, and by United Geophysical Corporation. Although the Qt aquifers are only 50 feet thick a well 200 feet deep will probably pump about 400 g.p.m. of water because the aquifers appeared to be more permeable than in most localities in the Pleistocene terrace deposits.

San Vicente and 7th. - A new well site in the vicinity of United Geophysical's No. 3 test hole has been considered because the electric log of this hole indicates that about 100 feet of Qt aquifers are present between 65 or 70 feet, the probable present standing water level, and 256 feet (see Section E-E'). However the lower 40 feet of gravel and sand, between depths 200 and 256 appear to be quite silty and will probably produce little water. The 60 feet of water sand and gravel between 70' and 158' appear to be more permeable but only mud and no water was recovered from 120 feet where an attempt to recover a water sample was made, probably because of caving conditions. Although a well pumping 400 g.p.m. can probably be obtained here, Well Site D, in Lincoln Park, about a mile to the southeast, shows thicker, more permeable aquifers and is preferred.

Marine Street Park near 16th (Observation Well). - This is the site of the Marine Street water wells and pumping plant that were abandoned because of sea water invasion in 1941. The old wells were only 150 to 250 feet deep and may have obtained at least part of their water from shallow San Pedro aquifers (Poland et al 1959). The excellent electric log of Mobil Oil's Venice No. 1 (less than a mile southwest of Marine Street Park) where the upper 245 feet consisted of Qt gravel, sand and silt containing salt water suggests the following explanation:

(1) These Marine Street wells obtained part or all of their water from Qt aquifers that are locally marine (contain sea shells) and resemble the older marine San Pedro sands here.

(2) The San Pedro aquifers are abnormally shallow here and were invaded by sea water coming from Qt salt water gravel and sand that are directly in contact with the San Pedro sand below.

In view of the very poor, featureless electric log of United Geophysical No. 5 which might indicate that considerable salt water remains in these sands and the vulnerability of Marine Street Park to subsurface sea water intrusion, I recommend that only an observation well about 300 feet deep be drilled here. Such an observation well would warn against future intrusions of sea water, especially when future wells at Well Sites A or B may be pumping large quantities of fresh water from below sea level as the Chernock wells have been doing for many years. The Chernock wells are in another fault block and have not been affected by sea water invasion to date. Poland states that the Chernock wells may yet be invaded by salt water in future years so long as heavy pumping with static water levels below that of the sea continues (see Section B-B').

Respectfully submitted,

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