Native and Contaminated Ground Waters in the Long Beach-Santa Ana Area, California

By A. M. PIPER, A. A. GARRETT, *and others*

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NATIVE AND CONTAMINATED GROUND WATERS IN THE LONG BEACH-SANTA ANA AREA, CALIFORNIA

By A. M. PIPER, A. A. GARRETT, and OTHERS

ABSTRACT

In the greater part of the coastal zone of the Long Beach-Santa Ana area, which includes parts of Los Angeles and Orange Counties, Calif., virtually all water wells yielded water of excellent quality until the late twenties, but at that time certain wells near the coast began to yield salty water and subsequently a number of wells were abandoned. Native salty waters have existed west of the Dominguez Gap and south of the Dominguez Hill, beneath the Long Beach Plain and a narrow zone extending southeast along the coast nearly to Huntington Beach, and locally in the Irvine tract east of the Santa Ana River. However, areas of inferior water that existed as of 1945 within the Dominguez Gap west of Long Beach, in the Santa Ana Gap west of Newport Beach, and on the Huntington Beach Mesa had resulted from progressive depreciation of water quality during the preceding 15 years. Available data include about 5,600 comprehensive chemical analyses and 9,000 partial analyses by several agencies.

In downward succession the area contains (1) a body of unconfined water at shallow depth, which is essentially continuous from the ocean through the five gaps between the coastal hills and mesas, and far inland; (2) a principal body of naturally fresh water which is confined at most places and which occurs chiefly in the lower division of the Recent alluvium, in nearly all deposits of Pleistocene age, and in the upper division of the Pico formation; and (3) a body or bodies of saline connate water. The unconfined water is extensively of inferior quality and locally is grossly contaminated. The principal water body is tapped by wells as much as 1,655 ft deep and is the source of nearly all the very large withdrawal of ground water. Over most of the area its chloride content is from 5 to 40 ppm, hardness from 11 to 300 ppm, and dissolved solids from 160 to 450 ppm. The connate waters underlie all the area; their salinity ranges from 25 to 100 percent of that of ocean water.

To depths ranging from 250 to 750 ft, the confined waters are largely of the calcium bicarbonate type, with hardness from 115 to 300 ppm. Below, in the lower part of the San Pedro formation and in the upper division of the Pico formation the native fresh waters are of the sodium bicarbonate type, with hardness from 11 to 100 ppm, but commonly no more than 50 ppm.

Native waters of inferior quality are widespread in the unconfined shallow body and are of diverse chemical character; those of poorest quality occur near the coast and are sodium chloride waters whose greatest known concentration is 160 percent of that of ocean water. Those in the principal

confined body include waters high in sulfate content and are common at moderate depth along the inland margin of the coastal plain. Sodium chloride and sodium sulfate waters also occur along the coast and locally near the Palos Verdes Hills and the Newport Mesa. Those near the coast contain as much as 18,000 ppm of dissolved solids, but farther inland they commonly contain no more than about 6,250 ppm.

Other than ocean water, the potential saline contaminants are the connate waters in the rocks of Tertiary age, oil-field brines and oil-refinery wastes, and fluid industrial wastes. The connate waters are sodium chloride brines ranging about from 10,000 to 39,000 ppm of dissolved solids. They have been tapped by several thousand oil wells but there is no evidence that they have moved upward into any fresh-water body.

As oil-field waste, the connate brines formerly were discharged rather promiscuously onto the land surface—locally in the Dominguez field and generally in the Long Beach and Huntington Beach fields. As of 1945 they are still so discharged to some extent in the Huntington Beach field, but with this exception they now are largely piped to the ocean or to central disposal works. As of 1945, effluent from such works is discharged into the San Gabriel River within a mile of the ocean, into the Los Angeles River about 4 miles inland, and into the Dominguez Channel at several places throughout its reach. Owing to former promiscuous discharge onto the land surface, oil-field brines have accumulated locally beneath the flank of the Dominguez Hill, probably rather extensively beneath the Signal Hill uplift, and rather widely beneath the Huntington Beach Mesa. Those accumulations definitely are the source of contaminating brines which have invaded the fresh water at certain places, and they will remain as potential sources of contamination almost indefinitely. In the western part of the area, brine-disposal works which serve the Long Beach oil field coincide with a focal area of intense contamination in a water body that natively was of excellent quality.

Industrial wastes of diverse chemical character have been discharged into the Los Angeles River at several places, but so far as is known these have been less concentrated and less voluminous than the oil-field brines. As of 1945, oil-refinery wastes, commonly similar in chemical character to the oil-field brines, are discharged in part into the Dominguez Channel and thence to the ocean.

Many of the contaminated waters have been profoundly modified in chemical character after admixture of the contaminant, especially by base-exchange substitution of calcium and magnesium for sodium. Thus, the slightly contaminated or moderately contaminated waters commonly contain calcium and chloride as their dominant constituents; from their ordinary constituents it is usually impossible to discriminate between contamination by ocean water and that by oil-field brine or connate water. Determinations of iodide or borate are reported in but few of the available chemical analyses, and only to that extent aid in discriminating the source of contamination. It is suggested that these two minor constituents, together with barium, be determined in future analyses of contaminated waters.

Areas in which the fresh ground water has been contaminated are described in detail—the Santa Ana Gap, Huntington Beach Mesa, in and near the Alamitos Gap, and the northeast part of the Newport Mesa, all in Orange County; also, the Dominguez Gap, a part of the Torrance Plain, and the southwest flank of Signal Hill, all in Los Angeles County.

INTRODUCTION

GENERAL NATURE OF THE CHEMICAL PROBLEMS

Until the late twenties, virtually all water wells in the greater part of the Long Beach-Santa Ana, California, area yielded water of good quality and of low or moderate dissolved-solids content. At that time, however, a few wells in certain parts near the coast began to yield salty water, and subsequently some wells were abandoned as the chemical quality of their water depreciated progressively.

Plate 1 outlines the districts in the coastal zone of the Long Beach-Santa Ana area in which certain of or all the ground-water bodies had a chloride content exceeding 50 ppm in 1943–44; that is, the districts which then contained water with a chloride content substantially greater than that of the native waters extensively withdrawn for use. These districts include several whose water had been naturally of inferior quality: most of the area west of the Dominguez Gap and south of the Dominguez Hill, the Long Beach Plain and the narrow zone which extends southeastward along the coast nearly to Huntington Beach, and locally in the Irvine tract east of the Santa Ana River. However, the areas of inferior water existing as of 1943–44 within the Dominguez Gap west of Long Beach, in the Santa Ana Gap west of Newport Beach, and on Huntington Beach Mesa had resulted from progressive depreciation of water quality during the preceding 15 yrs.

In the middle thirties, as the ground-water head continued to recede, the depreciation in water quality caused deep concern on the part of local agencies charged with the conservation of ground-water supplies in the coastal-plain area. A most critical question apparently was at issue: Could withdrawals of ground water for the many considerable requirements of the area be continued freely and indefinitely without an ultimate substantial increase in the areas of salt-water contamination along and near the coast?

This report examines the chemical aspects of that question by: (1) describing, so far as feasible, the chemical character of the ground waters native to the area, both those widely utilized and those of inferior quality; (2) describing the chemical features of the potential sources of salt-water contamination (the ocean, native bodies of saline connate water, works for the disposal of waste fluids from the several oil fields, and the reaches of streams that carry fluid industrial wastes); (3) determining the lateral extent of present salt-water contamination in each of the several water-bearing zones of the area; and (4) evaluating the tendency, if any, for depreciation in water quality to become more intense or more widespread.

Near the inland edge of the coastal plain, the chemical quality of waters drawn from wells also has depreciated markedly in the vicinities of certain oil fields of the Coyote Hills uplift and in the general vicinity of Huntington Park to the northwest. Neither the chemical aspects nor the causes of water-quality depreciation in these particular areas are treated herein.

SCOPE AND SOURCES OF ANALYTICAL DATA

The chemical character of native waters in and near the Long Beach-Santa Ana area has been investigated by many workers and agencies with different objectives. From these investigations about 6,500 analyses of ground waters—not including those made by the city of Long Beach—were available to the Geological Survey for use in the investigation that led to this report. Of these, about 3,500 analyses include determinations of the three common acid radicals (bicarbonate, sulfate, and chloride) and of the two alkaline-earth bases (calcium and magnesium); the rest are much less comprehensive. All these data have been studied critically but only representative analyses are presented herein (tables 29, 30); many others are treated generally by graphic methods. The scope and sources of the analytical data are briefly given later. Plate 2 shows the location of wells and other sampling points in the area, both those for which analytical data are given in this report and those to whose analytical data only general reference is made.

The first evaluation of ground-water quality within the Long Beach-Santa Ana area was made in connection with the investigation of water wells in all the coastal plain of southern California by Mendenhall and others (1905a, b) in 1903–4. In this investigation the approximate dissolved-solids content of the waters from several thousand wells was computed from their electrical conductances, corrected to 60° F. These data show in a general way the range in the quality of waters in the area as disclosed by the initial extensive development of the ground-water bodies, but before any of those bodies had begun to depreciate in quality. The data for the Long Beach-Santa Ana area are generalized on plate 2 by lines showing equal content of approximate dissolved solids.

In 1921, analyses of water from four of the public-supply wells of the city of Long Beach were made by the Geological Survey and subsequently published (Collins, 1923, pp. 28–29).

From April 1925 through February 1926, the Shell Oil Company analyzed samples from several hundred producing water wells in and near the Long Beach-Santa Ana area. The results, which are the basis of an interpretative paper by Morse (1943, pp. 475–511), have been made available to the Geological Survey for its study under certain publication restrictions. Of these, 370 analyses are for wells within the area herein studied.

Between March 1931 and April 1933, the Division of Water Resources in the California Department of Public Works co-operated with the Bureau of Plant Industry in the United States Department of Agriculture to investigate the chemical character of irrigation supplies in all the coastal-plain basins. In that examination samples for analysis were taken from wells 1 to 2 miles apart over all the coastal plain, and at closer intervals wherever critical problems of water quality existed. In addition, supplemental analytical data were compiled from many public and private agencies. These supplemental data include 544 anal-

TABLE 1.—*Scope of data by the California Division of Water Resources on chemical character of water from wells in the Long Beach-Santa Ana area, 1931–33 and 1937–39* [1]

	Coastal zone	Inland zone	Total
Number of wells for whose waters there are:			
Four or more comprehensive analyses	47	21	68
Three or fewer comprehensive analyses	108	262	370
Determinations of chloride, but not comprehensive analyses	89	72	161
	244	355	599
Number of analyses:			
Comprehensive	433	518	951
Others	526	268	794
	959	786	1,745

[1] The data in the body of this table include the 544 comprehensive analyses and many other analyses by agencies other than the California Division of Water Resources but published by that agency in its Bulletin 40–A.

yses for 247 wells in the Long Beach-Santa Ana area in the period from 1918 to 1932. The analyzing agencies, the analytical results, and conclusions drawn from those results appear in two publications (Scofield, 1933; California Dept. Public Works, Div. Water Resources Bull. 40–A, 1933).

Beginning late in 1937, the Division of Water Resources again analyzed the water from selected wells in the area—from seven of these wells at intervals of 1 to 4 months. Nearly all the wells from which samples were taken for this study had been sampled in the earlier program of 1931–33. The analytical data were made available to the Geological Survey by the State agency.

Table 1 shows the scope of the analytical data of these two programs within the area of concern to the Geological Survey, as of December 1939.

Beginning in July 1932, the Water Department of the city of Long Beach has made a monthly analysis of a sample from each of its public-supply wells active at the time; also certain inactive wells have been sampled occasionally. As of July 1943, analyses for 31 wells were available to the Geological Survey from this source—from 1 to 123 analyses for each of the wells. Table 2 shows the scope of this analytical record.

Since 1929 the Los Angeles County Flood Control District has made determinations of the bicarbonate and chloride content of water samples from selected wells; of these determinations, about 1,800 have been of samples taken about monthly at 10 to 16 selected wells in the western part of the coastal zone. From April 1932 until March 1935 the Water Department of the city of Long Beach made determinations of the chloride content of water samples taken monthly at about 80 wells and irregularly at about 40 test holes in and near the Dominguez Gap and in the western part of the coastal zone. These monthly determinations have been continued for 40 to 50 of these wells. In all, about 6,000 determinations of chloride have been made by the city.

Beginning in 1930 the Orange County Flood Control District has analyzed samples from many wells in the eastern part of the area. Some 457 analyses for 119 wells are known to the Geological Survey; they generally comprise determinations of chloride, carbonate, bicarbonate, and electrical conductivity. Four or more such analyses have been made for each of 47 wells, and 50 wells have been sampled only once by this agency. From this factual record 370 analyses have been published (California Dept. Public Works, Div. Water Resources Bull. 40–A, 1933).

TABLE 2.—*Chemical analyses for public-supply wells at Long Beach, by municipal Water Department, as of July 1943*

Geological Survey well No.	City designation	Number of analyses	Duration of analytical record embodied in this report
3/12-31E3	Bixby Dairy well	1	August 1934.
31G1	North Long Beach well 1	28	July 1932–July 1937.
32B3	Funderburk well	7	July 1932–January 1943.
36D1	North Long Beach well 2	27	July 1932–March 1937.
4/12-6K1	North Long Beach well 4	63	Aug. 1934–Dec. 1940.
13D1	Commission well 4	49	January 1933–May 1942.
13F1	Commission well 6	80	January 1933–June 1943.
14B1	Commission well 2	94	August 1931–June 1943.
14C1	Commission well 5	122	January 1933–July 1943.
14D1	Commission well 1	122	July 1931–July 1943.
14P1	Wilson Ranch well 1	111	January 1933–July 1943.
15B1	Commission well 3	101	October 1934–July 1943.
17N1	Development well 7	98	August 1932–July 1943.
17N2	Development well 8	71	August 1932–July 1943.
17Q1	Development well 4	34	July 1932–Dec. 1941.
18R1	Development well 6	52	August 1932–June 1943.
20C1	Development well 3	80	August 1932–July 1943.
20G1	Development well 5	26	August 1932–1940.
21M2	Citizens well 7	108	July 1932–July 1943.
21M4	Citizens well 6	123	August 1932–July 1943.
21M5	Citizens well 5	122	August 1932–July 1943.
24M2	Wise Ranch well 1	113	August 1932–July 1943.
24M4	Wise Ranch well 2	92	July 1932–October 1942.
28H1	Alamitos well 9	105	July 1932–July 1943.
28H4	Alamitos well 12	50	July 1932–July 1937.
28H6	Alamitos well 8	91	July 1932–June 1943.
28H7	Alamitos well 11	81	July 1932–July 1942.
28H9	Alamitos well 1	4	August 1933–March 1938.
28H10	Alamitos well 7	1	August 1937.
4/13-1F1	North Long Beach well 3	31	July 1932–April 1935.
23G2	Silverado Park well 1	12	July 1931–Nov. 1933.

NOTE.—In its cooperative program in Los Angeles and Orange Counties, the Geological Survey has designated wells by numbers or symbols that indicate the locations according to rectangular land surveys as follows:

For well 5/11-28K1, for example, the first part of the symbol indicates the township and range (T. 5 S., R. 11 W., San Bernardino base line and meridian), the digit or two digits following the hyphen indicate the section

In addition to the extensive records just reviewed, many smaller lots of critical analytical data have been contributed to the Geological Survey for study. These include contributions by the Los Angeles Department of Water and Power, the Southern California Water Co., the Corps of Engineers, the Southern California Edison Co., Ltd., and a number of industrial concerns which utilize ground-water supplies. Certain of these data were made available only for purposes of general interpretation, and are not here cited specifically. An unpublished paper by L. J. Alexander on the chemical character of well waters on the coastal plain, was made available to the writers.

(sec. 28), and the letter indicates the 40-acre subdivision of the section as shown on the accompanying diagram.

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

Within each 40-acre tract the wells are numbered serially as indicated by the final digit or digits of the number. Thus, well 28K1 is in the NW¼SE¼ sec. 28, and is the first well in that tract to be listed.

This system of numbers is applied to all parts of the coastal plain. In the small parts of the area that once were public land, the official Federal land survey is followed. In nearly all the remainder of the area, except the extensive Irvine tract, the land once was or still is subdivided according to extensions of the Federal survey, so that the system applies readily. For a few small areas land lines are projected because no rectangular survey has ever existed. In some other areas, as within the city of Long Beach, the projected lines are shifted slightly to coincide with main roads.

The extensive Irvine tract, the easternmost part of the area, is subdivided into blocks, numbered serially from 1 to 185; nearly all these blocks are rectangular and a mile square. For well I–123R1 in this part of the area, for example, the initial letter indicates Irvine tract and the digits following the hyphen indicate the block (no. 123). The remainder of the number indicates the location of the well in projected 40-acre subdivisions of the block corresponding to the 40-acre tracts in the standard section of land.

Representative analyses of the connate waters that have been encountered in drilling for and producing oil from beneath the fresh-water zone in parts of the area have been published by Morse (1943), Jensen (1934), Lahee and Washburne (1934, p. 833) and Grizzle (1923). These data have been extensively supplemented by connate-water analyses made available by several oil companies. In particular, the Union Oil Company and the Tidewater Associated Oil Company granted access to their data files.

The Geological Survey is deeply grateful to the several contributors of these comprehensive and invaluable analytical data. Without them, the broad interpretation of ground-water quality undertaken in this report would have been altogether infeasible.

In connection with its field canvass of water wells in the coastal zone between December 1940 and July 1941, the Geological Survey took an initial water sample from each suitable well. In all, about 900 wells were so sampled, or about half the active or potentially active water wells. So far as possible these samples were taken from the discharge pipes of pumping wells or were dipped from storage tanks into which certain wells were being pumped intermittently. From some wells which had no pumps or whose pumps were inactive, samples were bailed or withdrawn by a portable hand pump from or just below water surface. After this initial examination and into 1943, samples for partial analysis were taken at intervals of about 3 months from 60 to 100 of these water wells to evaluate possible changes in the chemical character of the water; in 1944, additional samples were taken periodically from a few significant wells in Santa Ana Gap. Still other samples were taken at roughly 3-month intervals in 1941 and 1942 from 62 shallow observation wells constructed by the Geological Survey on low land in the coastal zone to tap unconfined water bodies that overlie the confined bodies from which water is withdrawn for use.

Certain wells of special interest have been sampled at other times and by other means. Thus, samples were taken from six deep observation wells drilled by the Geological Survey at places critical to the water-supply problems of the area and from several exploratory wells bored by Los Angeles County on housing-project sites. A number of wells have been sampled at successive depths below the water surface to disclose possible variation in chemical character of the water with increasing depth. A few wells were sampled repeatedly during pumping intervals of several hours duration, until the character of the water discharged became essentially constant; this procedure sought to determine the time-quality relationship existing in those particular wells.

Samples from streams and sloughs were taken periodically in the coastal zone of the area and in the inland zone at points beyond the reach of ocean water with the changes of tide. Because all the streams except the Los Angeles River are intermittent within the area and flow naturally only during infrequent periods of storm run-off, the samples so taken show the general character of industrial wastes and other fluids that are discharged into the stream channels. Several ponds and brine sumps were sampled for analogous reasons.

As of December 1944, the Geological Survey had made 2,306 field analyses of waters in connection with the investigation covered by this report. Of these, 151 analyses were of samples from 41 points on streams and from 29 ponds or sumps; 2,155 were of samples from 965 wells. The analytical data are given in tables 31 to 33. In addition, the Geological Survey has taken samples for comprehensive analysis from 33 wells, from 2 brine sumps, and from the ocean on the offshore side of the San Pedro breakwater; these have been analyzed at the Water Resources laboratories at Washington, D. C., or at Albuquerque, N. Mex., and are incorporated in tables 29 and 30.

RELATIONSHIP BETWEEN CONDUCTIVITY AND DISSOLVED SOLIDS IN WATERS OF THE AREA

In the preceding exposition of the scope of analytical data, and elsewhere in this report, reference is made to the approximate content of dissolved solids in the ground waters as calculated from their electrical conductances by Mendenhall and others (1903–4). Also, certain illustrations and discussions to be introduced will involve corresponding calculations from the field examination of waters during the investigation here reported.

For the data after Mendenhall, there is no published statement of the coefficient used to convert conductivity into content of dissolved solids. The calculated values of the present investigation have been derived according to plate 3 which shows the relationship between conductance and the "sum" of dissolved solids for 25 heretofore unpublished analyses of representative ground waters from the Long Beach-Santa Ana area by the Geological Survey, and for 161 published analyses (California Dept. Public Works, Div. Water Resources Bull., 1933) of ground waters from that area and its vicinity. In this relationship, the "sum" of dissolved solids is slightly less than "total dissolved solids" as would have been determined by chemical analysis because it does not include the relatively small amounts of silica, organic matter, iron, aluminum, some water of crystallization, and other minor dissolved constituents. These minor constituents do affect the conductance but, from the 25 comprehensive analyses by the Geological Survey here involved, they would constitute only a small part of the residue on evaporation, or total dissolved solids. They are here excluded from consideration because they are not reported in the 161 published analyses.

If plate 3 is entered with the measured values of conductance, and if corresponding values for the sum of dissolved constituents are interpolated from the mean curve, the deviation of these interpolated values from the sum as determined from chemical analysis is less than 5 percent for 40 percent of the 186 waters, less than 10 percent for 70 percent of the waters, and greater than 20 percent for only 4 percent of the waters. All the waters whose analyses deviate as much as 20 percent from the mean curve are waters of unusual composition. For conductance values ($K \times 10^6$) less than 2,000, the deviation is less than 10 percent for 90 percent of the waters that fall in that range. Thus, for most natural ground waters of the area, the mean curve shown on plate 3 can be used with fair assurance to interpolate the sum of dissolved constituents from the measured conductance.

The mean curve of plate 3*A* can be expressed precisely by formula (1) and approximately by formula (2) which follow. Plate 3*B* yields values for the mean ratio between conductance and sum of constituents; that is, for the coefficient "C" of formula (2). Thus, either formula can be used in lieu of interpolating from the plate.

$$S = 0.52\ (K \times 10^6)^{1.027} \tag{1}$$

$$S = C\ (K \times 10^6) \tag{2}$$

In these formulas S = sum of dissolved constituents in parts per million; K = specific conductance in mho-centimeters; and C = a coefficient, whose numerical value ranges moderately as shown by plate 3*B*.

REGIONAL BODIES OF GROUND WATER

As explained elsewhere (Poland, Piper, and others), in general there are at least three distinct bodies of ground water in the Long Beach-Santa Ana area. In downward succession these three are: (1) a body of semiperched and essentially unconfined water which occurs in the upper division of the alluvial deposits of Recent age and which is essentially continuous from the ocean through the five gaps between the coastal hills and mesas and far onto the Downey Plain; (2) a principal body of naturally fresh water which is confined over most of the area and which occurs chiefly in the lower division of the alluvial deposits of Recent age, in nearly all the deposits of Pleistocene age, and in certain parts of the underlying Pico formation (upper division); and (3) a body or bodies of saline connate water beneath the principal fresh-water body throughout the area.

The body of semiperched water supplies only a relatively few water wells of small capacity. In the several gaps across the coastal belt of hills and mesas, it occurs only in the upper 20 to 50 ft of the Recent deposits and at many places is separated from the underlying confined-water zone by relatively impermeable beds. As will be explained specifically, the waters of this body range widely in chemical character. Over much of the Downey Plain inland from the Newport-Inglewood zone, they are naturally of the calcium bicarbonate type and suitable for most ordinary uses, but locally are now deteriorated substantially by accumulations of irrigation or industrial wastes. Everywhere between the coast and the general axis of the Newport-Inglewood zone they are naturally of inferior and nonuniform quality; also, in certain districts they have become grossly contaminated by waste fluids from industrial operations. Thus, the semiperched body locally is a potential source from which the underlying principal fresh-water body may become contaminated through wells inadequately cased in the Recent alluvium.

The principal confined body includes the sources for substantially all the large withdrawal of ground water in the area. It occupies (1) the lower division of the alluvial deposits of Recent age, which contain the Gaspur water-bearing zone of the reach from the Whittier Narrows to Terminal Island, the Talbert water-bearing zone of the reach from the Santa Ana Canyon to the Santa Ana Gap, also the so-called 80-foot gravel of Bolsa Gap and its correlative which reaches from the vicinity of Compton inland to the Los Angeles Narrows; (2) all deposits of Pleistocene age, that is, any correlatives of the terrace cover and Palos Verdes sand that may exist beneath the Downey Plain, but chiefly the unnamed upper Pleistocene deposits and the underlying San Pedro formation in all parts of the area except the very highest segments of the Newport-Inglewood zone; and (3) a considerable part of the Pico formation, of upper Pliocene age. The base of this principal water body is as much as 2,600 ft below sea level along the crest of the Newport-Inglewood zone but under the central part of the Downey Plain is as much as 8,000 ft below land surface. Thus, the total volume of materials occupied by the body is very large indeed; only its upper part, to depths as great as 1,655 ft below land surface, has been tapped by water wells and its greater part lies below the depths to which it is now practicable to drill for water.

Over nearly all the area and through their full vertical range the waters of this principal confined body are fresh or essentially fresh, but of several chemical types as will be explained. However, in several local areas along the coast—chiefly in the vicinity of the Palos Verdes Hills, beneath the Long Beach Plain, from Alamitos Gap to Huntington Beach Mesa, and beneath parts of Newport Mesa—the waters of the principal confined body are naturally saline and of connate or diluted-connate origin. Also, in Dominguez and Santa Ana Gaps the native fresh waters of the body have become strongly contaminated with salines during the last several decades. Later sections of this report describe the character of these particular connate waters and of the contaminated waters.

The main body of connate water occurs in rocks of Tertiary age at depth beneath all the area. Its upper boundary is relatively abrupt; electric logs of oil wells and oil-test holes indicate that in much of the area there is substantially no zone of transition from the overlying waters that are essentially fresh, but locally there is a transition zone several hundred feet thick. As a whole the containing rocks are largely impermeable and the connate waters exist in sandy members that are of relatively low permeability, that are separated by impermeable members substantially thicker, and that probably are not in free hydraulic continuity with one another. The salinity of most of these connate waters ranges about from 25 to 100 percent of that of ocean water. They are one among several potential contaminants of the principal fresh-water body, because they are brought to the land surface in large aggregate volume in connection with the extraction of petroleum from the several oil fields along the Newport-Inglewood structural zone.

RANGE IN CHEMICAL CHARACTER OF WATERS FROM WELLS IN THE AREA

As figure 1 shows, the waters from wells in the area have ranged extraordinarily in chemical character. This figure includes one-point plottings of substantially all the analytical data

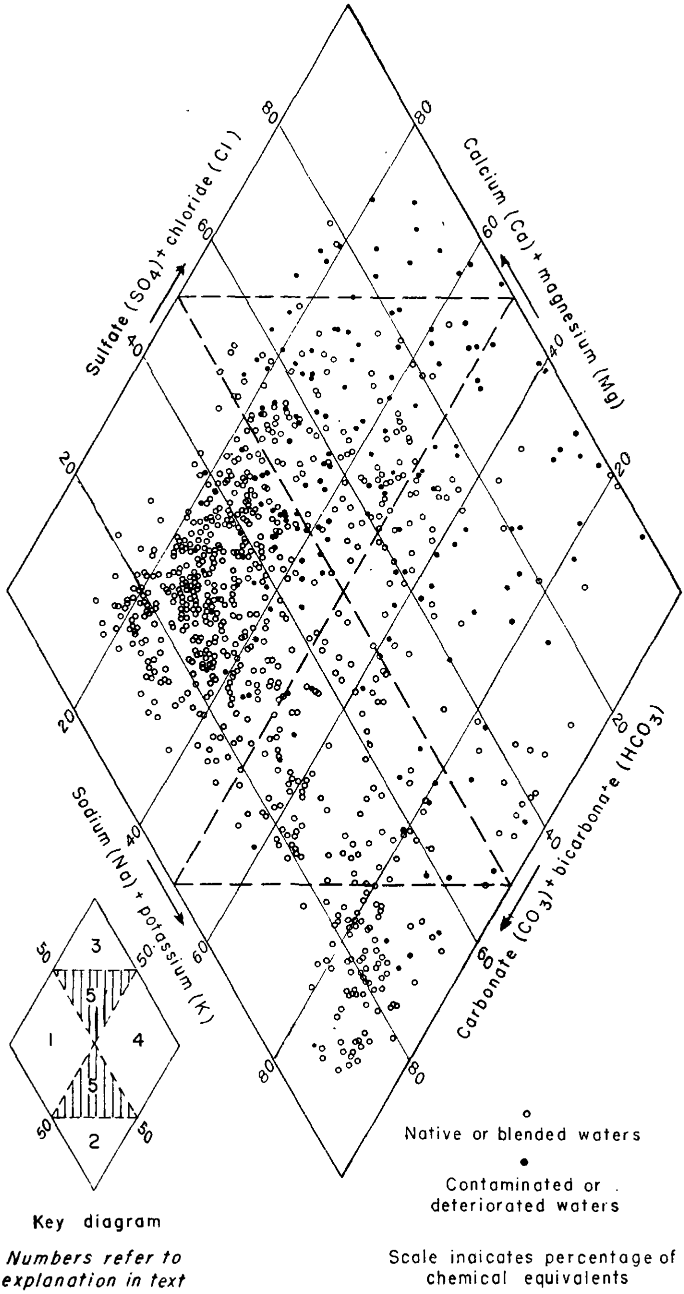


FIGURE 1.—Chemical character of 894 water samples from 735 wells of the Long Beach-Santa Ana area, 1925–43. In the key diagram, area 1 spans the plottings of analyses in which carbonate hardness ("secondary alkalinity") exceeds 50 percent of all the dissolved solids, in terms of chemical equivalents; area 2, those in which carbonate alkali ("primary alkalinity") exceeds 50 percent; area 3 those in which noncarbonate hardness ("secondary salinity") exceeds 50 percent; area 4, those in which noncarbonate alkali ("primary salinity") exceeds 50 percent; area 5, those in which no one of the preceding four characteristics is as much as 50 percent.

available. They include native waters, or those whose chemical character is natural to a particular water-bearing zone and locality; blended waters, or those from wells tapping several zones from which dissimilar native waters are mingled during withdrawal; and contaminated waters, or those whose native character has been modified by the influx, either into the water-bearing zone or into the well, of contaminants derived from sources either outside of or within the body of materials tapped by water wells.

The range in chemical character of these waters is remarkable, considering the relatively small extent of the area. Thus, the plottings of both native waters and contaminated waters are dispersed over nearly all the field of the figure, which represents all possible proportions of the constituents commonly dissolved in natural waters. In certain of the native waters the dissolved constituents are almost wholly calcium and magnesium bicarbonates; these are characterized by "carbonate hardness." From these there are full gradations to soft waters whose dissolved constituents are very largely sodium and bicarbonate, and to waters with large noncarbonate, or "permanent," hardness; also, from hard and soft waters alike there is an incomplete gradation to saline waters whose dissolved constituents are largely sodium, chloride, and sulfate.

In conjunction with plates 1 and 2, the following table 3 affords a perspective of the problems of water quality by showing the general chemical character of native waters, of contaminated or deteriorated waters, and of potential contaminants by geographic subdivisions of the area. As will be shown, these diverse waters can be largely segregated into a few native types, of which each is substantially peculiar to a certain stratigraphic zone and geographic range.

TABLE 3.—*Ranges in general chemical character of native ground waters, contaminated ground waters, and potential contaminants, as of 1940–43*

Class of water and subarea	Chloride (ppm)	Hardness (ppm)	Conductance (K x 10 [6] at 25°C)	Dissolved solids (ppm) [1]
Native ground waters which are widely utilized:				
Coastal zone west of the Santa Ana River	7–35	11–250	270–600	160–350
Inland zone west of the Los Angeles River	20–40	170–285	500–750	300–450
Inland zone between the Los Angeles and Santa Ana Rivers, excluding the alluvial cone of the Santa Ana River above Anaheim	5–35	175–300	350–650	210–375

TABLE 3.—*Ranges in general chemical character of native ground waters, contaminated ground waters, and potential contaminants, as of 1940–43* —Continued

Class of water and subarea	Chloride (ppm)	Hardness (ppm)	Conductance (K x 10[6] at 25°C)	Dissolved solids (ppm)[1]
Alluvial cone of the Santa Ana River above Anaheim and inland zone east of the Santa Ana River, including the Irvine tract	13–400	15–650	350–1,800	215–1,200
Contaminated ground waters (greatest known concentrations):				
Western part of the coastal zone, in the Gaspur water-bearing zone of the Dominguez Gap	4,400	3,300	13,000	8,000
Eastern part of the coastal zone, in the Talbert water-bearing zone of the Santa Ana Gap	5,000	4,500	14,000	8,500
Northern part of Newport Mesa, in certain shallow zones	450	1,500	3,500	2,500
Potential contaminants and potential sources of contamination:				
Ocean water	18,700–19,900	6,000–6,600	45,000–50,000	33,000–35,600
Oil-field brines associated with oil-bearing zones	5,000–23,000	350–5,000	15,000–60,000	9,500–38,600
Modified oil-field brines and refinery wastes[2]	70–100,000	90–24,000	1,000–150,000	580–(?)
Los Angeles River:[3]				
Between Firestone Boulevard and Wardlow Road (nine sampling points)	65–190	300–385	1,100–1,500	600–900
Between Spring Street and Anaheim Street (four sampling points)	500–3,000	300–800	2,000–8,000	1,200–5,000
Dominguez Channel (three sampling points)[4]	150–10,000	225–2,200	1,200–25,000	650–18,000
Unconfined shallow ground-water bodies within the several gaps through the Newport-Inglewood uplift[5]	18–42,000	130–14,500	340–76,000	200–70,000

[1] Estimated in part from relation between specific conductance and "sum" of dissolved constituents.

[2] Waste fluids in undrained or infrequently drained sumps may be intermittently diluted by rain or concentrated by evaporation. In most samples from such sources the chloride content commonly has ranged between 1,000 and 20,000 ppm. The greatest concentration thus far determined—100,000 ppm or nearly 5½ times the concentration of ocean water—results from extreme concentration by evaporation.

[3] Fluid industrial wastes of many kinds enter the river upstream from Wardlow Road; oil-field brines and oil-refinery wastes enter downstream.

[4] Oil-field brines and oil-refinery wastes, with minor industrial wastes, constitute most of flow.

[5] Salinity and general quality of the water range widely from place to place. In general, salinity decreases inland and is greatest in certain tideland areas where the shallow ground water is infrequently replenished from the ocean and is concentrated progressively by evaporation.

CHARACTER, DISTRIBUTION, AND GEOCHEMISTRY OF NATIVE WATERS

ZONES OF WATER QUALITY

Within the deposits tapped by water wells in the Long Beach-Santa Ana area there are eight vertical zones or ranges, tentatively discriminated, which are distinct from one another in the chemical character of their native fresh waters. They are distinct in the sense that at any particular locality the native water of each range shows some characteristic difference in chemical composition from those of other ranges above or below, but not in the sense that the waters of any one range are of uniform composition throughout the area. Between certain ranges the distinction in composition of the waters is striking, but between others it is only slight. Of these eight ranges, the uppermost is that occupied by the body of semiperched and essentially unconfined water described on page 12; seven underlying ranges span the full thickness of the principal confined-water body which sustains the large withdrawals of fresh water.

Of the seven ranges in the principal confined-water body each seems to coincide with a particular stratigraphic range, notwithstanding the fact that the strata are substantially deformed into a relatively broad syncline beneath the Downey and Tustin Plains, and into a somewhat complex pattern of folds and faults within the Newport-Inglewood belt (Poland, Piper, and others).

Under these conditions the depth to any one range varies several hundred feet within the area. In succession downward, the seven ranges of the confined-water body are as follows:

Range 1.—The Gaspur and Talbert water-bearing zones which constitute the lower division of the deposits of Recent age, whose thickness ranges between 40 and 100 ft, and whose bases are from 100 to 150 ft beneath the land surface.

Range 2.—The uppermost Pleistocene deposits (which lie beneath all the Downey and Tustin Plains), to a depth placed somewhat arbitrarily at 200 ft below the land surface.

Range 3.—The main body of the unnamed upper Pleistocene deposits and strata presumably correlative with or in hydraulic continuity with those beds—deposits which together range in thickness from a feather edge in several rather extensive parts of the Newport-Inglewood belt to 1,000 ft or more in the general vicinity of Santa Ana and whose base passes into the overlying 200-ft zone commonly along the flank of the Newport-Inglewood belt but plunges inland to depths inferred to be as much as 1,300 ft below land surface.

Range 4.—A relatively thin but productive water-bearing zone which appears to have hydraulic and lithologic continuity beneath most of the Downey Plain to the west of Huntington Beach and Buena Park, which is roughly from 125 to 1,000 ft below the land surface there, and which locally is correlated specifically with the topmost part of the San Pedro formation.

Range 5.—In the general vicinity of Long Beach and Wilmington, the upper half of two-thirds of the San Pedro formation and of the Silverado water-bearing zone in that formation; also, elsewhere in the area, the range that spans water-bearing zones in apparent hydraulic or lithologic continuity with this upper part of the San Pedro. Even though this so-called San Pedro commonly is 150 to 550 ft thick between the coast and the inland flank of the Newport-Inglewood belt, locally it thins to a feather edge or is absent; its base is 200 to 1,000 ft below land surface. Inland from the crest of the Newport-Inglewood belt the range commonly thickens and its base plunges to depths as great as 1,200 ft below land surface in the vicinity of Buena Park; still farther east its base presumably is even deeper but can not be determined on the basis of information now available.

Range 6.—The remaining lower part of the San Pedro formation, which in the general vicinity of Long Beach and Wilmington includes the lower part of the Silverado water-bearing zone and the underlying basal division of the San Pedro. Data now available do not define the thickness and depth of this range throughout the area; extensively in and near the Newport-Inglewood belt, however, it is about 300 to 750 ft thick and the known depth of its base below land surface is as much as 1,570 ft. Along the crest of the Newport-Inglewood belt its base is ordinarily about 475 to 800 ft below land surface, except that at Signal Hill the depth is as little as 160 ft and that southeast across Newport Mesa the depth diminishes from some 350 ft to a feather edge immediately below the land surface. In the deepest part of the regional syncline that underlies the Downey Plain, about 2 miles south of Buena Park, the depth to the base of the range is inferred to be about 3,300 ft.

Range 7.—The upper division of the Pico formation which, so far as is now known, is tapped by only one producing water well in the area: number 5/11–28K1 in the Bolsa Gap. This lowest range of the seven contains the deepest fresh waters known to exist in the area. Its depth and thickness have been described in the separate report on geologic features (Poland, Piper, and others).

As has been implied, strict correlation between these seven ranges or zones of water quality and the several geologic formations of the area is possible only for the general vicinity of Long Beach and Wilmington, for which comprehensive data on fauna are available. Southeastward into Orange County and throughout the inland half of the area such data are lacking, and of necessity the several zones are discriminated wholly on the basis of hydraulic or lithologic continuity as suggested by data from wells. Thus, for the Long Beach-Santa Ana area as a whole there is some overlap in the stratigraphic limits of the several ranges of water quality as now discriminated. In terms of physical character of their component materials, their thickness and horizontal extent, and their geologic structure the several ranges are described more fully in the separate report just cited.

Plate 4 suggests the relative extent and thicknesses of the several ranges here treated; also, it shows their vertical succession and the general chemical character of their native waters (some blended) and of contaminated waters. The plate includes two vertical sections that extend inland across the area from Terminal Island and from Santa Ana Gap, respectively in the eastern and western parts of the area.

On plate 4 and elsewhere in the report the general chemical character of each water is indicated by a binomial symbol written in the form of a decimal fraction, whose two terms are (1) the percentage of hardness-causing constituents (calcium and magnesium) among the cations (bases) and (2) the percentage of bicarbonate (and carbonate, if present) among the anions (acids). For example, the symbol 64.80 would indicate a water in which calcium and magnesium amount to 64 percent of all the cations, in terms of chemical equivalents; also one in which the weak acids carbonate and bicarbonate amount to 80 percent of all the anions, in like terms. Numerically, the first term of the symbol is the percentage of calcium and magnesium from the following table 4, and the second term is the percentage of carbonate and bicarbonate from that table.

The complement of this binomial symbol indicates the percentage amounts of nonhardness-causing constituents, or "alkalies," among the bases, and of noncarbonate acids. For the example just introduced, the complement is 36.20, which indicates 36 percent sodium and potassium, and 20 percent sulfate and chloride, in chemical equivalents.

This decimal-fraction symbol brings out several characteristics of a water simply but specifically. Thus, the water commonly withdrawn from the shallower wells of the area contains chiefly calcium, magnesium, and bicarbonate; its symbol approaches 100.100 as a limit. For its fairly common opposite from the deeper wells, a sodium bicarbonate water, the symbol approaches 0.100 as a limit. The first term of the symbol indicates relative hardness in percentage of total equivalents. If the second term exceeds the first, all the hardness is carbonate, or temporary, hardness; however, if the second term is smaller, some of the hardness is noncarbonate, or permanent, and the relative amount of noncarbonate hardness is indicated by the numerical difference between the two terms. Also, the first term of the symbol is the percentage complement of the "percent sodium" introduced by Scofield (1933, pp. 22–23) to measure the effect of a water on the physical properties of a soil when applied for irrigation. Thus, if this term is greater than about 50, the physical condition of the soil is not likely to be impaired seriously; but if the term is less than about 40, serious impairment may result.

NATIVE FRESH WATERS OF GOOD CHEMICAL QUALITY

GENERAL CHARACTER OF THE WATERS

Plate 5 shows the chemical character of 30 typical ground waters from the principal confined body, grouped according to the seven stratigraphic ranges or zones previously defined and identified as to geographic location of the source. As this plate suggests, all the native confined fresh waters that underlie the greater part of the Downey Plain (waters from beneath certain marginal areas excluded) are relatively dilute—dissolved solids range from 200 to 500 ppm, on the average diminish with increasing depth below the land surface to a minimum about at middepth in the San Pedro formation, and then increase somewhat in the lower part of the San Pedro and the upper division of the Pico formation. Also, downward into or through the so-called upper San Pedro most native confined waters contain calcium and bicarbonate as their two principal constituents, but at greater depth—in the lower San Pedro and in part of the upper Pico, at least—the native waters contain sodium and bicarbonate almost to the exclusion of other constituents. This is the outstanding contrast in the chemical quality of the waters in the area: those containing calcium as their principal base are relatively hard (generally from 115 to 300 ppm), whereas those in which sodium is the principal base are exceptionally soft (11 to about 100 ppm, but largely no more than 50 ppm).

This striking contrast in chemical character of the confined fresh waters and the smaller contrasts among the seven stratigraphic ranges are explained specifically in following pages, on the basis of analyses from 167 key wells selected from the several thousand analyses available. Each analysis so selected is believed to be essentially typical of the water native to a single stratigraphic zone in the locality of its source; together, these analyses span essentially the full range in chemical character of the fresh ground-water bodies, so far as that character is now known. The chemical character of these 167 selected analyses is shown by the following table 4 in percentage chemical equivalents, and by table 30 in parts per million. The locations of the source wells are shown by plates 6 to 9, inclusive.

TABLE 4.—*Character of representative native fresh ground waters of good quality*

[See table 30 for description of sources and for analytical data in parts per million]

Well number on plate 2	Dissolved solids (ppm)	Cations (percentage equivalents)			Anions (percentage equivalents)			Range of perforations in casing or depth of well (feet below land surface)
		Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3) [1]	Sulfate (SO_4)	Chloride (Cl) [2]	
Waters from the unconfined shallow body								
[Generally semiperched except locally along the inland flank of the coastal plain. Location of sources shown on plate 6]								
2/12-13R1	[3] 272	59.2	22.2	18.6	75.6	15.8	8.6	50
36Q3	[3] 296	55.8	23.0	21.2	72.6	20.6	6.8	48
3/12-30C1	[3] 612	53.4	27.8	18.8	84.4	10.6	5.0	10
33N2	[3] 329	45.2	18.0	36.8	75.2	14.0	10.8	17
4/12-22F1	[3] 298	36.6	18.0	45.4	75.2	12.0	12.8	11
4/13-6J1	[3] 308	51.4	14.8	33.8	63.4	24.8	11.8	95
5/10-9P2	[3] 483	56.0	27.2	16.8	50.0	29.4	20.6	20
5/11-21P2	389	53.0	19.0	28.0	43.0	22.4	34.6	102
Average	373	51.4	21.2	27.4	67.4	18.8	13.8	
Minimum	272	36.6	14.8	16.8	43.0	12.0	5.0	11
Maximum	612	59.2	27.8	45.4	84.4	29.4	34.6	102
Waters from the Gaspur water-bearing zone in the alluvial deposits of Recent age, or range 1, between Whittier Narrows and Dominguez Gap								
[Location of sources shown on plate 6]								
3/12-5G	281	62.2	16.8	21.0	83.8	8.4	7.8	200
10E1	328	58.8	18.0	23.2	77.0	13.0	10.0	79–141
19L1	[3] 255	54.0	18.4	27.6	80.0	12.4	7.6	106–140
3/13-36D1	[3] 404	52.6	13.6	33.8	68.6	19.6	11.8	200
4/13-2P4	[3] 338	52.4	11.4	36.2	61.8	25.6	12.6	161
15A3	[3] 449	50.0	17.0	33.0	53.0	28.6	18.4	100–135
35M3[4]	[3] 318	23.2	15.6	61.2	66.2	14.4	19.4	111–139
Average	343	55.0	15.8	29.2	70.6	18.0	11.4	
Minimum	255	50.0	11.4	21.0	53.0	8.4	7.6	79–141
Maximum	449	62.2	18.4	36.2	83.8	28.6	18.4	200

TABLE 4.—*Character of representative native fresh ground waters of good quality*—Continued

Waters from the Talbert water-bearing zone in the alluvial deposits of Recent age, or range 1, between Santa Ana Canyon and Santa Ana Gap; also from the "80-foot gravel" in the alluvial deposits of Bolsa Gap

[Location of sources shown on plate 6]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
4/10-13C	340	49.8	17.0	33.2	60.4	19.0	20.6	180
28N1	[3] 329	53.4	15.6	31.0	62.0	14.2	23.8	128
31Q1	[3] 353	51.8	19.4	28.8	60.0	20.0	20.0	167
4/11-36R1	[3] 275	55.6	19.2	25.2	73.2	17.0	9.8	94
5/10-7J	344	59.0	10.6	30.4	63.2	20 8	16.0	200
9G1	[3] 301	55.6	17.4	27.0	67.6	18.8	13.6	214
5/10-21P1	[3] 261	49.6	20.8	29.6	73.4	16.4	10.2	110
30Q1	339	55.8	18.0	26.2	66.6	20.6	12.8	85-138
32C1	[3] 326	56.4	17.4	26.2	67.2	18.8	14.0	105
32J2	[3] 275	47.0	21.4	31.6	70.2	20.6	9.2	149-163
5/11-10H1[5]	[3] 268	53.2	19.4	27.4	77.0	14.0	9.0	80
13D1[5]	[3] 280	52.8	19.4	27.8	68.6	21.8	9.6	80
6/10-6B1	274	56.6	16.2	27.2	72.8	18.6	8.6	140
8D2	[3] 260	47.4	10.4	42.2	71.0	18.8	10.2	75-108
18C2	[3] 238	40.4	17.2	42.4	76.0	12.8	11.2	98-143
6/11-12C2	265	48.6	9.6	41.8	78.6	15.4	6.0	161
Average	296	52.0	16.8	31.2	69.2	18.0	12.8	
Minimum	238	40.4	9.6	25.2	60.0	12.8	6.0	80
Maximum	353	59.0	21.4	42.4	78.6	21.8	23.8	214

Waters largely from range 2, the latest Pleistocene deposits not more than about 200 ft below the land surface

[Location of sources shown on plate 7]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
2/11-30N6	[3] 425	54.8	25.0	20.2	66.2	23.6	10.2	100
3/11-5Q	287	32.6	14.0	53.4	63.2	22.4	14.4	144
6D	385	59.6	19.0	21.4	72.0	16.4	11.6	135
28P2	[3] 277	40.4	18.8	40.8	68.8	15.6	15.6	98
30D1	[3] 356	55.6	21.8	22.6	69.6	19.6	10.8	99-131?
31A1	[3] 306	53.4	21.2	25.4	75.8	13.8	10.4	123-176
3/12-12G2	377	57.4	16.8	25.8	74.4	18.4	7.2	40-112
23E1	[3] 376	53.8	24.2	22.0	70.6	15.4	14.0	94-140
29B	248	65.6	16.8	17.6	85.8	9.0	5.2	158
33R	260	66.0	12.6	21.4	88.6	6.8	4.6	250
4/11-13L1	[3] 254	51.2	21.6	27.2	78.2	10.8	11.0	
16E1	[3] 252	40.2	25.6	34.2	78.6	12.6	8.8	84
22H1	[3] 285	48.6	17.2	34.2	72.6	16.4	11.0	198
4/13-12C1	270	45.4	8.6	46.0	71.6	14.4	14.0	138
5/9-8J1	427	52.2	20.0	27.8	53.4	33.4	13.2	200-218
5/10-13B4	[3] 366	53.6	20.6	25.8	59.0	23.6	17.4	100-140
15E1	[3] 350	53.0	18.4	28.6	68.2	18.4	13.4	163
27H	315	54.4	6.6	39.0	68.2	19.8	12.0	180
I-11B1	[3] 454	51.0	23.8	[3] 25.2	49.8	36.6	13.6	200
Average	330	52.0	18.6	29.4	70.4	18.2	11.4	
Minimum	248	32.6	6.6	17.6	49.8	6.8	4.6	84
Maximum	454	66.0	25.6	53.4	88.6	36.6	17.4	250

Waters from range 3, the unnamed upper Pleistocene deposits

[Beyond the vicinity of Long Beach and Wilmington, from water-bearing zones that seem to have essential hydraulic continuity with the unnamed upper Pleistocene. Location of sources shown on plate 8]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
2/12-26R5	[3] 257	51.8	21.0	27.2	76.2	15.4	8.4	233-430
31H1	[3] 283	44.8	18.4	36.8	72.4	12.0	15.6	431-499
33L1	[3] 263	57.2	21.6	21.2	83.4	9.0	7.6	356-390
2/13-25A2	348	49.0	18.2	32.8	61.0	26.6	12.4	220-228
3/9-32J1	482	49.0	13.4	37.6	56.4	16.2	27.4	264
3/11-18G1	[3] 290	60.6	18.0	[3] 21.4	74.2	14.0	11.8	270
26D1	[3] 369	30.8	21.8	47.4	62.4	26.8	10.8	275
32R3	[3] 264	44.4	22.8	32.8	75.0	15.8	9.2	271
35J2	[3] 298	42.8	25.8	31.4	71.4	19.2	9.4	360-380

TABLE 4.—*Character of representative native fresh ground waters of good quality*—Continued

Waters from range 3, the unnamed upper Pleistocene deposits—Continued

[Beyond the vicinity of Long Beach and Wilmington, from water-bearing zones that seem to have essential hydraulic continuity with the unnamed upper Pleistocene. Location of sources shown on plate 8]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
3/12-6N	360	52.4	17.8	29.8	68.4	21.6	10.0	300
9L1	[3] 275	58.8	20.4	20.8	80.0	11.4	8.6	409–491
24G	333	58.8	8.8	32.4	72.6	19.8	7.6	250
36G1	[3] 236	58.0	18.4	23.6	85.4	10.2	4.4	167–224
3/13-20H1	[3] 342	51.6	18.8	29.6	60.4	29.6	10.0	178–195
23A	334	52.4	14.8	32.8	65.0	24.2	10.8	350
4/9-7P1	[3] 372	50.0	16.0	34.0	56.0	22.2	21.8	200–492
17H	455	44.2	22.0	33.8	43.8	26.4	29.8	200
21J1	[3] 504	54.4	20.4	25.2	42.4	36.0	21.6	550
27E1	[3] 368	46.0	23.0	31.0	55.4	31.8	12.8	416–792
30N	412	57.2	16.8	26.0	54.0	17.0	29.0	206
33H1	[3] 479	49.6	26.2	24.2	49.6	39.4	11.0	132–430
4/10-1D1	[3] 430	47.8	18.4	33.8	59.0	17.6	23.4	280–455
6F	305	56.4	18.0	25.6	68.6	21.6	9.8	790
8J1	475	60.8	19.0	20.2	61.4	18.6	20.0	200–312
14H1	353	52.6	12.4	35.0	61.0	18.4	20.6	326–408
23D1	[3] 283	53.2	20.2	26.6	67.4	17.6	15.0	271–401
28D1	354	59.2	18.6	22.2	63.2	20.6	16.2	579
4/11-3P1	[3] 270	51.0	20.2	28.8	72.0	16.8	11.2	195–246
8D1	[3] 264	44.4	18.0	37.6	71.4	8.0	20.6	218–320
19Q1	[3] 257	47.8	22.0	30.2	75.8	16.6	7.6	285
5/9-10D1	470	51.2	21.8	27.0	46.0	27.4	26.6	450
19R1	[3] 429	48.0	24.6	27.4	55.8	34.2	10.0	715
13B3	373	54.0	17.6	28.4	56.8	27.4	15.8	426–487 885–907
18B	269	56.8	17.2	26.0	74.0	17.4	8.6	475
35B	352	51.0	19.8	29.2	58.4	32.0	9.6	336
5/11-13L1	280	57.6	16.0	26.4	71.6	18.8	9.6	280–300
17E2	[3] 263	52.6	22.8	24.6	75.4	15.6	9.0	145–153
45G2	[3] 345	38.6	20.4	[3] 41.0	73.0	15.4	11.6	
86N1	[3] 456	38.8	35.0	[3] 26.2	48.0	30.8	21.2	200–318
Average	347	51.0	19.6	29.4	64.8	21.0	14.2	
Minimum	236	30.8	8.8	20.2	42.4	8.0	4.4	145–153
Maximum	504	60.8	35.0	47.4	85.4	39.4	29.8	426–907

Waters from range 4, the uppermost part of San Pedro formation

[In the absence of comprehensive faunal information, a water-bearing zone that appears to have hydraulic and lithologic continuity extensively across the coastal plain is here taken as the uppermost part of the San Pedro formation. The zone may include some of the lowest members in the unnamed upper Pleistocene deposits. Location of sources shown on plate 8]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
2/12-31M1	362	51.8	17.6	30.6	60.2	27.8	12.0	650
2/13-15N4	[3] 364	49.0	22.6	28.4	59.2	28.8	12.0	531
25H2	348	52.2	16.8	31.0	61.0	26.8	12.2	518–563
3/12-29K	236	49.4	15.8	34.8	84.0	8.6	7.4	650
31E	338	53.0	12.2	34.8	63.2	24.4	12.4	348
36B	240	63.8	18.2	18.0	78.4	14.4	7.2	945
3/13-34D2	[3] 301	45.2	16.0	38.8	59.6	24.6	15.8	374
4/11-1P1	300	61.8	19.0	19.2	70.0	19.2	10.8	544
14K	340	55.4	17.4	27.2	66.6	22.2	11.2	575
24Q1	361	56.2	17.2	26.6	65.2	20.0	14.8	545–599
28J1	271	54.0	16.4	29.6	77.6	14.8	7.6	435–530
29L2	378	54.4	19.4	[3] 26.2	77.0	15.6	7.4	382–398
35Q	294	58.6	13.4	28.0	72.8	17.8	9.4	550
4/12-1D	237	68.6	14.0	17.4	87.6	8.2	4.2	1,023
4J	253	63.8	16.6	19.6	86.8	7.2	6.0	300
13G1	235	62.8	9.8	27.4	89.6	6.6	3.8	140–165 512–540
14C1	283	59.4	11.4	[3] 29.2	84.0	8.6	7.4	240–300
15D1	215	45.8	6.6	47.6	84.8	7.2	8.0	256–270
24M1	228	57.2	15.8	27.0	85.2	7.4	7.4	300–318
5/11-21Q3	[3] 239	45.4	19.4	35.2	75.2	14.6	10.2	180
23A1	[3] 256	52.6	20.2	27.2	71.6	17.6	10.8	208–258
26H1	239	54.0	9.6	36.4	76.8	17.8	5.4	400
6/11-1C1	[3] 250	47.0	20.6	32.4	75.4	14.2	10.4	130–182
Average	285	54.8	16.0	29.2	74.6	16.2	9.2	
Minimum	215	45.2	6.6	17.4	59.2	6.6	3.8	130–182
Maximum	378	68.6	22.6	47.6	89.6	28.8	15.8	1,023

TABLE 4.—*Character of representative native fresh ground waters of good quality*—Continued

Waters from range 5, the uppermost part of San Pedro formation, inland and eastward beyond the Silverado zone

[In this table the correlations with the upper and lower parts of the San Pedro formation are only relative; because comprehensive faunal data are lacking, they are based to a large extent on the apparent lithologic or hydraulic continuity of certain water-bearing zones.

[Location of sources shown on plate 9]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
2/12-19C	367	47.6	19.4	33.0	59.2	24.8	16.0	680
3/11-20D	227	60.2	18.0	21.8	82.8	12.2	5.0	775
34P	283	53.4	17.4	29.2	73.0	16.0	11.0	1,200
3/12-3M1	[3] 268	56.8	20.4	22.8	81.2	10.6	8.2	608
8F1	298	61.8	18.8	[3] 19.4	78.0	11.4	10.6	578–628
33H1	240	54.6	15.2	30.2	83.2	9.6	7.2	778–874
3/13-2B1	454	54.0	18.4	27.6	57.2	29.6	13.2	732
22H3	[3] 297	46.8	19.2	34.0	68.0	21.8	10.2	669–688
4/11-2K	319	48.4	20.8	30.8	68.8	22.4	8.8	1,100
8E2	315	42.0	10.8	47.2	68.2	22.0	9.8	223–237 540–618
10E1	[3] 294	42.2	24.2	33.6	69.0	20.2	10.8	553–731
5/10-16J	248	50.8	13.4	35.8	72.6	18.6	8.8	900
25A4	224	21.2	5.6	73.2	61.2	26.0	12.8	957
26D2	[3] 266	43.8	21.2	35.0	70.8	20.8	8.4	800
5/11-4A1	275	53.4	15.6	31.0	74.8	17.0	8.2	830–913
9G1	304	55.4	13.6	31.0	71.6	19.2	9.2	900
14C2	251	59.2	13.4	27.4	80.2	12.6	7.2	600–700
6/10-8G1	[3] 304	4.4	5.8	89.8	76.0	7.8	16.2	169–286
Average [6]	294	52.0	17.4	30.6	72.4	18.0	9.6	----------
Minimum[6]	227	42.0	10.8	19.4	57.2	9.6	5.0	223–618
Maximum[6]	454	61.8	24.2	47.2	83.2	29.6	16.0	1,200

Waters from range 5, the upper part of the Silverado water-bearing zone in the San Pedro formation

[Includes a few waters from just beyond the Silverado zone to the east, but similar in character to those from the zone itself. Location of sources shown on plate 9]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
3/12-31E3	328	51.6	7.4	41.0	74.6	10.8	14.6	705–907
4/11-19K2	258	41.6	9.6	48.8	76.8	16.6	6.6	417–432
4/12-21M3	209	33.4	6.8	59.8	77.6	8.6	13.8	420
25H1	277	46.8	15.0	38.2	73.0	18.6	8.4	396–496
27K1	[3] 173	45.2	11.0	43.8	82.4	13.4	4.2	228–237
4/13-1F1	316	30.8	4.2	[3] 65.0	58.6	25.2	16.2	385–439
15A2	[3] 208	23.8	13.8	62.4	76.6	5.2	18.2	830–980
15B3	[3] 229	39.6	20.0	[3] 40.4	71.6	10.0	18.4	760–780
19J2	[3] 224	26.8	18.6	54.6	82.8	1.0	16.2	325
22E1	221	26.4	11.2	62.4	81.2	1.6	17.2	415–645
5/12-1D	261	37.8	10.2	52.0	75.2	17.4	7.4	440
Average	246	36.8	11.6	51.6	75.6	11.6	12.8	--------------
Minimum	173	23.8	4.2	38.2	58.6	1.0	4.2	228–237
Maximum	328	51.6	20.0	65.0	82.8	25.2	18.4	830–980

Waters from range 6, the lower part of San Pedro formation, beyond the Silverado water-bearing zone

[Location of sources shown on plate 9]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
2/13-27B11	[3] 334	48.8	22.8	28.4	61.8	27.6	10.6	928–1,600
3/11-6P2	[3] 461	13.6	10.4	76.0	70.0	3.2	26.8	653–670
17B	235	30.6	2.4	67.0	59.4	13.6	27.0	964
26B1	385	13.0	1.6	85.4	59.0	22.8	18.2	695–715
29A	214	24.2	15.0	60.8	71.8	3.2	25.0	1,200
3/12-8F1	339	47.2	11.4	[3] 41.4	62.0	21.0	17.0	920–998 1,416–1,492
5/10-23L1	[3] 213	7.0	4.4	88.6	75.6	14.8	9.6	1,350

TABLE 4.—*Character of representative native fresh ground waters of good quality*—Continued

Waters from range 6, the lower part of San Pedro formation, beyond the Silverado water-bearing zone—Continued

[Location of sources shown on plate 9]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
5/11-18R1	218	9.4	1.6	89.0	81.8	8.0	10.2	895
21Q1	[3] 210	9.2	5.0	85.8	84.4	4.8	10.8	537
26P1	254	8.4	1.2	90.4	91.0	----------	9.0	510
28K1	[3] 352	5.8	6.8	87.4	92.4	0	7.6	293-396
29C1	198	12.6	3.0	84.4	83.4	5.0	11.6	333-416
5/12-12Q	214	8.8	1.4	89.8	89.0	2.8	8.2	600
6/10-3H2	250	7.8	1.2	91.0	88.0	1.2	10.8	637
6/11-1N1	[3] 297	11.8	6.2	82.0	92.0	0	8.0	600
I-6G1	[3] 422	3.2	5.2	[3] 91.6	85.8	5.8	8.4	420-570
Average [7]	280	11.8	4.6	83.6	80.2	6.2	13.6	------------
Minimum [7]	198	3.2	1.2	60.8	59.0	0	7.6	293-396
Maximum [7]	461	30.6	15.0	91.6	92.4	22.8	27.0	1,350

Waters from range 6, the lower part of the Silverado water-bearing zone

[Location of sources shown on plate 9]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
4/12-8L	244	9.0	3.8	87.2	79.6	----------	20.4	------------
15B1	243	7.8	.8	[3] 91.4	76.8	0.8	22.4	952-1,010
17N1	270	11.8	2.0	[3] 86.2	72.6	8.4	19.0	395-570
34B1	[3] 189	11.2	6.0	82.8	79.2	7.2	13.6	400-422
4/13-23G2	[3] 207	17.0	.0	83.0	80.2	.0	19.8	[8] 984
33D1	[3] 344	15.8	1.4	[3] 82.8	60.4	19.4	20.2	720-800
5/11-6A1	200	10.4	3.2	86.4	79.8	12.0	8.2	818-975
Average	242	11.8	2.4	85.8	75.6	6.8	17.6	------------
Minimum	189	7.8	.0	82.8	60.4	.0	8.2	395-570
Maximum	344	17.0	6.0	91.4	80.2	19.4	22.4	952-1,010

Waters from range 6, the basal part of the San Pedro formation, beneath the Silverado water-bearing zone in the southwestern part of the area

[Location of sources shown on plate 9]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
4/12-6K1	271	13.4	1.2	85.4	79.0	0.4	20.6	972-1,142
14D1	302	5.8	.6	93.6	75.6	.4	24.0	1,361-1,655
14P1	275	4.4	.8	94.8	83.4	2.4	14.2	1,024-1,354
21M2	248	8.0	1.8	90.2	84.2	.6	15.2	725-962
28H1	260	8.8	1.8	89.4	83.8	1.8	14.4	768-1,148
Average	271	8.0	1.2	90.8	81.2	1.2	17.6	------------
Minimum	248	4.4	.6	85.4	75.6	.4	14.2	725-962
Maximum	302	13.4	1.8	94.8	84.2	2.4	24.0	1,361-1,655

Waters from range 7, the upper division of the Pico formation

[Location of sources shown on plate 9]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
4/11-19R1	[3] 223	6.8	0.0	[3] 93.2	78.2	11.2	10.6	3,275-3,286
5/11-23P	316	4.2	1.0	94.8	91.0	1.0	8.0	2,900
5/13-3H	750	7.6	3.4	[3] 89.0	68.0	.8	31.2	1,300

[1] Includes carbonate (CO_3) and borate (BO_3) if present.

[2] Includes fluoride (F) and nitrate (NO_3) if present.

[3] Calculated.

[4] Analysis of January 28, 1923: approximately of native character (?). Data excluded from average and extremes.

[5] From "80-foot gravel."

[6] Analyses 5/10-25A4 and 6/10-8G1 excluded.

[7] Analyses 2/13-27B11 and 3/12-8F1 excluded.

[8] Formational sample obtained while drilling, at depth indicated.

UNCONFINED WATERS

The native unconfined waters in the area, which occur at and just below the water table, generally are fresh and of good chemical quality only beneath the inland part of the Downey Plain. There, these particular waters contain from 275 to 500 ppm of dissolved solids; in general, their concentration increases southward, that is, toward the coast or in the direction of ground-water movement. Along the inland flank of the plain they are characteristically calcium bicarbonate waters [1] (table 4 and pl. 6, wells 2/12–13R1 and 36Q3), but toward the coast they gain gradually in sodium and in chloride or sulfate and locally some pass into calcium sodium bicarbonate waters (well 3/12–38N2). These are the waters believed to be derived by local infiltration of rain or by seepage from streams, and that circulate more or less freely from the inland margin of the Downey Plain toward the coast. In and beyond the central part of the Downey Plain they pass, probably fingerwise, into waters of inferior quality that are described in another section of this report.

CONFINED WATERS

WATERS IN RANGE 1 (GASPUR AND TALBERT WATER-BEARING ZONES)

The Gaspur and Talbert water-bearing zones and other segments in the lower division of the alluvial deposits of Recent age (Poland, Piper, and others), function as regional ground-water arteries extending to the coast from Whittier Narrows and Santa Ana Canyon (see pl. 6). Coastward from their inland forebay areas and beginning about 4 miles downstream from Whittier Narrows and in the vicinity of Anaheim and Orange their waters are rather effectively confined, sustain a large part of the withdrawals for irrigation and other rural uses, and by inference are the principal sources of recharge to underlying confined-water zones with which either of the two is in contact. Thus, as is brought out later, the chemical character of the waters native to the Gaspur and Talbert zones influences the character of the waters native to the underlying and enclosing deposits to depths locally as great as 1,000 ft beneath the land surface.

From their respective forebay areas about to the inland flank of the hills and mesas of the Newport-Inglewood belt (see pl. 6),

[1] In this report, terms describing the general chemical character of a water are used in particular senses, as in the following examples: (1) "calcium bicarbonate" designates a water in which calcium amounts to 50 percent or more of the bases and bicarbonate to 50 percent or more of the acids, in chemical equivalents; (2) "sodium calcium bicarbonate" designates a water in which sodium and calcium are first and second, respectively, in order of abundance among the bases but neither amounts to 50 percent of all the bases; and (3) "sodium sulfate bicarbonate" designates a water in which sulfate and bicarbonate are first and second in order of abundance among the acids, as above.

the native waters of the Gaspur and Talbert zones range from 250 to 350 ppm in dissolved solids, and from 175 to 225 ppm in hardness. All are calcium bicarbonate waters essentially identical in chemical character with the shallow waters of the unconfined forebay area from which, presumably, they are derived. They move toward the coast so freely that they neither gain nor lose dissolved matter to any great extent, and consequently the chemical character of the native water in either zone does not range widely. In this inland part of the area, the consequential differences in chemical character are that the water of the Gaspur contains relatively more bicarbonate (see pl. 5, analyses 3/12–10E1 and 4/10–28N1) and perhaps is somewhat less concentrated on the average. Thus, the water of the Gaspur has only carbonate hardness, whereas that of the Talbert has some noncarbonate hardness at most places. This distinction applies to waters of underlying zones; that is, only carbonate hardness within the reach from the forebay area of the Gaspur about to the Newport-Inglewood belt, but a small proportion of noncarbonate hardness within the corresponding reach below the forebay area of the Talbert.

These calcium bicarbonate waters of the Gaspur and Talbert zones are among those classified by Morse (1943, p. 497) as "normal calcium carbonate water of the artesian strain." That of the Talbert zone is the source of "white" water in Orange County (so-called from its contrast with the colored "amber" water from certain underlying sources, as described on page 39.

Within their reaches across the Newport-Inglewood belt and onward to the coast, that is, within the Dominguez and Santa Ana Gaps, the native waters of both the Gaspur zone and the Talbert zone undergo substantial changes in chemical character (see pl. 6 and table 4). Thus, within and near the Dominguez Gap, the native waters of the Gaspur commonly gain from 25 to 40 percent in dissolved solids, so that concentrations increase to a maximum of 450 ppm; in order of decreasing amounts, the gain is largely in sulfate, sodium, chloride, and calcium (pl. 5, analysis 4/13–15A3). Hardness increases as much as a third, and as much as 25 percent of the hardness is noncarbonate. From data not here introduced, it is concluded that these changes in the character of the native Gaspur water within Dominguez Gap largely are caused by moderately concentrated and relatively hard water that is native to and enters the Gaspur from its arm which extends generally northward from Compton into the Los Angeles Narrows.

One well which taps the Gaspur zone about a mile inland from the coast—4/13-35M3, in the southern part of the Dominguez Gap—apparently yielded in 1923 sodium bicarbonate water with 318 ppm of dissolved solids and 113 parts of hardness. This water of 1923 may have been of a character locally native to the Gaspur, but data to confirm this tentative conclusion are not available.

Changes in the chemical character of the water native to the Talbert zone within the Santa Ana Gap are largely the opposite of those within the Dominguez Gap. Thus, within 2½ miles of the coast, the native water of the Talbert is of the calcium sodium bicarbonate type with dissolved solids about 250 ppm and hardness about 140 ppm. Analyses 6/10-8D2, -18C2, and 6/11-12C2 are typical (pls. 5 and 6 and table 4). In comparison with those farther inland, these native waters in the coastal part of the Talbert are somewhat less concentrated, are decidedly softer, and have no noncarbonate hardness. In terms of percentage chemical equivalents, magnesium and calcium are less but sodium is commensurately greater; and chloride is less but bicarbonate is more. It is inferred that these changes in chemical character are induced largely by an influx of water from underlying Pleistocene deposits with which the Talbert zone, at least locally, is in hydraulic continuity.

Within the Dominguez and Santa Ana Gaps, the waters in the Gaspur and Talbert zones are (1945) extensively and grossly contaminated. The present character and origin of these contaminated waters is described on pages 92 and 167.

WATERS IN RANGE 2 (UPPERMOST PLEISTOCENE DEPOSITS)

The confined-water zone here called range 2, with its base arbitrarily placed 200 ft below the land surface, probably occurs in part within the upper division of the Recent deposits but largely within undivided upper Pleistocene deposits. In general it does not yield water freely and so has been tapped extensively by wells only when a small supply is adequate and where the Gaspur and Talbert water-bearing zones do not exist, that is, within the central half of the Downey Plain and in outlying areas to the northwest and southeast. The distribution of representative wells on plate 7 is typical. However, range 2 extends continuously beneath the Gaspur and Talbert alike, where it is from 50 to 100 ft thick and is tapped by a few wells.

The native waters of range 2 are rather diverse in character, but the fragmentary data available suggest in that diversity an areal pattern which is repeated in underlying zones to a depth as great as 1,000 ft below the land surface. That pattern is discussed on pages 30–31.

For a distance of perhaps 1 or 2 miles beyond the Gaspur and Talbert water-bearing zones (and presumably beneath those two zones) calcium bicarbonate waters quite like those of the Gaspur and Talbert seem to be native in range 2 (uppermost Pleistocene deposits) across much of the main part of the Downey Plain. Analyses 3/12–29B, 5/10–15E1, and 5/10–27H are typical (see pls. 5 and 7). Presumably these particular waters have been derived from the forebay areas of the Gaspur and Talbert zones by percolation from those zones into the uppermost Pleistocene deposits. They would fall largely into Morse's (1943, pp. 497–499) "normal calcium carbonate water of the artesian strain."

Between the two presumed lobes of calcium bicarbonate water whose existence has just been implied, the native waters of range 2 appear to pass irregularly from rather hard and concentrated calcium bicarbonate water or from relatively soft sodium bicarbonate water along the inland edge of the Downey Plain (analyses 2/11–30N6 and 3/11–5Q, respectively) into moderately soft calcium sodium bicarbonate waters beyond the central part of the plain (analyses 4/11–22H1 and 4/13–12C1). The hard inland water contains from 400 to 500 ppm of dissolved solids and has a hardness of 250 to 300 ppm, including from 50 to 75 of noncarbonate hardness. In comparison with waters native to range 1 (the Gaspur and Talbert zones), it contains from 40 to 60 percent more dissolved solids and is about 50 percent harder. Presumably its dissolved constituents have been derived from the enclosing deposits, and its concentration remains high because the deposits are not highly permeable and are not in free communication with the Gaspur zone or the Talbert zone. This hard inland water includes a part of that which Morse designates as "normal calcium carbonate water of the nonartesian strain." The soft inland water of well 3/11–5Q is believed to be characteristic of its depth zone in the western part of the Coyote Hills uplift. According to Morse, this would be of the "modified sodium carbonate water of the nonartesian strain." The calcium sodium bicarbonate waters that are native in range 2 from the central part of the Downey Plain toward the coast contain from 250 to 300 ppm of dissolved solids and from 125 to 200 ppm of hardness, of which all is carbonate hardness. In comparison with native waters of range 1 (the Gaspur and Talbert zones), these contain from 15 to 25 percent less dissolved solids and from 15 to 40 percent less hardness. Presumably their chemical character results in part from natural softening.

In the outlying northwestern and southeastern parts of the area, the native waters of range 2 are diverse in character and commonly are of inferior chemical quality (see pp. 54–55).

WATERS IN RANGE 3 (MAIN PART OF THE UNNAMED UPPER PLEISTOCENE DEPOSITS)

Although diverse, the chemical character of the waters native to range 3 (the main body of the unnamed upper Pleistocene deposits) seems to fall into an areal pattern which also persists in certain underlying zones and whose existence in the overlying zone has been inferred. The principal elements of the general pattern seem to be as follows:

1. In Los Angeles County, a lobe of calcium bicarbonate water which reaches toward the coast from Whittier Narrows, which underlies the Gaspur water-bearing zone of the Recent deposits, but which extends considerably beyond either margin of that zone (at least beneath the inland half of the Downey Plain). Also, in Orange County, another but corresponding lobe of calcium bicarbonate water which underlies the Talbert water-bearing zone of the Recent deposits. According to the classification of Morse, the waters of these two lobes would fall largely into "normal calcium carbonate water of the artesian strain."
2. Between the two lobes of calcium bicarbonate water and roughly beneath Coyote Creek, a corridor within which sodium calcium and calcium sodium bicarbonate waters grade one into the other. Also, beyond the western lobe and in the extreme northwestern part of the area, waters of similar composition. In the classification of Morse, the softer of these waters would be of the "modified sodium carbonate water of the nonartesian strain."
3. Beyond the two lobes just described and toward the coast, a belt within which there is a gradation from calcium bicarbonate water toward or into sodium bicarbonate water. Here the sodium bicarbonate water would fall into Morse's "modified sodium carbonate water of the artesian strain."
4. In Orange County, from the lobe of calcium bicarbonate water northward into the Coyote Hills, a marginal belt whose native waters commonly contain both sodium and sulfate as prominent secondary constituents and are inferred to be of inferior quality extensively.
5. Also in Orange County, beneath much of the Tustin Plain and extending eastward to the flank of the Santa Ana Mountains, another marginal belt containing native waters which also are diverse, which at one place or another contain sodium, magnesium,

sulfate, or chloride in relative abundance, and which locally are of inferior quality (see p. 55).

The native waters of the two marginal belts just described are among those which Morse groups as "normal calcium carbonate water of the nonartesian strain."

Not all these elements of the general pattern are shown by the analytical data now available on waters native to range 3. Some are deduced from data on waters native to ranges 2 and 4. However, the composite pattern is here advanced tentatively as the basis for subsequent discussions of the origin and geochemistry of waters in the several ranges that together span the Pleistocene deposits.

In their lobe in Los Angeles County the calcium bicarbonate waters native to range 3 contain from 225 to 350 ppm of dissolved solids and from 150 to 200 ppm of hardness, which ordinarily is wholly carbonate hardness. In chemical composition all are very nearly like the native waters of the overlying Gaspur zone. Typical analytical data are those for wells 2/12–26R5 and 3/13–23A (pl. 5, tables 4 and 30). So far as is indicated by data now available, this lobe reaches from Whittier Narrows southwestward and southward at least to the latitude of Compton or somewhat beyond (pl. 8, wells 3/13–20H1 and 3/12–36G1). In Orange County the waters of the corresponding lobe contain about 15 percent more dissolved solids, are about 10 percent harder on the average, and nearly all have some noncarbonate hardness. Those beneath the inland half of the Downey Plain are very similar in composition to the native waters of the overlying Talbert zone. Typical analytical data are those for wells 4/9–7P1 and 5/11–17E2 (pl. 5). The lobe seemingly reaches from the Santa Ana Canyon westward at least to well 4/10–8J1, southwestward to well 5/11–17E2, and southward through well 4/9–30N at least to well 5/10–35B (see pl. 8). It affords part of the so-called white or relatively hard, uncolored water of Orange County.

Presumably these native calcium bicarbonate waters are of meteoric origin and are moving rather uniformly toward the coast from inland areas of replenishment. Tentatively it is inferred that they have been derived largely from the two regional ground-water arteries, that is, from the Gaspur and Talbert zones and ultimately from the forebay areas of those two zones.

In the corridor between these two lobes of calcium bicarbonate water in range 3—a corridor which is some 4 miles wide, lies about half in Los Angeles County and half in Orange County, and extends from the Coyote Hills southwestward about to Los Alamitos—native sodium calcium bicarbonate waters occur to the northeast, at least in part (well 3/11–26D1), but pass southwestward into calcium sodium bicarbonate waters (wells 3/11–32R3 and 4/11–19Q1). Presumably this corridor occupies a belt of impeded ground-water circulation, whose waters are derived at least in part from the Coyote Hills and are beyond the effective reach of any percolate from either the Gaspur zone or the Talbert zone. In the extreme northwestern part of the area, in the vicinity of Huntington Park and about midway between the Whittier Narrows and the Los Angeles Narrows, waters of this character again occur in range 3. Data for well 2/13–25A2 are typical. These waters probably are derived in part from the rocks of the Repetto Hills and La Merced Hills.

In the marginal areas in Orange County, that is, beneath the flank of the Coyote Hills and for 1 or 2 miles southward onto the Downey Plain, also beneath the greater part of the Tustin Plain, constituents derived from the older rocks of the adjacent foothills and highlands dominate the chemical character of waters locally native to range 3 (the unnamed upper Pleistocene deposits). North of Santa Ana the constituents so derived are largely sodium and sulfate; locally in the vicinities of Santa Ana and Irvine to the south, the constituents from adjacent older rocks are sodium and chloride. Thus, beneath these marginal parts of the area the native waters of range 3 are diverse in concentration and composition, and extensively are somewhat inferior in chemical quality. Those of usable quality include calcium bicarbonate sulfate water (analysis 4/9–21J1); calcium magnesium bicarbonate sulfate water (analysis I–86N1); and calcium sodium bicarbonate water (analyses 3/9–32J1 and 4/9–27E1). Presumably these intervene between the lobe of calcium bicarbonate water already described and the more concentrated waters of inferior quality that locally are fairly extensive beneath the margin of the Downey Plain. However, available data are not competent to indicate whether usable waters occur as fingers between bodies of inferior water on either side or whether they exist generally at some particular stratigraphic zone.

WATERS IN RANGE 4 (UPPERMOST PART OF THE SAN PEDRO FORMATION)

As here defined, range 4 is a relatively thin but productive water-bearing zone that appears to have hydraulic and lithologic continuity extensively across the coastal plain in Los Angeles County and eastward into Orange County about to the boundary between Rs. 10 and 11 W. In Dominguez Hill and other parts of the Newport-Inglewood belt in Los Angeles County, faunal information identifies this range strictly with the topmost part of the San Pedro formation. Farther inland, however, faunal information is not available and for that part of the area the range is ascribed to the topmost San Pedro wholly for convenience in description.

The analytical data available for the native waters of this range conform to the general areal pattern of water quality previously set forth, although they are too fragmentary to establish the pattern by themselves. Thus, in a presumed lobe of calcium bicarbonate waters in Los Angeles County, dissolved solids range from 350 to 225 ppm and in general decrease toward the coast; also, hardness ranges from 225 to 150 ppm, decreases coastward, and ordinarily is wholly of the bicarbonate type. In comparison with calcium bicarbonate waters of overlying range 3 (unnamed upper Pleistocene deposits) and range 1 (Gaspur water-bearing zone), these differ chiefly in containing slightly less dissolved solids on the average. The coastward reach of these waters is rather sharply defined and extends beyond that known for the overlying range 3. Thus, they extend to well 3/12–31E and to wells 4/12–4J and –24M1, but not to well 4/12–15D1. Plates 5 and 8 and tables 4 and 30 cover representative analytical data.

In Orange County only the western and southern fringes of the lobe of calcium bicarbonate waters are covered by available data—the reach is to wells 4/11–1P1, –29L2, and 5/11–23A1, but not to wells 5/11–21Q3 and –26H1. Here the waters contain from 375 to 250 ppm of dissolved solids; their hardness is from 150 to 225 ppm as in Los Angeles County, but characteristically and commonly is noncarbonate hardness in small part.

Toward the coast, the native calcium bicarbonate waters of range 4 (the topmost San Pedro) pass fingerwise into calcium sodium bicarbonate or sodium calcium bicarbonate waters. These are the least concentrated and the softest waters of this particular stratigraphic zone. An extreme is the water of well 4/12–15D1, with 215 ppm of dissolved solids and 98 parts of carbonate hardness. Water from well 6/11–1C1 is typical. These waters presumably have resulted from partial natural softening of calcium bicarbonate waters such as exist farther inland, a process explained more fully under the following description of native fresh waters in range 5.

WATERS IN RANGE 5 (UPPER PART OF THE SAN PEDRO FORMATION)

Calcium bicarbonate waters in Los Angeles County.—In the stratigraphic range herein designated for convenience as range 5 (the upper part of the San Pedro formation), the areal pattern of water quality and the geochemical relations between the several elements of that pattern are shown more clearly by available data than are those of any other water-quality range of the area. Thus, the inferred lobe of calcium bicarbonate waters in Los Angeles County reaches nearly as far and locally farther from Whittier Narrows than in the overlying two ranges—specifically, about to well 3/12–31E3 near Compton and to well 3/11–34P near Buena Park (pl. 9). In this lobe the waters range from 325 to 225 ppm of dissolved solids and from 200 to 150 ppm of hardness; both total solids and hardness seem to decrease radially from Whittier Narrows. Analysis for well 3/12–8F1 on plate 5 is typical. Here the lobe occurs on the north flank and along the axis of a broad syncline that plunges gradually southeastward; thus, in wells in T. 3 S., Rs. 11 to 13 W. it is commonly tapped between 500 and 1,000 ft beneath the land surface. Northeastward toward the Whittier Narrows and beneath the flank of the Coyote Hills the lobe presumably occurs at less depth.

Calcium bicarbonate waters in Orange County.—In Orange County, native calcium bicarbonate waters in range 5 have been tapped by a few wells west of Santa Ana, as in Nos. 5/11–4A1, –9G1, and –14C2. There the zone yielding these waters is from 600 to 900 ft beneath the land surface, and near midheight on the south flank of the regional syncline that underlies the Downey Plain. To the north and east this water-yielding zone is below the reach of existing water wells, so that data about its extent and depth are lacking. However, from the areal pattern of water quality in overlying ranges it would seem that a lobe of calcium bicarbonate waters extends westward and southwestward from the Santa Ana Canyon, with an outer margin about 4 miles east of Coyote Creek, from 3 to 8 miles inland from the coast, and roughly along the eastern edge of the Downey Plain from Santa Ana northward.

Waters of intermediate composition.—Between and beyond these two lobes (in a corridor that extends southwestward from Buena Park to Los Alamitos in the extreme northwestern part of the area, also in a frontal belt that reaches about to the inland flank of the hills and mesas of the Newport-Inglewood zone from Dominguez Hill southeastward at least to the vicinity of Landing Hill) the native calcium bicarbonate waters pass into calcium sodium bicarbonate or sodium calcium bicarbonate waters. Typical analytical data are those for wells 2/12–19C near Huntington Park, 3/13–22H3 near Compton, 4/11–2K and –10E1 near Buena

Park, and 4/12–27K1 near the inland flank of the Signal Hill uplift. Dissolved solids are from 375 to 175 ppm; hardness is between 200 and 85 ppm, decreases toward the coast, and is wholly of the bicarbonate variety except in the marginal area near Huntington Park.

In the corridor that extends southwestward from near Buena Park, these particular native waters are from 1,000 to 400 ft beneath the land surface, the depths to the principal water-yielding zones decreasing toward Los Alamitos. In the frontal belt, which lies on the south flank of the regional syncline and spans some of the intensely deformed elements of the Newport-Inglewood structural zone, the depths to principal aquifers vary rather widely and seemingly are erratic. For example, in well 3/13–22H3 near Compton, the principal aquifer is about 675 ft beneath the land surface; in well 3/12–31E3 at the head of the Dominguez Gap, about 700 to 900 ft; and in well 4/12–27K1 on the flank of the Signal Hill uplift, about 225 ft.

Southeastward in Orange County beyond Landing Hill, calcium sodium bicarbonate water is known to occur in range 5 only in the vicinity of well 5/10–26D2, which is about midway between the Santa Ana River and the western margin of the Tustin Plain. There, the aquifers known to contain this native water are roughly from 800 to 1,000 ft below land surface. Elsewhere across the front of the presumed lobe of calcium bicarbonate waters in Orange County, the upper San Pedro probably is not continuous and an unbroken frontal belt of calcium sodium bicarbonate waters in range 5 is not known to exist.

Sodium bicarbonate waters in Los Angeles County.—The calcium bicarbonate and calcium sodium bicarbonate waters described in the preceding paragraphs occupy a stratigraphic range which seems to be in hydraulic and lithologic continuity with the upper half or upper two-thirds of the Silverado water-bearing zone in the San Pedro formation, whose extent as now known is shown on plate 9 and whose physical character and geologic structure have been described in the separate report on geologic features of the area, previously cited. Within most of its reach in Los Angeles County—specifically, in all except its northern fringe that lies inland beyond the hills of the Newport-Inglewood belt, and except for local bodies of connate water described in another part of this report—this upper part of the Silverado water-bearing zone is characterized by sodium bicarbonate water. The content of dissolved solids ranges from 325 to 200 ppm; hardness, which is wholly bicarbonate hardness, ranges from 65 to 100 ppm. Between these general limits, the character of the water seems to vary according to both depth within the Silverado zone and distance from the inland edge of the zone. Typical analytical data are those for wells 4/13–1F1 and –22E1, 4/12–21M3, and 5/12–1D (see pls. 4, 5, and 9; tables 4 and 30). As here treated, the upper part of the Silverado zone generally is not more than about 250 ft thick but, according to geologic structure, its top is as little as 200 ft below land surface on the flanks of the Dominguez anticline and of the Signal Hill uplift but is as much as 750 ft below land surface in the syncline to the southeast, as in well 4/13–15A2.

Sodium bicarbonate water in Orange County.—In range 5 of Orange County, native sodium bicarbonate water exists locally beneath the northeastern part of the Santa Ana Gap, as in well 6/10–8G1 between 169 and 268 ft beneath the land surface, but within a mile or two to the east and to the south the same stratigraphic range includes chloride waters of connate origin, which will be described. Several miles to the northeast, well 5/10–25A4 encountered native sodium bicarbonate water presumably, at least in part, from range 5. Waters of this character are quite likely to be or to have been native in the particular stratigraphic range within a mile or two of the coast elsewhere in Orange County, although there is no information to confirm this.

Geochemical relations.—Throughout range 5 there appears to be substantial hydraulic continuity (1) beneath all the Downey Plain and probably a considerable part of the Tustin Plain; (2) beneath the hills and mesas of the Newport-Inglewood belt, except the highest parts of Dominguez Hill and of Signal Hill where the range is above water level, also the southern part of Newport Mesa where the Pleistocene wedges out by overlap on impermeable Miocene rocks; and (3) rather extensively beyond the Downey Plain to the north, beneath the frontal aprons and southern flanks of the Repetto, Puente, and Coyote Hills. From the coast inland to the present crest of the Newport-Inglewood zone and from 1 to 5 miles beyond, the strata of this range were deposited in successive shallow-marine, littoral, and beach environments. In much of that coastal part of the area, therefore, the strata were saturated first with ocean water. Still farther inland, to and beyond the present Repetto and Puente Hills, the strata of the San Pedro were deposited on an extensive coastal plain in successive lagoonal and river-flood-plain environments. Only in that inland part of the area could the strata of range 5 have been saturated first with fresh water derived from the land.

However, as just shown, the native waters of range 5 currently vary from the calcium bicarbonate type in certain inland lobes to the sodium bicarbonate type along the coast. As to the origin of these native waters, it is concluded that: (1) the saline connate water initially in the coastal part of the area was displaced by fresh water from the land, and was not removed by progressive dilution; (2) this displacement had been largely accomplished before the latest substantial deformation in the Newport-Inglewood zone in post-Palos Verdes time, and so before present "barrier" features had been developed; (3) by reaction with base-exchange media in the water-bearing materials, the sodium bicarbonate water now native has been produced by natural softening of the land-derived water (presumably a calcium bicarbonate water) by which the saline connate water was displaced; and (4) the sodium bicarbonate water is currently in chemical equilibrium with its containing materials, whose capacity for softening by base exchange cannot have been exhausted.

In this report it is concluded further that the waters native to range 5 are generally in continuous movement across the area toward the coast, and specifically that:

1. The two inland lobes of calcium bicarbonate water occupy the reaches into which—probably in relatively late geologic time and currently from the two forebay areas below the Whittier Narrows and the Santa Ana Canyon—water derived from the land has moved in sufficient volume to have exhausted the softening capacity of any base-exchange media.

2. In the belt that intervenes between these two lobes, in the area to the northwest near Huntington Park, and possibly elsewhere beneath the inland margin of the Downey and Tustin Plains the calcium sodium bicarbonate waters currently native are beyond the reach of the most vigorous ground-water movement at this time, probably once were much more extensive in the inland part of the area, and probably are somewhat similar in composition to the waters which first displaced saline connate water from the area of marine environment in San Pedro time.

3. The frontal belt of waters of intermediate composition occupies the reach into which land-derived water recently has moved only in such volume that the base-exchange media still may retain some small residual capacity for softening.

4. The coastal belt of sodium bicarbonate waters has not yet been reached by a substantial volume of land-derived water during the present hydrologic cycle, and those waters are a residual part of the waters formerly softened by base exchange and not

yet displaced from the area. On plate 5, analysis 3/12–8F1 would be typical of the unsoftened land-derived water, 4/11–2K of waters in the corridor not being flushed by land-derived water, 5/10–16J of slightly softened waters along the margins of the two calcium bicarbonate lobes, and 4/13–22E1 of substantially softened water.

These theoretical considerations lead to the conclusions that under natural conditions the two lobes of calcium bicarbonate water would extend themselves toward the coast and toward one another, and that the sodium bicarbonate waters would be displaced farther and farther toward the coast. Under the artificial condition of heavy withdrawal from range 5, especially from the upper part of the Silverado water-bearing zone in the southwestern part of the area, coastward displacement of the sodium bicarbonate water would be accelerated. Thus, both the natural and artificial trends are toward increasing hardness of the waters near the coast, although this change doubtless is very slow in terms of years and, as shown by the composition of the water withdrawn from an individual well, probably would be appreciable only over several years or several tens of years.

WATERS IN RANGE 6 (LOWER PART OF THE SAN PEDRO FORMATION)

Throughout that part of the area in which water wells reach range 6 (the lower part of the San Pedro formation or its approximate equivalent), that is, extensively in Los Angeles County, but in Orange County only from 4 to 8 miles inland from the coast (see pl. 9), the native fresh waters of that stratigraphic range differ strongly in composition from those of range 5 or of any overlying range. Characteristically they contain relatively much more sodium and, on the average, a little more bicarbonate; hence they are very soft. Native calcium bicarbonate waters are unknown; calcium sodium bicarbonate waters are known only from the northwestern part of the area (well 2/13–27B11 and the deeper zone reached by well 3/12–8F1, table 4 and pl. 9). There, these waters of intermediate composition may occupy a lobe that reaches from the Whittier Narrows to and somewhat beyond the junction of the Rio Hondo with the Los Angeles River, but that is much less extensive than the overlying lobe of calcium bicarbonate waters in range 5 (the upper San Pedro). Elsewhere in those parts of the area for which analytical data are available, range 6 contains only sodium bicarbonate waters, except certain local bodies of saline connate water. (See pp. 57–59.)

Among the native sodium bicarbonate waters of range 6 in Los Angeles County, concentrations range from 450 to 200 ppm of dissolved solids, and hardness from 190 to 15 parts. Characteristically, these sodium bicarbonate waters have a slight or distinct "amber" coloration, seemingly due to a small content of organic matter in colloidal suspension. They constitute Morse's "modified sodium carbonate water of the artesian strain" (1943, pp. 497–498). In general both the concentration and hardness of these waters decrease toward the coast, though somewhat erratically. Beneath the hills of the Newport-Inglewood belt and onward to the coast, that is, in the lower part of the Silverado water-bearing zone, dissolved solids are from 350 to 190 ppm, and hardness from 35 to 15 ppm (see pl. 5, analysis 4/12–15B1). Wells reach these waters from 650 to 1,200 ft beneath the land surface along and near the flank of the Coyote Hills, and from 400 to 1,000 ft beneath the land surface within the area of the Silverado zone.

In a local area immediately north of Signal Hill, a few wells draw water from a basal part of the San Pedro formation that underlies the Silverado water-bearing zone and that is from 725 to 1,655 ft beneath the land surface (table 4, pl. 9). All these yield sodium bicarbonate (amber) water with dissolved solids from 250 to 300 ppm and hardness from 10 to 30 ppm. This water is essentially identical in composition with the least concentrated and softest of the waters native to the Silverado water-bearing zone. Analyses 4/12–6K1 and –14P1 are representative (pl. 5 and table 4). The extent of sodium bicarbonate waters in this particular stratigraphic range is not known beyond the small local area.

Eastward into Orange County, sodium bicarbonate waters in range 6 are known within a belt extending about 4 miles inland from the coast and from Landing Hill to and across Huntington Beach Mesa. Characteristically, these waters of Orange County have an "amber" coloration, analogous to that of waters from the same stratigraphic range in Los Angeles County. Dissolved solids are from 200 to 400 ppm and hardness from 20 to 50 ppm. Wells tap the zone from 300 to 900 ft below land surface. Southeastward along the coast, across the Santa Ana Gap and onto the southern part of Newport Mesa, the so-called lower San Pedro wedges out and range 6 is not known to be tapped by water wells. To the northeast, however, it again yields sodium bicarbonate water from beneath the northernmost part of Newport Mesa and for at least 3 miles northward toward Santa Ana.

In this local area dissolved solids range from 200 to 425 ppm and hardness from 20 to 35 ppm; both seem to decrease away from the San Joaquin Hills. Well depths are from 400 to 1,350 ft and increase northward. Data for wells 5/10–23L1, 6/10–3H2, and I–6G1 are typical.

As has been stated, the soft, sodium bicarbonate waters here described and less characteristically those in range 5 previously described, are faintly or distinctly colored "amber" or "red", seemingly because of a small content of organic matter in colloidal suspension. It is presumed that this organic matter is derived from peat or carbonaceous substances in the parts of the San Pedro formation deposited in a lagoonal environment. Also, because this organic coloration is an almost invariable characteristic of those natural sodium bicarbonate waters whose hardness is less than about 50 ppm, it is suggested that such peat or carbonaceous substances may contain the base-exchange media of the highest potential for natural softening of any waters they contact.

The authors consider the waters of range 6 (lower San Pedro) to be analogous in origin and geochemistry to those of range 5 (upper San Pedro). If this is correct, it may be concluded that in late geologic time little or no land-derived water has reached or now is reaching range 6 from the two forebay areas below the Whittier Narrows and the Santa Ana Canyon. Also, that ground-water movement is much less vigorous than in range 5, and that little or none of the water first softened by base exchange has been displaced from the area. In other words, the areal water-quality pattern so strikingly developed in the overlying ranges extends downward only through range 5.

WATERS IN RANGE 7 (UPPER DIVISION OF THE PICO FORMATION)

Three wells have afforded analytical data on the chemical character of native water in range 7 (the upper division of the Pico formation) at widely separated places in the coastal half of the area. These are well 5/13–3H just east of Terminal Island, well 4/11–19R1 near Los Alamitos and about 5 miles from the coast and opposite Alamitos Gap, and well 5/11–23P at the northwest tip of Huntington Beach Mesa. Analytical data are given in tables 4 and 30, and locations are shown on plate 9. (See pl. 5 also.) Wells 19R1 and 23P tap sodium bicarbonate water in the upper Pico, very similar in chemical composition to that of range 6. The well near Terminal Island also taps sodium bicarbonate water but, among the native fresh waters of the area, it is relatively high in dissolved solids (750 parts) and in choloride (130 parts).

The data here summarized suggest that range 7, at depths greater than are now commonly reached by water wells, contains water of a chemical quality suited to many ordinary uses. At least some of the water seems not to be inferior to that which is now withdrawn from the deepest public-supply wells of the area.

BLENDED WATERS FROM WELLS

Many of the water wells in the area have casings perforated opposite two or more water-bearing zones, or have gravel envelopes surrounding the full length of their casings. A well of either of these types effectively taps all the water bodies penetrated and, when pumped, commonly blends the different chemical characters of those bodies. Thus, if the well has been pumped at a constant rate for a considerable time the several waters tend to blend in a fixed proportion, which depends largely on the physical characteristics of the several water-bearing materials and on the relative reductions in their pressure heads by pumping. If the static heads differ considerably, the proportions of blending and the chemical character of the blend may change appreciably with every change in the rate of withdrawal.

If the pump in such a well is shut down and stands idle for a time, water from the zone of greatest head circulates through the well into the zone or zones of lesser heads. Thus, the water in the bore of a well may become distinctly stratified in chemical character. When pumping is resumed, the first water discharged is that which was trapped in the pump column and is like that being discharged when pumping was stopped. As pumping is continued, the next water to be discharged is usually of a character peculiar to one or another of the permeable zones tapped, depending on the position of the pump intake in relation to the pattern of water stratification in the bore of the well. This water may or may not be from the zone of greatest head. Then, when pumping is continued still longer, water from the zone of greatest head which has accumulated in zones of lesser head is gradually withdrawn, and the well discharges a blend of relatively stable proportions drawn from all the zones supplying the well.

A striking example of variation in the chemical character of water withdrawn from a well whose casing is perforated in more than one water-bearing zone is afforded by the analytical record for public-supply well 4/12–20C1 (city of Long Beach, Development well 3), which is shown graphically by figure 2 and which is summarized in table 30. This well is 752 ft deep and its casing is perforated in three water-bearing zones—from 153 to 190 ft below the land surface, probably in the topmost part of the San Pedro formation (range 4); from 286 to 300 and from 315 to 330 ft, in the upper part of the Silverado water-bearing zone of the San Pedro formation (range 5); and from 390 to 602 ft, in the central and lower parts of the Silverado zone (ranges 5 and 6). These three water-bearing zones contain native waters of distinctive chemical quality—representative

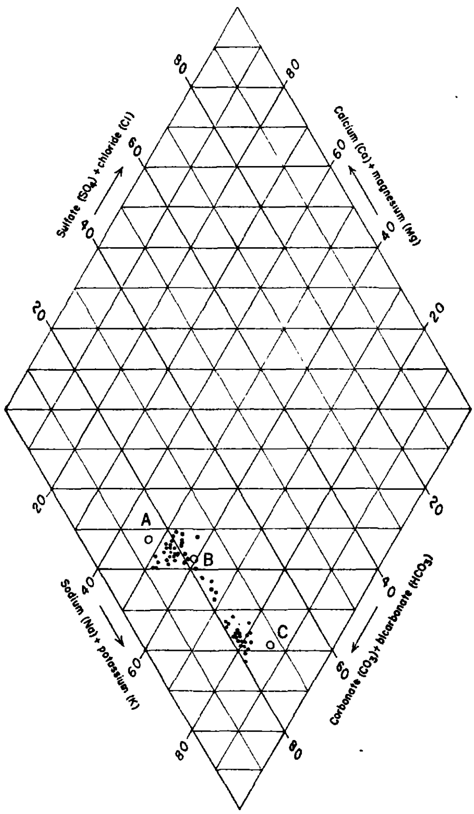


FIGURE 2.—Analyses of 82 samples from well 4/12–20C1 (city of Long Beach, Development well 3) in 1932–43, in relation to native waters in its vicinity. A, Native water from uppermost part of San Pedro formation, in well 4/12–15D1, range 4; B, native water from upper part of Silverado water-bearing zone in San Pedro formation, in well 4/12–21M3 range 5; C, native water from lower part of Silverado zone, in well 4/12–17N1, range 6. (After analyses by city of Long Beach, Chemical and Physical Testing Laboratory.)

analyses of the vicinity are for wells 4/12–15D1 for the topmost San Pedro, 4/12–21M3 for the upper part of the Silverado zone, and 4/12–17N1 for the lower part of the Silverado zone (see fig. 2, also tables 4 and 30).

Figure 3 shows changes in the chemical character of the water drawn from this well in September 1943, after its pump had been shut down throughout August. As the figure shows, both the chemical character and the temperature continued to change throughout the 9-hr interval of pumping on September 1, and had become only approximately stable when the pump was shut down over night; also, hardness changed substantially between September 7 and 13.

These data indicate that: the very first water discharged after the shut-down was approximately of the character native in the zone of the shallowest perforations, or in the topmost San Pedro; the character of the water discharged from the fifth to the twentieth minute of elapsed pumping time was very near that of the analyses which on figure 2 plot high and to the left, and that water was substantially a blend of waters native to the topmost San Pedro and to the upper part of the Silverado water-bearing zone; and the chemical character of the water discharged after intermittent pumping for 13 days was about that of water native to the lower part of the Silverado zone, and very nearly that of the analyses which on figure 2 plot low and to the right. In other words, although the well has 76 percent of its perforated casing in the middle and lower parts of the Silverado zone, the soft water native to that zone was not dominant in the discharge until after some 60 to 80 hr of pumping. Under such conditions, a single random sample could be a most misleading indicator of the chemical character of the water native in the principal zone tapped by the well.

Obviously, the significance of the analysis of a single sample of well water depends to a considerable degree on the antecedent pumping, and because pumping history commonly is not known, much of the analytical information available for the Long Beach-Santa Ana area is useless for determining the chemical character of native waters. Especially so are the data from the coastal half of the area in which wells of moderate depth may pass through several of the water-quality ranges.

Although the foregoing example of variable chemical character involved only native fresh waters all of good but of different qualities, its principles apply equally to wells in which one of the waters is an invading contaminant. Thus, if a well passes

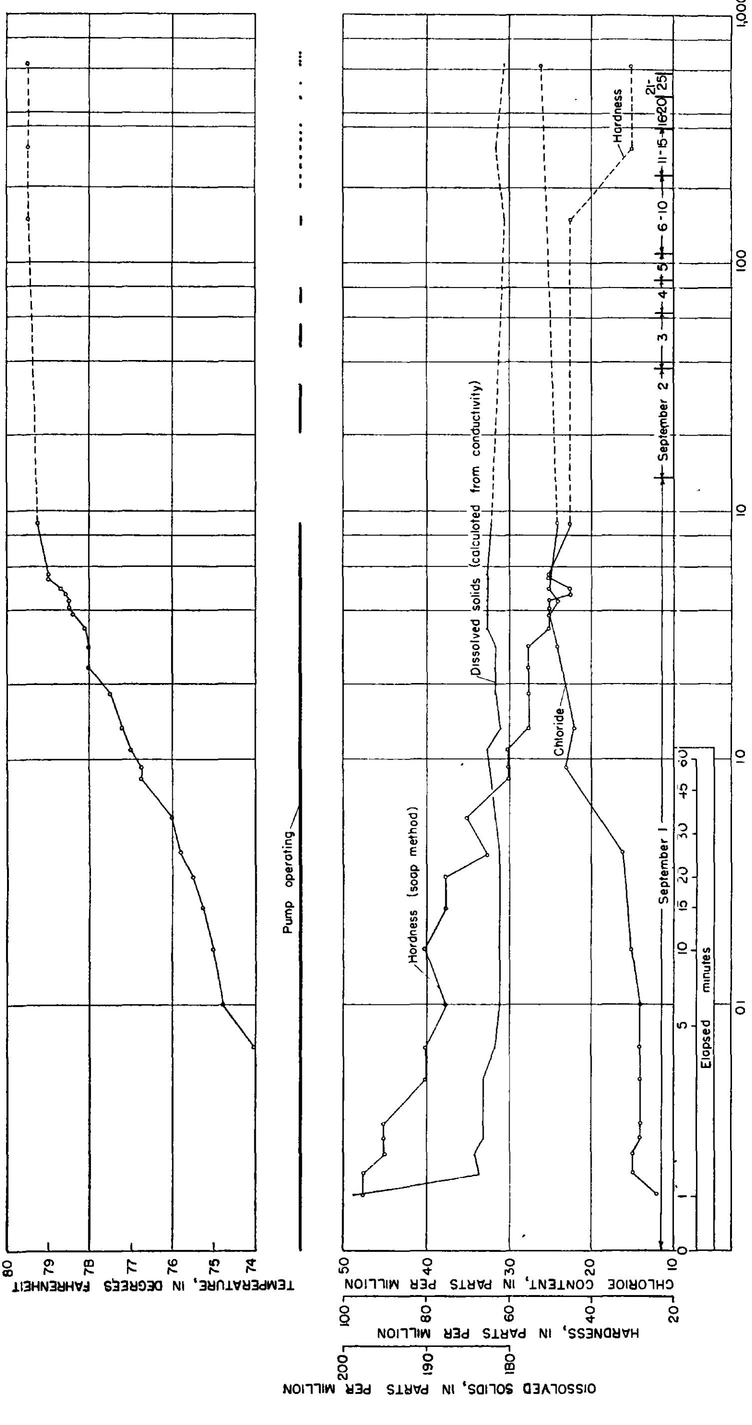


FIGURE 3.—Chemical character of water from well 4/12-20C1 (city of Long Beach, Development well 3) in relation to duration of pumping, September 1–27, 1943.

through a zone of contaminated water and its casing there is defective, or if one or more of its water-yielding zones is contaminated close at hand, the chemical character of the water discharged under intermittent pumping can vary widely and even obscurely. Examples of this sort are given in the subsequent discussion of contaminated waters.

PROGRESSIVE CHANGES IN CHARACTER OF WELL EFFLUENT, OWING TO MIGRATION OF WATERS BEYOND THEIR NATIVE ZONES

The analytical record for public-supply well 4/12–21M2 (city of Long Beach, Citizens well 7) illustrates a seemingly anomalous range in the chemical quality of its effluent—anomalous because under the most continuous and heaviest draft the quality of the effluent has been unlike that native to the stratigraphic range of its perforated casing. It is concluded (reasons will be given later) that this range in quality results from the migration of a substantial quantity of water beyond its native zone of occurrence.

This well is 1,105 ft deep and its casing is perforated discontinuously from 725 to 962 ft below the land surface, or wholly in the basal division of the San Pedro formation (lower part of range 6). Its yield is about 1,200 gpm.

The wide range in chemical quality of the effluent for more than a decade is shown by figure 4, which includes the plottings of 109 periodic analyses between 1932 and 1943. Relatively few of these analyses plot close to the character of the extremely soft water locally native to the basal division of the San Pedro formation, in which alone the casing of the well is perforated (see fig. 4, analysis 4/12–14P1). Rather, half the available analyses plot in a concentrated group whose position is intermediate between the plottings of native waters from the upper part of the Silverado water-bearing zone in the San Pedro formation (range 5), from the lower part of the Silverado zone (range 6), and from the basal division of the San Pedro (also range 6). About a third of the analyses are of relatively hard waters whose plottings on figure 4 are dispersed and vary upward nearly to those of waters native in the upper part of the Silverado zone. Regarding this wide variation in chemical character of the effluent from well 4/12–21M2 it is pertinent that:

1. All samples of the relatively hard water—that which is of diverse chemical character and whose analyses plot high on figure 4—have been taken in the first few minutes of pumping after relatively long periods of shut-down, throughout the life of the well. It is concluded that such water has accumulated

intermittently owing to small leakage through the casing or by downward percolation outside the casing, that it has been quickly discharged with each resumption of draft, and that its quality is not of consequence to the problem here treated.

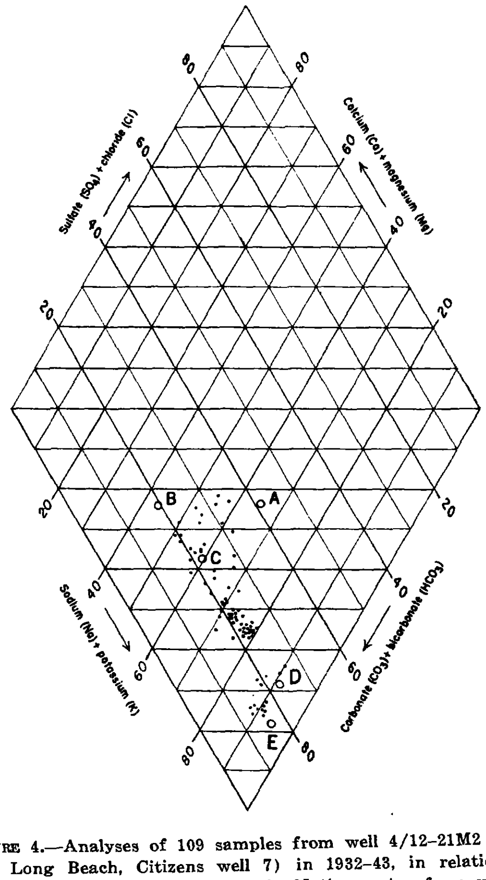


FIGURE 4.—Analyses of 109 samples from well 4/12–21M2 (city of Long Beach, Citizens well 7) in 1932–43, in relation to native waters of its vicinity. A, Native water from uppermost part of Silverado water-bearing zone in San Pedro formation, in well 4/13–1F1, range 5; B, C, native water from upper part of Silverado zone, in wells 4/12–27K1 and 4/12–21M3, respectively, range 5; D, native water from lower part of Silverado zone, in well 4/12–15B1, range 6; E, native water from basal division of the San Pedro formation, in well 4/12–14P1, range 6. After analyses by city of Long Beach Chemical and Physical Testing Laboratory.)

2. All samples of the extremely soft water—that which is similar in character to the water native in the basal division of the San Pedro and whose analyses plot lowest on figure 4—have been taken during withdrawals of several hours duration, presumably after the quality of the effluent had become about stable.

Of these, all were taken before late 1936 and all except two were taken before mid-1934. Adjacent wells 4/12–17Q1 and –20G1 to the west (city of Long Beach, Development wells 4 and 5, respectively) are analogous to 21M2 in that each commonly yielded extremely soft water before mid-1934 but not subsequently. Each of these wells has perforated casing both in the basal division and in the overlying Silverado water-bearing zone of the San Pedro formation. Adjacent wells 4/12–28H1 and –28H6 (city of Long Beach, Alamitos wells 9 and 8, respectively) are somewhat analogous to 21M2 in that each generally yielded the extremely soft water through 1934 and after 1939 or 1940, but during the interim commonly yielded substantially harder water. Of these two wells, 28H1 has perforated casing only in the basal San Pedro and 28H6 both in the basal division and in the overlying Silverado zone.

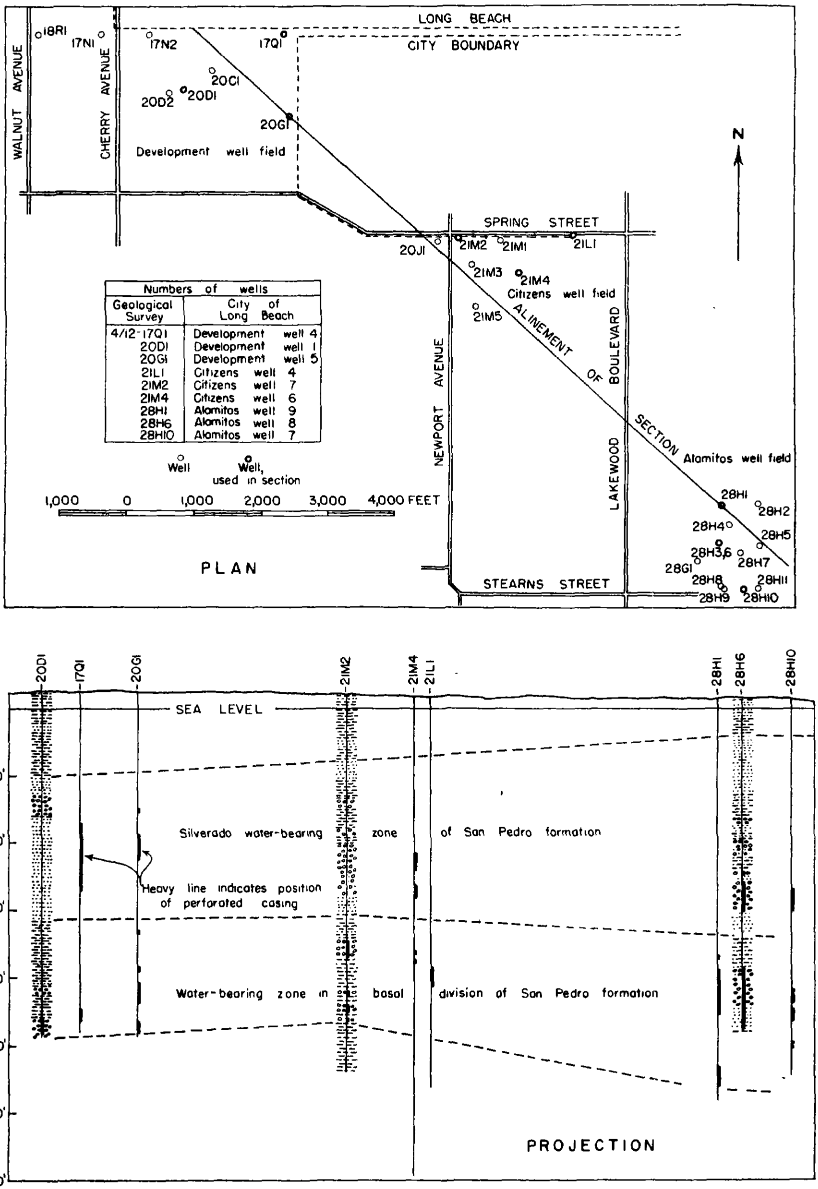
3. Among the samples of the water of intermediate hardness—those whose plottings concentrate in a small dense group in the center of the field on figure 4—all but one have been taken after 1936, nearly all have been taken during prolonged withdrawals, and many have been taken after weeks or even months of essentially continuous draft. Presumably, therefore, of all the 109 samples plotted on figure 4 these most reliably indicate the mean chemical character of the water body or bodies tributary to the well. Their chemical composition is that of a blend of about equal portions of waters native to the basal San Pedro, to the lower part of the Silverado zone, and to the upper part of that zone, that is, of waters native to ranges 6 and 5. Because withdrawal is at the rate of about 1,200 gpm, blending within the well in the proportions just indicated would require some 300 gpm from the basal San Pedro, 300 gpm from the lower part of the Silverado zone, and 600 gpm from the upper part of the Silverado zone. However, as has been stated, the well casing is perforated only in the basal San Pedro, and the casing is not gravel-packed. Under these conditions, it is believed that neither leakage through defective casing nor downward percolation outside the casing is at all adequate to explain the seeming blend, and it is concluded that probably after mid-1934 and certainly after 1936 the basal San Pedro at and near well 21M2 has been occupied by nonnative water of intermediate hardness.

Regarding this implied migration of water beyond its native zone, it is further pertinent that:

4. Before 1932 the basal San Pedro had been tapped only by nine public-supply wells among those of the Development, Citi-

zens, and Alamitos fields at Long Beach (see fig. 5); also, the yearly draft from all nine wells had been relatively light.

5. Between 1932 and 1934, three additional public-supply wells were drilled by the city of Long Beach to tap only the basal San



Numbers of wells	
Geological Survey	City of Long Beach
4/12-17Q1	Development well 4
20D1	Development well 1
20G1	Development well 5
21L1	Citizens well 4
21M2	Citizens well 7
21M4	Citizens well 6
28H1	Alamitos well 9
28H6	Alamitos well 8
28H10	Alamitos well 7

FIGURE 5.—Plan and section of the Development, Citizens, and Alamitos well fields at Long Beach, showing water-bearing zones and vertical range of perforated casing in wells that reach the basal division of the San Pedro formation.

Pedro—North Long Beach well 4 (4/12–6K1), about 4 miles north-northwest from the Citizens field; also Commission well 1 and the Wilson Ranch well (4/12–14D1 and –14P1, respectively), about 2½ miles east-northeast of the Citizens field.

6. Beginning in 1934, the total yearly withdrawal from the wells that tap the basal San Pedro has ranged from 5,650 to 11,000 acre-ft and under this very heavy draft the head on the water in the basal San Pedro has been as much as 2C ft below that of the water in the Silverado zone above. Under this differential head, every well with casing perforated both in the Silverado water-bearing zone and the basal division of the San Pedro formation would become a potential conduit for the movement of water downward into the basal San Pedro. Such conduits were afforded potentially by only five of the nine wells shown on figure 5.

7. Even under the heavy draft since 1934, outlying wells 4/12–6K1, –14D1, and –14P1 have yielded only the extremely soft water that has been described as native in range 6 (the basal San Pedro), but neither these nor any adjacent wells have casings perforated both in the basal San Pedro and in the Silverado.

From the conditions here set forth, it is concluded that since 1934 a very substantial volume of water has moved downward from the Silverado zone into the basal division of the San Pedro in the vicinity of the Development, Citizens, and Alamitos well fields; also, that this movement has taken place through the five deep wells with multiple zones of perforations, in response to the differential head created by heavy withdrawal from the basal San Pedro. This migration of water beyond its native zone has effected artificial replenishment of the native water body in the basal San Pedro.

Elsewhere in the area other fresh waters doubtless have migrated beyond their native zones in and near fields of closely spaced wells that have casings diversely perforated through successive water-bearing zones of high transmissibility, and that have been pumped heavily. Although conclusive analytical data seem not to be available, conditions favorable to such migration exist in well fields like that of the Dominguez Water Corporation in the Dominguez Gap northwest of Long Beach (wells 4/13–15A2, –15A5, –15A6, –15A7, –15A8, –15A11, –15B3, and –15B4). In such a field, substantial changes in the chemical character of the water withdrawn may take place over a term of years, in seeming variance from the native character of the water body or bodies tapped.

NATIVE WATERS OF INFERIOR CHEMICAL QUALITY

Although the native ground waters of the area are commonly of good chemical quality, native waters of inferior quality occur extensively in the unconfined body and locally beneath marginal parts of the area in the principal confined body. These waters of inferior quality are those which contain more than about 600 ppm of dissolved solids. In the unconfined body they are highly diverse in chemical character, but those of poorest quality are sodium chloride waters whose content of dissolved solids varies to a known maximum of 57,300 ppm, or about 160 percent of ocean-water concentration. In the principal confined body they include waters high in sulfate content and of diverse character at the inland margins of the Downey Plain, and saline waters of moderate to high concentration along the coast and locally in the vicinities of the Palos Verdes Hills and of Newport Mesa. Table 5 and plate 10 show the character of typical inferior waters.

TABLE 5.—*Character of representative native waters of inferior quality in the deposits commonly penetrated by water wells*

[See table 30 for description of sources and for analytical data in parts per million. See plates 6, 7, 8, and 9 for location of sources]

Well number on plate 2	Dissolved solids (ppm)	Cations (percentage equivalents)			Anions (percentage equivalents)			Range of perforations in casing or depth of well (feet below land surface)
		Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3) [1]	Sulfate (SO_4)	Chloride (Cl) [2]	
Waters from the unconfined shallow body								
4/11-22M1	[3] 12,391	11.2	19.0	69.8	9.2	57.6	33.2	7
4/12-28B1	[3] 1,433	4.6	4.8	90.6	73.8	10.4	15.8	15
5/11-18P4	[4] 57,300	4.6	17.2	78.2	1.0	8.4	90.6	8
6/10-18L1	3,280	31.8	24.8	43.4	22.0	23.2	54.8	14
Waters from uppermost Pleistocene deposits, not more than about 200 feet below the land surface								
2/13-14L1	[3] 778	52.8	23.6	23.6	36.6	30.6	32.8	180
3/10-32C2	677	56.4	17.6	26.0	46.0	30.6	23.4	197
4/13-19J4	[3] 787	34.2	19.2	46.6	30.4	5.4	64.2	100
5/9-19A1	989	55.2	29.0	15.8	30.8	44.6	24.6	44
5/10-24F1	540	56.2	21.6	22.2	47.4	31.8	20.8	200
6/10-2H1	2,730	47.6	21.2	31.2	12.2	61.4	26.4	200
I-43F1	[3] 954	28.8	19.8	[3] 51.4	35.0	29.8	35.2	135-202
I-45E1	[3] 680	52.0	24.2	[3] 23.8	36.4	47.0	16.6	38-86
I-45N1	[3] 1,106	22.0	20.2	[3] 57.8	32.0	54.2	13.8	31
I-63G1	[3] 3,059	13.0	9.0	[3] 78.0	18.8	52.2	29.0	172-220
I-142K1	[3] 1,173	29.4	28.6	[3] 42.0	27.0	53.2	19.8	60-220

TABLE 5.—*Character of representative native waters of inferior quality in the deposits commonly penetrated by water wells*—Continued

[See table 30 for description of sources and for analytical data in parts per million. See plates 6, 7, 8, and 9 for location of sources]

Number	Solids	Ca	Mg	Na+K	HCO_3	SO_4	Cl	Depth
Waters from unnamed upper Pleistocene deposits								
3/9-20M1	[3] 881	32.0	27.4	40.6	36.8	38.2	25.0	311
4/9-15R1	[3] 693	31.8	26.8	[3] 41.4	44.4	38.8	16.8	240
4/10-4C1	688	64.0	18.4	17.6	42.2	36.0	21.8	230-350
5/9-8B	719	54.4	28.0	17.6	47.2	23.8	29.0	600
5/10-9A1	[3] 701	51.0	22.8	26.2	44.6	31.6	23.8	310
I-84G1	[3] 618	18.8	20.4	[3] 60.8	50.4	28.6	21.0	235-1, 35
I-102J1	[3] 540	25.4	10.4	[3] 64.2	38.2	14.4	47.4	255-299
Waters from San Pedro formation								
4/12-32G1	[3] 1,015	30.8	21.8	47.4	27.2	6.0	66.8	130
5/11-29P1	3,611	12.4	5.8	81.8	13.0	.0	87.0	484-524
5/12-13D1	17,900	5.0	15.6	79.4	.2	8.0	91.8	190-210
5/13-6D1	[3] 1,115.	9.2	3.0	87.8	37.8	.2	62.0	809-888
6/10-8D4	[3, 5] 3,253	11.2	13.8	75.0	9.4	64.4	26.2	270
6/10-10E	891	4.0	.6	95.4	29.8	0	70.2	500

[1] Includes carbonate (CO_3) and borate (BO_3) if present.

[2] Includes fluoride (F) and nitrate (NO_3) if present.

[3] Calculated.

[4] Sodium chloride water with concentration 160 percent of that of the ocean.

[5] Formational sample obtained while well was under construction.

UNCONFINED NATIVE WATERS OF INFERIOR QUALITY

The unconfined waters that natively are of inferior quality occur largely, if not exclusively, within the coastward half of the Downey Plain. Well 4/11-22M1, which is near the center of the plain but which just reaches the semiperched water table in an area not known to include contaminated waters or to be near a source of contamination, reportedly has yielded a sodium sulfate water in a concentration somewhat more than 12,000 ppm. (See pl. 10.) Waters of similar chemical character but commonly of much less concentration occur locally beneath the Tustin Plain to the east (table 5, analysis I-45N1) and to the west, beneath the local arm of the Downey Plain that intervenes between Dominguez Hill and the Torrance Plain (table 30, analyses 4/13-8L1 and -10F1); they probably occur elsewhere at shallow depth in areas of retarded ground-water circulation adjacent to rocks of Tertiary age (such as occur in the Santa Ana Mountains and the Puente Hills). On the northeast flank of Signal Hill, test well 4/12-28B1 yielded sodium bicarbonate water of about 1,400 ppm—the chemical character suggests leakage from the Silverado water-bearing zone of the underlying San Pedro formation (see p. 35), and the dissolved-solids content suggests concentration by evaporation from the capillary fringe. It is inferred that native waters of similar character may occur elsewhere at shallow depth along the inland flank of the Newport-Inglewood zone in the reach from Signal Hill to Huntington Beach Mesa.

Along the coast and at least just beneath the water table, native sodium chloride waters of high concentration are common in the unconfined body. Rather commonly the concentration and composition of these are essentially the same as of ocean water, but locally the concentrations is substantially greater. Thus, test well 5/11–18P4 in Sunset Gap, about a mile inland, yielded water of nearly the same composition but with a concentration about 160 percent of that of the ocean. Presumably this was due to evaporation from the capillary fringe. (See pl. 10.) Well 5/11–21P2 has yielded calcium bicarbonate chloride water, and well 6/10–18L1 has yielded sodium calcium chloride water. These two waters are inferred to occur in a zone of transition between highly concentrated sodium chloride waters such as those just described and calcium bicarbonate waters characteristic of the zones of free ground-water circulation farther inland. From the features here described and from the numerous field analyses of shallow ground waters (see table 31), the writers conclude that these zones of native concentrated sodium chloride water and of transition to the inland calcium bicarbonate water extend inland for 2 to 6 miles beneath the several gaps through the coastal mesas and hills.

Especially within the coastward half of the Downey Plain these unconfined native waters are extensively unfit for use. However, there they are largely semiperched and separated from underlying water-bearing zones by bodies of silt or clay which are essentially impermeable. Under these conditions the unfit waters readily can be excluded from deep wells by placing and maintaining adequate casings. Only within two forebay areas at the inland margin of the Downey Plain—specifically, from the Whittier Narrows downstream about 4 miles and from the mouth of the Santa Ana Canyon downstream about to Anaheim and Orange—is there vertical hydraulic continuity from the water table to the lower division of the Recent deposits and to the underlying Pleistocene deposits. However, within those two small inland areas the native unconfined waters are wholly of good quality, as has been explained.

CONFINED NATIVE WATERS OF INFERIOR QUALITY

EXTENT AND GENERAL CHARACTER

The determinations of approximate dissolved solids by Mendenhall in 1903–4 (see pl. 2) and the analytical data since accumulated show native waters to be of decidedly inferior quality in the principal confined body beneath the inland margin of the Downey Plain in the general vicinity of Whittier, adjacent to the flank of the Puente Hills and the western part of the Coyote Hills uplift; beneath the Tustin Plain, adjacent to the flank of the Santa Ana Mountains; and at least discontinuously along the coast from the Palos Verdes Hills to the San Joaquin Hills. Further, and as explained later, they suggest that beneath all the marginal parts of the Long Beach-Santa Ana area waters of somewhat inferior quality are the rule rather than the exception.

These inland waters of inferior quality generally are of high sulfate content and are known to occur only in the uppermost Pleistocene deposits (those within 200 ft beneath the land surface) and at least locally in the unnamed upper Pleistocene deposits at somewhat greater depth. That is, they occur in deposits whose fresh waters have been ascribed to range 2 and the upper part of range 3. It is not known whether they occur elsewhere at some particular stratigraphic zone or zones or as lobes of random stratigraphic position fingering outward from the highlands that enclose the Downey Plain. However, at least locally, inferior waters are known to be both overlain and underlain by native waters of good quality and they are presumed to exist only in deposits which have small average permeability and which currently are not flushed by vigorous ground-water circulation. In general, their dissolved constituents are presumed to have been derived from the adjacent highlands. Their similarity to surface waters of the highlands is suggested by the following data on the chemical character of Santiago Creek, which drains the west-central part of the Santa Ana Mountains (table 6).

The coastal waters of inferior quality are generally of high chloride content and occur locally in the unnamed upper Pleistocene but extensively in the San Pedro formation and its probable correlatives, that is, in deposits whose fresh waters occur largely in ranges 3 and 5. Presumably they are of connate origin, diluted in various degrees by land-derived fresh water and largely trapped at faults and other features of geologic structure.

TABLE 6.—*Chemical character of Santiago Creek* [1]

Constituent	Parts per million	Percentage equivalents [2]
Calcium (Ca)	93	51.0
Magnesium (Mg)	32	28.9
Sodium and potassium (Na + K) [3]	42	20.1
Bicarbonate (HCO_3)	275	49.3
Borate (BO_3)	.76	.4
Sulfate (SO_4)	187	42.6
Chloride (Cl)	25	7.7
Hardness, as $CaCO_3$	354	
"Sum"	517	

[1] Northeast of Villa Park and 0.5 mile above mouth of canyon at box dividing flow between Serrano Water Co. and John T. Carpenter Water Co. Average of two analyses by University of California Citrus Experiment Station in October 1918 and June 1927, also of three analyses in 1932 by California Division of Water Resources.

[2] Cations and anions separately.

[3] Calculated.

INFERIOR WATERS IN THE UPPERMOST PLEISTOCENE DEPOSITS (RANGE 2 OF THE FRESH WATERS)

In the far northwestern part of the area, well 2/13–14L1 near Huntington Park has yielded a calcium bicarbonate sulfate water containing nearly 800 ppm of dissolved solids, 243 ppm of carbonate hardness, and 265 ppm of noncarbonate hardness. Other very hard waters occur in the vicinity, presumably are native, and so suggest that moderately concentrated waters high in sulfate content may be fairly extensive in the uppermost Pleistocene in the vicinities of the Los Angeles Narrows and the Whittier Narrows. From general information, it is inferred that the native waters of inferior quality farther east in the vicinity of Whittier, and still farther east along the south flank of the Coyote Hills, are commonly of somewhat the same composition.

To the south, between Wilmington and Dominguez Hill, the uppermost Pleistocene deposits (there correlated specifically with the unnamed upper Pleistocene) contain water of inferior quality at least locally, as at well 4/13–19J4 (see table 5). There sodium chloride bicarbonate water in a concentration of about 800 ppm is native and—like the sodium chloride waters of the San Pedro formation, to be described—is probably of connate origin but considerably diluted with land-derived calcium bicarbonate water. In the same district a presumably native calcium chloride bicarbonate water was found in a concentration of 520 parts per million (well 4/13–19H1).

This district near Wilmington, which is essentially the eastern part of the Torrance Plain, was sparsely settled and contained no wells at the time of the survey by Mendenhall (1905c) in 1904, possibly because it was flooded recurrently by the Laguna Dominguez. However, to the northwest and somewhat beyond the Long Beach-Santa Ana area, many wells 70 ft or less in depth then produced water containing 1,000 ppm or more of dissolved solids. Accordingly, it is concluded tentatively that in the district near Wilmington somewhat inferior waters are native extensively within the uppermost Pleistocene deposits. In some part the known and inferred waters of inferior quality in the district now may be contaminated. Information about this possibility may result from an investigation being extended northwestward from the Long Beach-Santa Ana area by the Geological Survey.

In the far southeastern part of the area, from Santa Ana to and beyond Irvine, the native waters of the uppermost Pleistocene formation pass eastward from the calcium bicarbonate water of good quality (table 4, analyses 5/9–8J1 and I–11B1) through inferior calcium sulfate waters, to sodium sulfate and sodium chloride waters (table 5 and pl. 10, analyses 5/9–19A1, 6/10–2H1, I–63G1, and I–43F1). Known concentrations range up to 3,059 ppm of dissolved solids (analysis I–63G1) and known hardness up to 1,424 ppm (analysis 6/10–2H1). Such waters are of the "marginal run-off strain" of Morse (1943, p. 484).

The westward reach of these native inferior waters is defined rather sharply in the data by Mendenhall (1905a), which are generalized on plate 2 and which indicate that 1903–4 waters containing from 600 to 1,000 ppm of dissolved solids were encountered commonly by wells of moderate depth within a belt about a mile wide extending roughly from Main Street (the boundary between Rs. 9 and 10 W.) eastward to the vicinity of Tustin. The inferior waters of this particular district, presumably calcium sulfate waters in large part, may be native in the sense that their dissolved constituents have been derived locally and from within the uppermost Pleistocene deposits. Waters of much less concentration occur at the water table above, and waters of relatively low concentration and of good quality occur in the unnamed upper Pleistocene and in the San Pedro formations below.

To the east, beyond Tustin, the sodium sulfate waters in the uppermost Pleistocene are most common beneath the northeastern half of the Tustin Plain adjacent to the flank of the Santa Ana

Mountains, and the sodium chloride waters occur more commonly beneath the southern part of the Tustin Plain adjacent to the San Joaquin Hills. Data not here introduced suggest that waters of these two compositions are native to the Tertiary rocks of the uplands that enclose the Tustin Plain—sodium chloride waters to the rocks of the San Joaquin Hills and sodium sulfate waters to the rocks of the Santa Ana Mountains and to the Puente Hills farther north and northwest. Thus, it seems probable that moderately concentrated waters of these two sorts may occur commonly in the uppermost Pleistocene deposits along much of the inland margin of the Tustin and Downey Plains in Orange County.

INFERIOR WATERS IN THE UNNAMED UPPER PLEISTOCENE DEPOSITS (RANGE 3 OF THE FRESH WATERS)

In most of the area the waters native to the unnamed upper Pleistocene deposits at depths greater than 200 ft beneath the land surface are of good quality as already described, but waters of inferior quality and of diverse composition have been withdrawn from wells that tap the unnamed upper Pleistocene in Orange County along and near the flanks of the Coyote Hills, the Santa Ana Mountains, and the San Joaquin Hills. In the available analyses total dissolved solids range from about 900 to 500 ppm, and in general decrease southward; hardness ranges from 482 parts to 172 parts (table 5 and pl. 10, analyses 5/9–8B and I–102J1, respectively). Composition varies widely and erratically among calcium bicarbonate sulfate waters (analysis 4/10–4C1), calcium sodium sulfate, bicarbonate, and similar waters (analyses 3/9–20M1 and 4/9–15R1), and sodium chloride bicarbonate water (analysis I–102J1).

In the central part of the coastal plain in Orange County, nearly west of Santa Ana and just west of the Santa Ana River, relatively concentrated calcium bicarbonate sulfate water appears to occur locally at moderate depth in the unnamed upper Pleistocene deposits, as at well 5/10–9A1. This condition suggests that fingers of the inferior water may extend westward several miles beyond the area in which such waters are common, as described in the preceding paragraph.

In the area from which these inferior waters have been withdrawn, and especially in the district from Tustin southeastward to and beyond Irvine, water wells commonly have casings perforated in an aggregate length of several hundred feet or are of gravel-packed construction. Thus, the wells may draw water from several zones whose native waters are of diverse character. Also, all the available analytical data are based on random samples for which the antecedent pumping history is not known. Under these conditions, three tentative conclusions are drawn about the chemical character of waters native to the unnamed upper Pleistocene in Orange County:

1. Waters of inferior quality are native largely in the uppermost part of the deposits at depths generally less than 300 ft below land surface; at least locally the native waters at greater depth are of good quality beneath the Downey Plain, beneath much of the Tustin Plain, and possibly beneath the lower flanks of the adjacent highlands.

2. Within their stratigraphic range the inferior waters native to the highlands (analysis 3/9–20M1) pass westward and southward into the native calcium bicarbonate waters of good quality which have been described, so that within a zone of transition along and near the margin of the lowland plains the native waters are of diverse and intermediate composition. (See table 5, analyses 4–10/4C1, 5/10–9A1, and I–102J1).

3. To a considerable extent, the diverse character of the waters withdrawn from the deeper wells of the area results from blending of inferior native waters from shallow zones with waters of high quality native to deeper zones. (See table 5, analysis I–84G1; also table 30, analyses I–8H1, –86R1, –121C1, –123K1, and –156C1.)

INFERIOR WATERS IN THE SAN PEDRO FORMATION (RANGES 5 AND 6 OF THE FRESH WATERS)

Sodium chloride waters in a wide range of concentrations are native in the San Pedro formation (1) locally beneath the flank of the Palos Verdes Hills; (2) beneath the eastern part of the Dominguez Gap and southeastward along the coast about to the far side of Bolsa Gap (in which 14-mile reach they are extensive if not continuous from the coast inland to the master faults of the Newport-Inglewood structural zone); and (3) beneath the eastern part of the Santa Ana Gap and the adjacent central and southern parts of the Newport Mesa. In all three districts the San Pedro formation is of marine origin and the sediments of which it is composed were deposited in ocean water. The sodium chloride water currently native there in the San Pedro are believed to be of connate origin, either because the marine waters of deposition were trapped locally by faults and so were not displaced by fresh water or because ocean water has reoccupied the permeable materials along much of the coast after the structural features of the Newport-Inglewood zone were formed.

Analysis 5/13–6D1 (table 5 and pl. 10) is typical of the sodium chloride water locally native in the lower part of the Silverado water-bearing zone of the San Pedro formation at the northeastern flank of the Palos Verdes Hills. This water has a chloride content of about 450 ppm and a dissolved-solids content of about 1,200 parts; probably it is held in a local structural trap. Its origin involves more than simple dilution of a connate ocean water by land-derived fresh water; rather, dilution has gone on with nearly complete reduction of sulfate and substantial replacement of magnesium and calcium through base-exchange reactions.

The extent of this native water of inferior quality in the Silverado zone is not shown clearly by data available to the writers. Southward and southeastward, it may reach to the eastern part of Terminal Island, as is suggested by the report that well 5/13–3K1 there encountered salty water, and by the electric logs of several oil wells on the south flank of the Wilmington anticline. To the north and east, it appears to grade irregularly through native waters which are of good quality but in which the dissolved-solids and chloride contents are substantially greater than in the Silverado water-bearing zone to the north and beneath the Dominguez Gap to the east. For example: in the waters drawn from wells 4/13–33E2 and –33E8, about 2 miles east-northeast of well 5/13–6D1, the total-dissolved-solids and chloride contents are respectively about 400 and 100 ppm; in those drawn from wells 4/13–31E3 and –31E4, a mile northwest of 6D1, dissolved solids and chloride are respectively about 380 and 70 parts; in the waters drawn from well 4/13–30G1, nearly 2 miles north of 6D1, also from wells 4/13–33D1 and –33D2 about 2 miles east-northeast, dissolved solids are from 230 to 340 parts and chloride about 45 parts; but in the waters from well 4/13–19J2 about 3 miles north, and from well 22E1 about 4 miles northeast of 6D1, dissolved solids and chloride are about 220 and 25 ppm, respectively. (See analyses in table 30.) The two waters last cited are typical of the native waters of good quality already described.

Within this area adjacent to the Palos Verdes Hills, certain wells have yielded somewhat contaminated waters which should not be confused with the presumed native waters just described. These contaminated waters are described in a following section of this report.

To the east, locally beneath a small part of the Dominguez Gap and probably beneath all the Long Beach Plain, it is inferred that sodium chloride waters of at least moderate concentration are native and extensive in the San Pedro formation between the coast and the Newport-Inglewood zone. Analysis 4/12–32G1 of table 5 suggests the chemical composition. The northwestward reach of this native salt-water body seems to have ended about at the Los Angeles River, as is shown by Mendenhall's data of 1903–4 (see pl. 2, line indicating concentration of 1,000 ppm). Possibly it reached to the easternmost part of Terminal Island and there merged into the native water body of inferior quality adjacent to the Palos Verdes Hills.

Southeastward along the coast from Alamitos Gap to Bolsa Chica Mesa, concentrated salt water is native at many places in the Pleistocene deposits and may well extend laterally throughout those deposits and vertically to the base of the San Pedro formation. Analysis 5/12–13D1 (table 5 and pl. 10), which is typical, indicates a composition almost identical with that of ocean water but a total-solids content one-half that of ocean water. On the other hand, analysis 5/11–29P1, which is believed to represent a native salty water between the coast and the Newport-Inglewood structural zone, has a total-solids content about 10 percent of that of ocean water, but a composition more like that of certain oil-field brines. Other analytical data, including those of table 29, suggest that extensively in these particular salt waters the dissolved solids range from 50 to 100 percent of the dissolved solids in ocean water.

With four exceptions to be explained later, the available analytical data for this coastal reach from Alamitos Gap to Bolsa Chica Mesa suggest that waters of good quality now exist throughout the San Pedro formation inland from the master faults of the Newport-Inglewood zone, but that salt waters occupy the area between those faults and the ocean. These data are drawn from the work by Mendenhall in 1904, and by the Geological Survey and local agencies in 1941–43; they are summarized in the following table 7.

Along the coastal side of the master fault of the Newport-Inglewood zone within the reach here treated, water of good quality is known to occur only in test well 5/11–18P1, which in July 1941 yielded water containing only 35 parts per million of chloride. This well is about 200 ft coastward from the master fault, is 125 ft deep, and its casing is perforated in a bed of gravel and sand that extends from 110 to 148 ft below land surface. The static level of its fresh water ranges from 3.7 to 6 ft above mean

TABLE 7.—*Chloride and dissolved solids in waters of the San Pedro formation along the coast from Alamitos Gap to Bolsa Chica Mesa, as of 1904, 1941–42, and 1945*

[Based on analytical data of the Geological Survey, the Los Angeles County Flood Control District, and the Orange County Flood Control District]

Number of well on plate 2	Depth of well or of perforations, in feet	Date	Parts per million	
			Dissolved solids [1]	Chloride
Wells inland from master fault of Newport-Inglewood zone				
257	130	1904	200	
258	184	1904	220	
5/11-18R1	700–800	Apr. 25, 1942	[2] 218	12
20L2	158	Jan. 23, 1942	240	16
28Q1	273	Mar. 14, 1941	190	18
29A5	83–89	Mar. 20, 1941	240	18
29C4	[3] 157	Dec. 22, 1941	175	14
5/12-11G1	70–92, 187–214	Jan. 14, 1942	220	27
		April. 18, 1945		[4] 252
11H1	296	June 28, 1942	11,500	[4] 7,000
12L1	668–709			16
12P1	185	Nov. 10, 1930		21
		Sept. 11, 1942	610	[4] 211
12P6	348–362	July 14, 1942	275	14
Wells between the master fault and the coast				
256	300	1904	830	
302	100	1904	5,000	
5/11-18N1	179–209, 229–249	July 21, 1941	25,500	18,200
18P1	109–124	July 21, 1941	235	35
29E1	169–219	July 25, 1941	21,200	13,100
29E2	100–120	July 25, 1941	23,500	16,500
29P1	484–524	Mar. 18, 1941	4,100	2,050
5/12-12P2	684–715			([5])
13D1	190–210	Jan. 30, 1942	27,500	18,800
13D2	130–140	Jan. 29, 1942	20,000	13,200

[1] Approximate; calculated from electrical conductivity.
[2] Determined by analysis.
[3] Well unused; sampled at 147 ft below land surface.
[4] Well probably contaminated, as described in text.
[5] Well reportedly abandoned owing to salt water.

sea level, fluctuates diurnally with the tide, and is essentially free from seasonal fluctuations. Evidently hydraulic discontinuity across the Newport-Inglewood zone here is so extensive that seasonal fluctuations of pressure head are not transmitted from the inland water bodies. Under these conditions the fresh-water body tapped by well 18P1 either is maintained by percolation through the fault barrier to offshore springs, or is stagnant and floats on underlying salt water. Of these alternatives, it is inferred that the fresh-water body must be derived from leakage through the fault barrier but that, with the differential head now prevailing, the amount of such leakage is very small. Otherwise some seasonal fluctuations of pressure head would be transmitted to the coastal side of the fault.

In contrast, test well 5/11–18N1, which was drilled 168 ft southwest of well –18P1, yields water whose chloride content is about 18,000 ppm, a salinity substantially that of the ocean. This second and deeper test well taps beds of gravel and sand from 172 to 212 and from 221 to 251 ft below land surface. Its water level fluctuates only with the tide, ranges from 3.0 feet above to 0.5 ft below mean sea level, and in general is about 3 ft below that in well 18P1. This difference in water level in the two test wells doubtless indicates a hydrostatic balance between the fresh-water body of well 18P1 and the underlying salt-water body of well 18N1. Evidently no fresh water leaks through the fault barrier into either of the two water-bearing zones tapped by the deeper of the two wells.

All data available indicate that waters high in chloride content now occupy virtually all the San Pedro formation between the coast and the master faults of the Newport-Inglewood zone from Alamitos Gap at least to Bolsa Chica Mesa, are native in that coastal reach, and are essentially of connate origin in the sense that the permeable materials along the coast presumably were reoccupied by ocean water after the barrier features of the Newport-Inglewood zone had been developed. The ocean water of reoccupation has been modified substantially by reduction of its sulfate and by loss of part of its magnesium through base-exchange reactions.

Still farther southeastward along the coast, from the Bolsa Gap onto the Huntington Beach Mesa, the reach of this native body of salt water is not shown clearly by data now available. Fragmentary information suggests that it could not have reached the southeastern corner of the mesa, at least in the lower part of the San Pedro formation, and probably did not reach that far within the upper part of the formation.

The native saline waters beneath the central and southern parts of the Newport Mesa and the adjacent eastern part of the Santa Ana Gap include sodium sulfate water (analysis 6/10–8D4, table 5) and sodium chloride waters in concentrations ranging at least from 900 to about 5,000 ppm of dissolved solids (analyses 6/10–10D3 and –18J2). At least locally beneath the eastern part of the Santa Ana Gap the sodium sulfate water is native in the uppermost part of the San Pedro formation, which there lies immediately beneath the Talbert water-bearing zone in the alluvial deposits of Recent age. This particular type of water is very nearly like that native to the uppermost Pleistocene deposits beneath the central part of the Tustin plain (pl. 10, analysis I–63G1) and, like that water, presumably has been derived from a calcium sulfate water through base-exchange reactions. The underlying sodium chloride waters are of modified connate origin—connate ocean water diluted with land-derived fresh water, but with sulfate reduced completely or nearly so and with magnesium and calcium very largely exchanged for sodium. Both types of native saline water beneath the Newport Mesa—the sodium sulfate and sodium chloride waters—seem to exist only within and by virtue of a fault trap, whose features are described in the separate report on geologic features (previously cited), and which locally has impeded the circulation of ground water. The precise extent of the trapped connate water is not known.

CONTAMINATION OF NATIVE FRESH WATERS

GENERAL EXTENT OF WATER-QUALITY DEPRECIATION

Beginning in the late twenties, as has been stated, a few wells in the coastal zone of the Long Beach-Santa Ana area began to yield salty water and subsequently a number of wells were abandoned as the quality of their water depreciated progressively. Plate 1 has outlined those districts in the coastal zone in which certain of or all the ground-water bodies had a chloride content exceeding 50 ppm in 1942, that is, a chloride content substantially greater than that of the native fresh waters of good chemical quality. Salty waters were and are native in certain of these districts (pp. 57–59) but the areas of high-chloride-content water existing as of 1942 in the Dominguez Gap west of Long Beach, in the Santa Ana Gap west of Newport Beach, in the central part of the Huntington Beach Mesa, and locally in the northern part of the Newport Mesa had resulted from depreciation of water quality during the preceding 15 yrs. This depreciation has been caused by an influx of salines from sources partly within and partly beyond the body of materials penetrated by water wells.

As will be shown specifically, the depreciated waters most commonly are high in chloride content, a condition which suggests ocean water and oil-field brine as the most obvious potential contaminants. In many, however, calcium and magnesium are much more prevalent than sodium, so that the depreciation has involved more than the simple admixture of ocean water or oil-field brine with native ground water of good chemical quality. Other waters have depreciated principally by increase in sulfate, a type of modification that suggests contamination by industrial wastes or by certain waters which are of inferior quality but which are native in the deposits tapped by water wells.

In a certain sense, the users of ground water in the area might be considered wholly responsible for the prevention and control of water-quality depreciation by contaminants that occur naturally within the deposits tapped by water wells, that is, by "interior" contaminants as discriminated in this report. By the same token, however, those same users should not be wholly responsible for the control of depreciation by contaminants that do not occur naturally within the deposits, that is, by "exterior" contaminants.

CHARACTER AND OCCURRENCE OF POTENTIAL EXTERIOR CONTAMINANTS

The potential exterior contaminants, derived from sources beyond the stratigraphic range of the water wells, of the area include ocean water, connate waters from the rocks of Tertiary age, and waste fluids of industrial and miscellaneous origins. For each of these the mode of occurrence is briefed in following paragraphs, and the chemical character is shown by the representative analytical data of table 29 and by figure 6.

OCEAN WATER

The highly saline water of the ocean is an obvious potential contaminant for two reasons. It is probably in extensive hydraulic continuity with the native fresh-water bodies, especially at the Dominguez and Santa Ana Gaps by way of the basal division of the alluvial deposits of Recent age and likely so along almost all the coast by way of coarse-grained members in the San Pedro formation. Second, tides cause ocean water to overrun certain rather extensive tidal flats from which it may percolate downward into a fresh-water aquifer wherever the overlying materials are permeable.

The extreme reach of ocean water into the area is indicated by observations of the Geological Survey during a maximum spring tide, the 6.9-ft tide which crested at 10:07 a.m. (Pacific standard time) on January 7, 1943. These observations briefly are:

1. In the channel of the Santa Ana River, 1.5 miles inland, or to Hamilton Street which crosses the channel on a fill above high-tide level. At its crest the tidal water occupied the entire 300 ft width of channel between levees from the coast to a point about 300 yd downstream from Hamilton Street. Ebb flow began at 11:08 a.m.

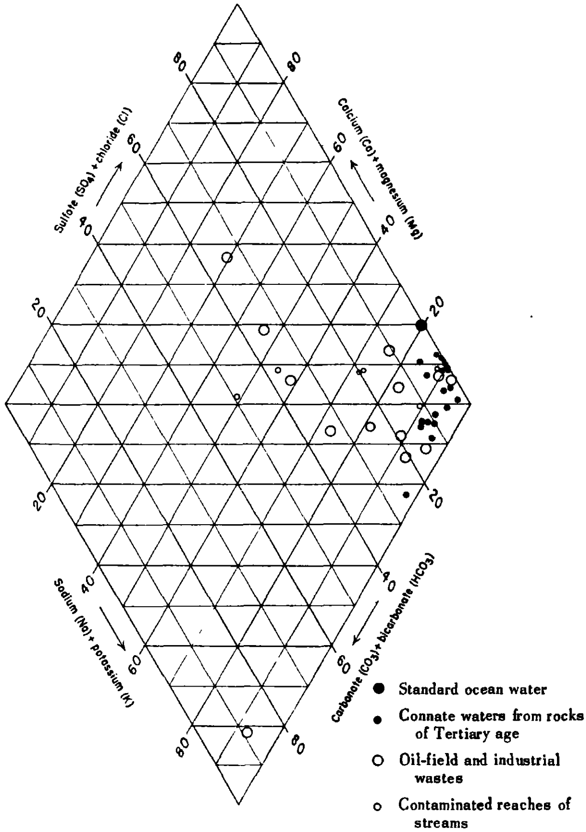


FIGURE 6.—Chemical character of potential exterior contaminants.

2. In the San Gabriel River, about 2 miles inland or to a point 2,800 ft south of East 7th Street. Tide reversal occurred at 10:45 a.m.

3. In the Los Angeles River, flood tide was noted at 7th Street at 10:25 a.m. The inland reach was 0.95 mile or to a point 1,300 ft beyond 7th Street.

In the Dominguez Gap, the natural tidal flats have been extensively raised by artificial fills, so that even during maximum spring tides the ocean water does not extend greatly beyond the banks of the Los Angeles River and of the Dominguez Channel. However, on the tidal flats of the Alamitos Gap, maximum tides reach roughly to the center of sec. 2, T. 5 S., R. 12 W., or about 0.5 mile inland beyond the axis of the Newport-Inglewood structural zone which affords the barrier to water movement below the water table. In the Sunset Gap, tidal overflow is confined almost completely to the flat south of Bolsa Avenue, but extends eastward roughly to the southwest corner of sec. 17, T. 5 S., R. 11 W. In this gap, maximum spring tides extend inland about 0.7 mile beyond the Newport-Inglewood structural zone. In the Bolsa Gap the tides once extended inland as much as 0.5 mile beyond the structural zone in one arm of Bolsa Bay, but currently the reach of salt water is constrained by dikes and controlled at a gate structure across the main arm of the bay. In the Santa Ana Gap, extreme tidal reach is about 0.5 mile inland in secs. 13 and 14, T. 6 S., R. 11 W., and about the same distance on the lowland east of the Santa Ana River. It reaches almost to the structural zone.

The data on ocean water in table 29 include a "standard" analysis and actual analyses for two stations in or near the Long Beach-Santa Ana area. All analyses show the usual characteristics of ocean water: sodium and chloride the dominant dissolved constituents with chloride from 18,300 to 19,000 ppm, and about three times as much magnesium as calcium (in nearly all the native ground waters of the area calcium substantially exceeds magnesium). Bicarbonate in the ocean water is only about 140 ppm, or considerably less than in nearly all the ground waters, and sulfate is about 2,600 parts or several times greater than in any of the ground waters of good quality.

CONNATE WATERS IN ROCKS OF TERTIARY AGE

Beneath the principal body of confined fresh water in all the area, or below the upper division of the Pico formation, such permeable zones as exist contain brines of connate origin. These connate-water zones are overlain by and fingered between bodies of claystone and siltstone which are essentially impermeable and each of which is hundreds of feet thick. Also, in all the area no salt-water springs are known to the writers who have also found none described in the technical literature. Thus, it is concluded that all the connate waters of the Tertiary rocks naturally were confined effectively. There are virtually no natural conduits affording hydraulic continuity between the connate waters and the overlying fresh-water bodies, not even among the faults of the Newport-Inglewood structural zone. However, the confining beds have been pierced, and artificial conduits between the fresh-water and connate-water zones now are afforded by the thousands of oil wells in the area—those of the Dominguez, Long Beach, Seal Beach, and Huntington Beach fields along the Newport-Inglewood structural zone; those of the Wilmington field, which is just west of the Los Angeles River between the Newport-Inglewood structural zone and the coast (see pl. 1); also those of the

Sante Fe Springs, West Coyote, East Coyote, Richfield, Montebello, West Whittier, and Whittier fields near or along the inland margin of the area. Thus, the connate water-bodies in the Tertiary rocks which yield the brines that are withdrawn with oil from the several fields constitute exterior sources of potential contamination.

CHEMICAL CHARACTER

The analytical data of table 29 suggest the range in chemical quality of the connate waters as indicated by formational samples or by samples taken from brine separators at oil wells known to tap a single stratigraphic zone. All these analyses from the several fields in the coastal zone are of sodium chloride waters ranging from 6,000 to 23,400 ppm of chloride and from 10,000 to 39,000 parts of dissolved solids. That is, their chloride content ranges from 32 to 123 percent of that of standard ocean water, and their dissolved-solids content ranges from 29 to 112 percent. The divergence between these two ranges is related to certain characteristic differences of composition between ocean water and the connate water, which are brought out in table 8.

TABLE 8.—*Comparison of chemical character of standard ocean water with that of known connate waters in the coastal zone of the Long Beach-Santa Ana area*

[Data on connate waters based on analyses in table 29. Percentage equivalents for principal constituents as indicated, and separately for cations and anions]

	Parts per million			Percentage equivalents			
	Ocean water	Connate waters		Ocean water	Connate waters		
		Maximum	Minimum		Maximum	Average	Minimum
Barium (Ba)	0.05	142	24				
Strontium (Sr)	13	20	2.6				
Calcium (Ca)	400	1,679	1,117	3.4	13.2	5.6	2.0
Magnesium (Mg)	1,272	713	5	17.6	9.6	3.2	.2
Sodium (Na)	10,556	13,319	3,384	77.4	95.8	91.2	83.6
Potassium (K)	380			1.6			
Borate (BO_3)	25	386					
Carbonate (CO_3)	0	238	0	.4	24.6	6.0	.4
Bicarbonate (HCO_3)	140	4,607	0				
Sulfate (SO_4)	2,649	165	.0	9.3	1.4	.2	.0
Iodide (I)	.05	80	30				
Bromide (Br)	65	200	25				
Chloride (Cl)	18,980	23,386	5,963	90.3	99.6	93.8	75.0
Fluoride (F)	1						
"Sum"	34,482	38,800	9,940				
Ratios:							
Calcium to magnesium				0.19	52.4	6.24	0.60
Calcium to sodium				.04	.14	.06	.02
Magnesium to sodium				.23	.11	.04	.002
Carbonates (as HCO_3) to sulfate				.04	1,190	132	1.12

These connate waters from Tertiary rocks, at least those within the coastal zone of the Long Beach-Santa Ana area, are of marine origin, and presumably have been derived from an ocean water not greatly unlike the standard ocean water of table 8. Regarding that standard, however, the connate waters have undergone certain fundamental modifications in the proportions of their principal dissolved constituents. Among the bases (cations) the calcium has increased considerably in some waters but has decreased in others, and the magnesium has decreased (to its virtual disappearance from some waters) about inversely as the sodium has increased. Among the acid constituents (anions) the carbonate and bicarbonate have increased greatly in most waters, the sulfate is very greatly diminished in all waters and

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into solution from mineral constituents of the enclosing rocks, but not until the sulfate of the connate ocean water had been largely reduced (because the solubility product of barium sulfate is very small among those of other potential compounds of the constituents in natural waters). The large quantity of borate in many connate waters presumably has been derived also from mineral constituents of the enclosing rocks, but the details of its origin are obscure.

POTENTIAL CONTAMINATION BY CONNATE WATERS AT DEPTH BELOW LAND SURFACE

In the deformed rocks of the Newport-Inglewood structural zone, the top of the connate-water body ranges from 1,000 to 2,500 ft (Poland, Piper, and others) below sea level. It is highest beneath the central part of Signal Hill where it is several hundred feet above the deepest producing fresh-water zone to the northeast. Northwestward along the structural zone, the topmost connate-water zone declines nearly to 2,500 ft below sea level at the Dominguez Gap, then rises to about 1,500 ft below sea level at the crest of the Dominguez Hill. Southeastward from Signal Hill it is some 2,000 ft below sea level about to the Bolsa Chica Mesa, then rises to about 1,500 ft at the Santa Ana Gap and beneath the northern part of the Newport Mesa. Inland from the Newport-Inglewood zone it plunges about 4,000 to 4,500 ft below sea level along a line from Compton to and beyond Los Alamitos.

Among the several coastal oil fields, the confining bed that overlies the connate-water body in the Tertiary rocks was breached by the discovery wells of the Huntington Beach field in 1920, of the Long Beach field in 1921, of the Dominguez Field in 1923, of the Seal Beach field in 1926, and of the Wilmington field in 1936. Successively deeper zones and lateral extensions were sought in each of the four fields along the Newport-Inglewood zone until, as of about 1940, the deepest wells reached 9,000 to 10,000 ft below the land surface, and about 3,400 productive wells had been drilled. Even deeper drilling is now (early 1945) in progress in the Long Beach field. Thus, connate-water zones have been tapped extensively and through a very wide vertical range in the coastal zone of the Long Beach-Santa Ana area, and for some 25 yr their saline waters have been potential exterior contaminants. Within this period, the connate waters could have reached and contaminated some fresh-water body either by percolation at depth beneath the land surface or by percolation downward from the land surface after they had been withdrawn with oil.

Among the oil fields along or near the inland margin of the area (p. 62), the impermeable beds that confine the connate waters were breached first in 1897 by the discovery wells of the Whittier field. Thus, as of 1945, in that inland part of the area the connate waters had been a potential exterior source of contamination for 48 yr.

Wherever its static pressure level is higher than that of a fresh-water body, connate water of course can flow directly into the fresh-water aquifer provided hydraulic continuity is afforded through oil wells that have inadequate or defective casings or that have been inadequately plugged before being abandoned. This necessary hydraulic continuity is not likely to be afforded by producing oil wells in which the fluid level commonly is drawn down as much as 1,500 ft or even more below land surface, or far below either the static level or the pumping level in any water-supply well of the area. However, in any nonproducing or abandoned oil well the fluid pressure would rise to some extent, perhaps substantially; also, any top waters or bottom waters that were shut off during construction of the well would maintain their pressure heads undepleted. Under such conditions, every instance of casing failure or of inadequate plugging might afford the hydraulic continuity necessary for contamination of a fresh-water body.

Little specific information is available to the writers about static level of the connate waters in the oil wells. Only in the Santa Ana Gap is the connate-water head known currently to be above that of the fresh-water zones. Thus, an abandoned oil-test well in that area, 6/11–13Q1, reportedly is plugged 228 ft below land surface but, as of 1945, flows a very small amount of saline water under a head at least 1 foot above land surface and some 3 ft above the drawn-down head of the Talbert fresh-water-bearing zone. Its analysis in table 29 shows that this water is essentially connate in character. In this part of the area the pressure heads are such that the contamination in the Talbert water-bearing zone (pp. 92–126) could have been caused in part by percolation of connate water from one or more of the several nonproducing or abandoned oil wells. However, none of these oil wells is known to be a specific source of such contamination by percolation at depth below the land surface. The data available to the writers for other parts of the coastal area are incompetent to show whether such contamination has occurred or is hydraulically possible.

WASTE BRINES FROM THE COASTAL OIL FIELDS

In the five oil fields in the coastal zone of the area (p. 65), most of the brine that is raised to the land surface is separated immediately from its accompanying oil by settling. However, some brine is emulsified with its oil and separation must be induced by adding certain chemicals or commercial products (commonly sodium oleate, sodium resinate, phenol, or miscellaneous sulfonated organic compounds). It the early years of these fields, it is reported that a considerable quantity of the waste fluid (connate water, almost exclusively) was disposed of near the point of origin by discharge into drainage ditches or natural channels, into undrained sumps, into abandoned oil wells, or into bored holes that bottomed within the formations commonly penetrated by water wells. These early practices have been discontinued largely, but not wholly, and most of the oil-field wastes now (1945) are transported by pipe lines to the ocean or to some central disposal works. Current and former practices of waste disposal in the five fields are described specifically in the following paragraphs.

DOMINGUEZ FIELD

Beginning with the drilling of the discovery well in 1923, the Dominguez oil field has been developed very largely by the Shell Oil Co. and the Union Oil Co. Thus, this field has been relatively free from the disposal of small volumes of waste brine at widespread localities, as has been, and to a small extent still is, the practice in other fields which have been developed by many operators. Consequently, past contamination and the possibilities of future contamination of fresh-water bodies by waste fluids of the Dominguez oil field are relatively rather sharply localized.

According to information supplied by the Deepwater Chemical Co. and the Union Oil Co. (personal communications, October 1945), since about 1930 at least a part of the waste fluids from the oil wells of the Dominguez field ordinarily have been piped to the plant of the Deepwater Chemical Co. for extraction of iodine. As of 1930, about 90,000 gal of waste brine was delivered daily to this extraction plant, solely by the Union Oil Co. As of early 1945, about 500,000 gal of fluid each day was supplied jointly by the Shell Oil Co. and the Union Oil Co., or some 90 percent of the total from the field. The extraction plant is situated 0.1 mile north and 1 mile west of the intersection of Wilmington Avenue and Victoria Street, on the northwest flank of Dominguez Hill. Its effluent, which is essentially connate water (see table 29), is piped to an outfall on the Dominguez Channel 0.4 mile northwest of Avalon Boulevard. When the iodine-extraction plant is idle, the waste fluids are piped directly to the Dominguez Channel through the same line. As of 1945, therefore, the disposal of waste fluids from the Dominguez oil field presumably avoids any substantial contamination of fresh ground-water bodies, except as existing contamination might be intensified by the common usage of the Dominguez Channel as a drain for industrial wastes (see p. 80).

However, all waste fluids of the Dominguez oil field have not always been conveyed from the area by pipe lines. Thus, the unpublished report on a stream-pollution survey by the water department of the city of Long Beach in 1932 indicates that waste fluids from the wells of the Union Oil Co. then were piped to the plant of the Deepwater Chemical Co. as in 1945, but that at least a part of the waste from the wells of the Shell Oil Co. in 1932 was being discharged into a ravine high on the southwest flank of the Dominguez Hill.

This report states that also in 1932, waste fluids from the Shell wells were discharged into the crater of a blown-out oil well—Reyes well 27 near the crest of Dominguez Hill, just west of Wilmington Avenue and 0.3 mile south of Victoria Street. This well blew out June 7 to 25, 1925. In May 1932, the Shell Oil Co. was requested to stop discharging brines into the crater and it is understood that the practice was discontinued soon afterward. The quantity of waste brine so discharged onto the land surface as of 1932 is not known specifically, but during that year the Shell Oil Co. produced about 56,000 gal of brine each day. However, if such disposal had been practiced generally since the discovery of the field in 1923, several hundred acre-feet of waste brine could have infiltrated the land surface and percolated to permeable materials natively saturated with fresh water.

The fragmentary information available to the writers suggests that any such past accumulation of waste brine from the Dominguez oil field probably would occur largely beneath the southwest flank of the Dominguez Hill, whence it would tend to percolate southward and southeastward. Presumably some such accumulation has been the source for part of the contamination that exists as of 1945 in the Gaspur water-bearing zone beneath the Dominguez Gap, but neither the present nor the ultimate extent of the body of contaminating brine can be traced fully at this time.

LONG BEACH FIELD

Unlike the Dominguez field, the Long Beach oil field has been developed by many operators whose holdings range from a single well to scores of wells. During the decade following discovery of the field in 1921, a very large volume of brine was discharged indiscriminately at or near the producing wells. Coordinated disposal of waste fluids was not extended over the whole field until the early thirties, but subsequently nearly all the brines and waste fluids have been piped from the wells and refineries to disposal works established by Oil Operators, Inc., and by the Shell Oil Co.

The works of Oil Operators, Inc., include ten sumps that cover 27 acres adjacent to the east levee of the Los Angeles River within the city of Long Beach and 4 miles inland from the coast. (See fig. 7.) It is reported that some of these sumps originally were excavated to a depth of 60 ft, but all now are nearly filled with an accumulation of "rotary mud" and sludge. The dikes between the several sumps show some asphaltic paving, at least above the present water surface.

Disposal of brines in this series of sumps began about 1927 by a few operators in the Long Beach field. Brines are accepted for disposal only from wells and refineries for which memberships in the operating corporation are purchased—these memberships numbered 930 as of 1931, increased to 1,177 in December 1935, and with declining production diminished to 912 by December 1944.

Waste fluids from member wells and refineries are piped to the sumps where any residual petroleum is separated and recovered. As of 1945 residual fluid is then discharged to the Los Angeles River through flumes at two distinct points, one 175 ft and the other 480 ft north of Wardlow Road. In 1933 and 1934, it is reported that 4,200,000 gal of waste fluids were discharged from the sump system daily. Currently (1945), because the number of contributing wells has diminished, the daily discharge has decreased to 65,000 bbl or 2,730,000 gal. From 1928 through 1943, a Mr. Yorsten of Oil Operators, Inc., reports that a total of 398 million bbl, or 51,300 acre-ft of waste fluid, had been discharged to the river.

According to analyses of samples made by the Geological Survey in 1941–43, and several partial analyses of samples made by the city of Long Beach from 1932 to 1934 (see tables 29 and 33), the residual fluid discharged into the river from these sumps is essentially a blend of connate brines whose content of chloride has ranged at least from 9,000 to 16,000 ppm. That is from 50 to 85 percent of the chloride content of ocean water. However, from 1928 until 1934, effluent from the sumps was acidulated with sulfuric acid for the extraction of iodine; during that period

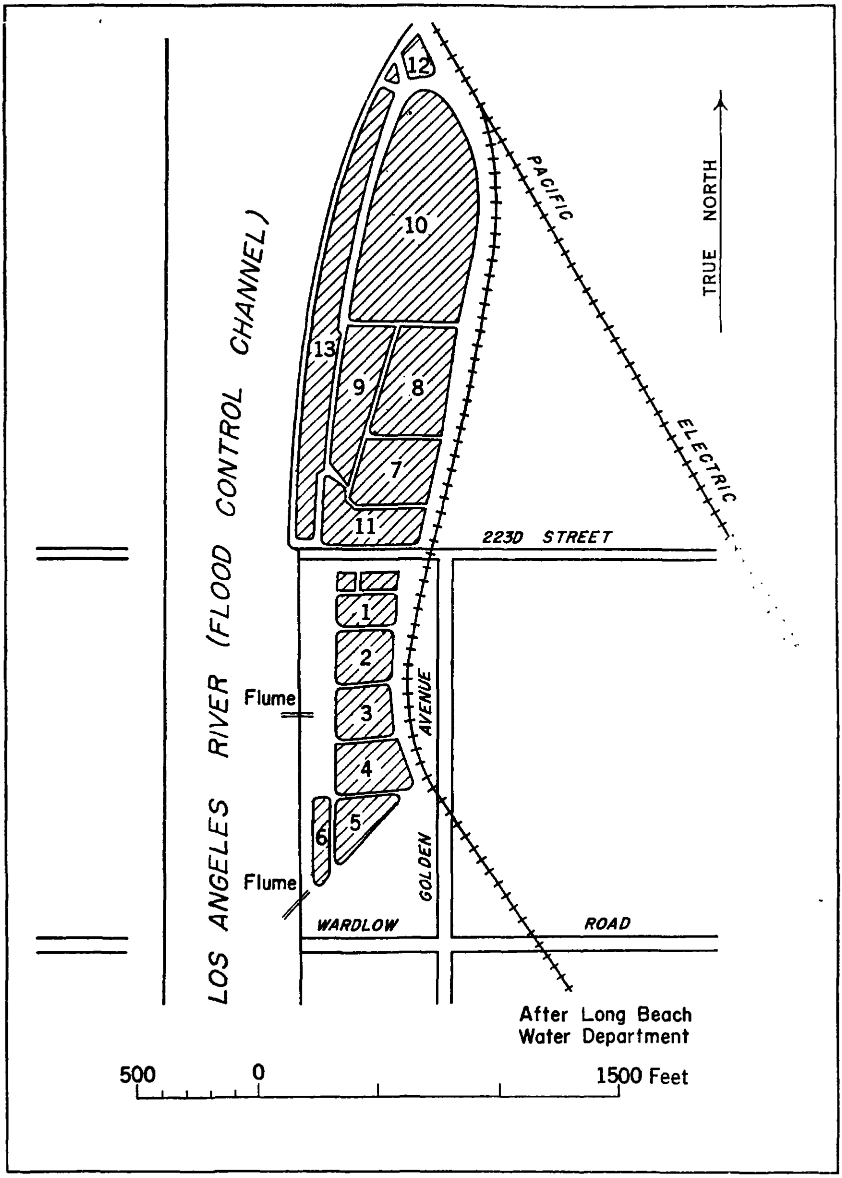


FIGURE 7.—Plan of brine sumps of Oil Operators, Inc., in northwestern part of Long Beach oil field. (After Long Beach Water Department.)

the residual waste discharged into the river probably contained substantially more sulfate than was found in 1941 in the complete analysis by the Geological Survey.

The series of six sumps operated by the Shell Oil Co. for the disposal of waste brines from its wells in the Long Beach field are located low on the east flank of Signal Hill, along the east side of Newport Avenue 0.2 mile north of Stearns Street. Their depth below natural land surface is not known. On the north, east, and south the upper part of the sump walls are earth dikes, which in part are faced with timber and whose top is 4 feet above general land surface. The total fluid surface is about 4 acres.

As of March 1945, about 700,000 gal of brine was piped to these sumps daily from 230 wells. The chloride content of the brine—as sampled in 1942 by the Geological Survey from a pipe discharging into the largest sump of the six—is 16,000 ppm (table 33). So far as is known, all the brine discharged from these sumps after the residual oil is skimmed off is piped to the plant of the Dow Chemical Company near Seal Beach for removal of iodine. The waste from this plant is discharged (as of 1945) into the tidal reach of the San Gabriel River, about three-fourths mile from the coast.

The daily output of brine from the sumps of Oil Operators, Inc., and of the Shell Oil Co. currently (1945) is 3.4 million gal, which is virtually the total quantity of brine withdrawn from the 1,250 active wells in the Long Beach field. According to E. L. Albrecht, fire chief of Signal Hill, brine from no more than a dozen wells in the field now (1945) is discharged locally into undrained sumps or onto the land surface. Thus, in the past decade, probably relatively little waste brine from the oil wells infiltrated below the land surface within the Long Beach field. However, the disposal works of Oil Operators, Inc., just beyond the northwest edge of the field, doubtless have been the source for a substantial part of the salt water that heretofore contaminated the Gaspur water-bearing zone beneath the Dominguez Gap. (See p. 176.) So far as is known to the writers, no brine from the sumps of the Shell Oil Co. has yet (1945) invaded any usable body of fresh ground water, although it is not unlikely that some has infiltrated to the shallow, unconfined body of ground water which locally is of inferior quality naturally. If so, that unconfined body locally may have become an intensified interior source of potential contamination.

In strong contrast to the localized possibilities of ground-water contamination by these two coordinated disposal systems, during the decade after the Long Beach oil field was discovered in 1921 waste brines in large quantity doubtless infiltrated rather widely beneath that field. Until the early thirties the methods of waste disposal in the field were largely indiscriminate. Thus, the unpublished report on the stream-pollution survey of 1932 by the city of Long Beach, also a paper by Brown (1935, pp. 171–177) summarizing some results of that survey, indicate that brine, acid sludge, refinery effluent, and other wastes were discharged into scores of bored "cesspools," into undrained sumps and pits, or onto the land surface. As of 1925, the waste brine from numerous wells was discharged overland into the gutters of Spring Street and thence eastward through the Cerritos drain and other open ditches to the tidal reach of the San Gabriel River. Thus, the waste fluids flowed overland rather widely on the north or inland flank of the Signal Hill, and the outfall ditches extended about 5 miles along the edge of the Downey Plain just inland from the flanks of Signal Hill and of Alamitos Heights. During at least part of this early period, 25 of the wells in the Jergins Trust group yielded 1,500 bbl (63,000 gal) of waste brine daily; this brine was piped to a city-operated sump whose outfall reached the Los Angeles River about 2 miles from the coast.

Altogether, several thousand acre-feet of waste brine may have infiltrated below the surface of the Long Beach oil field during this early period. Regarding historic and potential contamination of fresh ground-water bodies, this accumulation of brine creates three distinct conditions:

1. In the central part of the field, beneath and near Signal Hill, the infiltrated brine probably has been confined in large part between the structural traps afforded by the Cherry Hill fault on the southwest or coastal side of Signal Hill and by the Northeast Flank and Reservoir Hill faults on the northeast or inland side of the hill. Immediately inland from this probable body of trapped brine, numerous public-supply and private wells now withdraw large volumes of fresh water from highly permeable strata that, at least locally, probably are physically continuous with zones in which brine is trapped and that would be hydraulically continuous with those zones except for the imperfect barrier effects of the faults. So far as the writers know, under the fresh-water heads that have existed historically in the inland area of heavy withdrawal, no brine has yet (1945) migrated across the faults and contaminated any usable fresh water body. However, it is quite possible that some brine will be drawn through the faults locally, and into the productive fresh-water bodies. Thus, the probable body of trapped brine constitutes a possible source of future contamination, but its potential ultimate reach can not be estimated from data now available. Toward the coast the probable body of trapped brine

would abut, across the Cherry Hill fault, against bodies of ground-water that natively are of very inferior quality (p. 59), and does not threaten to contaminate usable water bodies there.

2. In the northwest part of the field, from Signal Hill across Los Cerritos, any infiltrated brine probably would be confined largely on the southwest by structural traps at the Cherry Hill fault. However, there are no known structural traps to restrain such brine from percolation northeastward (inland) or northwestward beneath the Dominguez Gap. It is inferred that northwestward percolate has caused a part of the known contamination of the Gaspur water-bearing zone beneath the eastern part of that gap (p. 176), but so far as now known (1945), no infiltrated brine has percolated to and beyond the inland edge of the oil field in Los Cerritos area and there contaminated any fresh ground-water body. For example, well 4/13–13J1, constructed in December 1943 and gravel-packed from land surface into the uppermost part of the Silverado water-bearing zone, encountered water substantially of native quality along the northeast edge of that field. However, the probable pressure of infiltrated brine within the northwest part of the Long Beach oil field constitutes a residual threat of contamination, either by percolation into a fresh-water-bearing zone or by leakage into wells which tap fresh water beneath the infiltrated brine but whose casings are inadequate or become deteriorated.

3. In and adjacent to the eastern part of the field, along the inland base of Signal Hill and southeastward along the flank of Alamitos Heights, there are no known structural traps to restrain infiltrated brine from percolating inland. However, except through wells with inadequate or defective casings, downward percolation beyond the zone of unconfined, semiperched ground water doubtless is largely prevented by underlying impermeable strata which there intervene above the productive fresh-water zones. Thus, in and near that eastern part of the field, any infiltrated brine probably has been dissipated in large part into the semiperched ground-water body which natively is moderately to highly saline and which of itself constitutes an interior source for the potential contamination of inadequately cased wells. Nonetheless, the likelihood of such contamination probably has been increased locally by brines from the Long Beach field.

SEAL BEACH FIELD

The main part of the Seal Beach oil field is in the Alamitos Gap, on the tidal flat northwest of Landing Hill. From this field, a substantial and perhaps the greater part of the waste brine is piped to the plant of the Dow Chemical Company near Seal Beach, for extraction of iodine. Some brine may be or may have been wasted at the wells, but because the field largely is on a tidal flat and is underlain by ground-water bodies of which all at shallow depth are natively very saline, any such local disposal of waste brine probably does not increase the likelihood of contamination.

HUNTINGTON BEACH FIELD

Like the Long Beach field, the Huntington Beach oil field has been developed by many operators who first used diverse methods of waste disposal. Currently (1945), a substantial and perhaps a major part of the waste brine from this field is piped to the ocean, but indiscriminate disposal within the field still is practiced somewhat widely as of 1945. Thus, the waste brine from certain wells and groups of wells long has been and is being discharged into certain natural depressions on the land surface, in which the impounded brine is alternately diluted by storm runoff and concentrated by evaporation; several of these artificial ponds are perennial. Brine from other sources is discharged into gullies that drain northwestward onto the floor of the Bolsa Gap and inland beyond the reach of the tides into that gap. Chemical analyses of waters from the ponds and from the gullies in 1941–42 are given in table 33.

As these analytical data show, in certain typical holding ponds the chloride content of the brines commonly has been from 12,000 to 20,000 ppm, but has ranged at least from 1,750 to 100,000 parts, owing to dilution by storm runoff and to concentration by evaporation. In the gullies and at points of outfall into them, the range has been at least from 525 to 15,000 parts.

From the known production of oil in the Huntington Beach field it is estimated that many hundred, and possibly several thousand acre-feet of waste brine have been discharged (as of 1945) into the several holding ponds and sumps or drained overland to the floor of the Bolsa Gap. Doubtless a substantial part of the salines in this brine has infiltrated below the surface of the Huntington Beach Mesa and has led to contamination of fresh-water bodies, as in the central part of the oil field (see p. 141). Furthermore, brine discharged on the mesa or onto the floor of the Bolsa Gap has invaded the "80-foot gravel" of the gap (Poland, Piper, and others) locally in sec. 26 and possibly in sec. 33, T. 5 S., R. 11 W. Although the salt water reported in the "80-foot gravel" at a well in sec. 33 may have come from the Bolsa Bay, it is unlikely that saline water from that source would have penetrated downward to the "200-foot aquifer" of the underlying San Pedro formation, which also was reported saline there. Thus, it is probable that at least the "200-foot" aquifer has been contaminated by westward circulation from beneath the mesa.

In Bolsa Gap, the fresh-water body of the "80-foot gravel" and its confining bed, like the principal fresh bodies beneath other parts of the Downey Plain near the coast, are overlain by native waters of inferior quality that occur at shallow depth beneath land surface and that are natural potential sources for contamination through any well not tightly cased down into the confining bed. Also, as in the area adjacent to the eastern part of the Long Beach field, the body of native but unusable water at shallow depth beneath the Bolsa Gap probably has been invaded locally by waste brine from the Huntington Beach field so that, inland beyond the tidal reach, the potentiality for contamination from above may have been increased.

WILMINGTON FIELD

The Wilmington oil field is west of the Los Angeles River and extends inland from less than a mile to 3 miles from the Cerritos Channel and the innermost basins of Los Angeles Harbor. (See pl. 1.) The eastern part of the field is underlain by Recent alluvial deposits of the Los Angeles River and by tidal deposits, but the western part of the field occupies part of the low Torrance Plain and is underlain by Pleistocene deposits.

At least three of the principal operators in the field pipe their waste brine directly to tidewater. However, as of 1945, many other operators reportedly discharge brine into sumps or onto the land surface near their wells and let it "evaporate or seep away." Because the chemical quality of the shallow ground water differs in the eastern and western parts of the Wilmington field, the potentialities for contamination by waste brine differ, as follows:

1. In the Recent deposits which underlie the eastern two-thirds of the Wilmington field the shallow unconfined ground water naturally is very saline and had been grossly contaminated for several years before the discovery oil wells were drilled in 1936. In addition, the subjacent Gaspur water-bearing zone here contains water of poor quality, which no longer is used except intermittently for industrial purposes. Hence surface disposal of waste brine within the area of Recent deposits probably will not increase local potentialities for contamination of the deeper Silverado water-bearing zone. (See pp. 195–197.)

2. In the Pleistocene deposits which underlie the western part of the Wilmington oil field, the native shallow ground water, tapped by wells from 20 to 30 ft deep, contained not more than 750 ppm of total solids. Also, as late as 1941, wells not more than 75 ft deep here produced water of fair quality. For example, the water then produced from well 4/13–29M1, 68.5 ft deep, contained 176 parts of chloride and that from well 4/13–32D1, 73.3 ft deep, contained 32 parts. However, it is probable that the brines being disposed at or near land surface in this westerly part of the oil field now (1945) are increasing or soon will increase the salinity of the water in these shallow Pleistocene deposits. If this shallow ground-water body becomes more saline owing to such disposal, it will then be a potential source of contamination to the underlying water-bearing zones, especially the Silverado zone, through defective well casings.

WASTE BRINES FROM THE INLAND OIL FIELDS

Waste brines from several oil fields along and near the inland edge of the area (p. 65) now are conveyed to the ocean by the Orange County Cities Joint Outfall Sewer on the east, and by the pipe lines of the Santa Fe Springs Waste Water Disposal Co. on the west. The alinements of these outfalls are shown on plate 2.

The main pipe line of the Orange County Cities Joint Outfall Sewer extends from La Habra about 23 miles to an outlet offshore from the Santa Ana Gap. This line was constructed in 1924 from Fullerton to the coast and later was extended north to Buena Park and La Habra. On land, the line was constructed first of concrete tile from 16 to 48 in. in diameter, depending on grade, but has been replaced piecemeal by bell-and-spigot, vitrified-clay tile. The last section of line so replaced was the 9-mile reach from Garden Grove nearly to the coast, after heavy damage to the line in 1938 by flood waters. The offshore section of the line is of cast-iron pipe.

This regional sewer carries waste brines from several oil fields on and near the Coyote Hills and sewage from the several cities within its reach. As of 1945, its reported load is about 10,000,000 gal a day. The chemical character of the fluid conveyed is suggested by the analyses of eight samples taken in late December 1932 from the effluent of the sewage-treatment plant which is adjacent to the west levee of the Santa Ana River in the inland part of the Santa Ana Gap, about 700 ft south of Ellis Avenue (see pl. 11). The most concentrated of these eight samples contained 90 ppm of calcium, 44 parts of magnesium, 1,035 parts of sodium, 583 parts of bicarbonate, 55 parts of sulfate, 1,562 parts of chloride, no nitrate, and 31 parts of borate (1938, California Dept. of Public Works, Div. Water Resources Bull. 40–A, p. 125).

The two outfall lines of the Santa Fe Springs Waste Water Disposal Co. extend about 15 miles from the skimming sumps at Santa Fe Springs to an outlet on the tidal reach of the San Gabriel River, about a mile from the ocean and 1,000 ft north of Hathaway Avenue. Lines 1 and 2 were placed in operation in 1929 and 1937, respectively. Each is constructed of 6-ft sections of vitrified-clay tile from 16 to 36 in. in diameter, with bell-and-spigot joints sealed with asphaltic cement, and is laid from 6 to 11 ft below land surface.

As of early 1945, the two lines transport 100,300 bbl (4,212,000 gal) daily of waste brines from the Santa Fe Springs, West Coyote, and Montebello oil fields. Recent chemical analyses are not available but data published by Morse (1943, p. 492) suggest that this waste, unless diluted at the head of the outfall, is much like that from the disposal works of Oil Operators, Inc., of the Long Beach field, which is analyzed in table 29.

Because this report concerns the contamination of fresh-water bodies only in the coastal zone, the two outfall systems from the inland part of the area are pertinent only in the remote contingency of contamination in the coastal zone by fluids leaking from one outfall or the other. Of the contamination now discriminated (1945), none is known to have originated in such leakage. Before these outfalls were put into operation the waste brines of the inland oil fields were disposed of locally and in considerable part, indiscriminately. Fresh-water bodies were contaminated in and near several of the inland fields, but they are not treated in detail by this report.

INDUSTRIAL WASTES IN NATURAL WATER COURSES

All the streams that discharge to the ocean across the coastal zone of the area receive effluent from sanitary-sewage plants and intermittently receive some natural effluent from the shallow, unconfined ground-water body which extensively is of inferior quality. (See pp. 51–52.) In these particular artificial and natural effluents the dissolved solids locally and intermittently reach a maximum 1,250 ppm, the chloride and sulfate reach 500 parts jointly, and sodium commonly is the most abundant base. These moderately concentrated effluents can not have caused any substantial part of the contamination with which this report is concerned because their content of dissolved solids is only a minor fraction of the dissolved solids in much of the contaminated water. This statement would apply only where the water table of the semiperched water body intersects the stream and makes a common straight-line profile with the stream surface at medium stream stage. In Dominguez Gap, the river feeds the shallow water table at all times. In Santa Ana Gap, because of local tile drain systems, the water table probably slopes away from the Santa Ana River throughout the year.

In addition to the oil-field brines that are being discharged into the tidal reach of the San Gabriel River (pp. 74, 79), into the Los Angeles River in northwest Long Beach (p. 72), and into the Dominguez Channel southwest of Dominguez Hill (p. 70), fluid wastes from processing and manufacturing industries are being discharged (as of 1945) and have been discharged in substantial volumes into the Los Angeles River, the Dominguez Channel, Compton Creek, and possibly into Coyote Creek but, so far as is known to the writers, not into any other stream in the area. The nonorganic wastes of high concentration and of relatively large volume are those from oil refineries and chemical plants. These commonly are sodium chloride or sodium sulfate waters that are somewhat more dilute than the oil-field brines. Typical analyses for these and for other industrial wastes are given in table 29.

Inland from the coastal zone miscellaneous industrial wastes formerly were discharged into the Los Angeles River at numerous places from Vernon downstream, and into the Rio Hondo at least in the vicinity of El Monte (according to an unpublished report on a stream-pollution survey by the city of Long Beach, 1932). Analyses of samples taken at points of waste discharge have been published (1933, California Dept. of Public Works, Div. Water Resources Bull. 40–A, pp. 127–128). During intermittent periods of storm runoff these were highly diluted but not so diluted during periods of minimum stream flow. Thus, nonorganic wastes of inland origin and intermittently of high concentration have flowed into the coastal area. Some of these saline wastes are known to have infiltrated below the land surface in the inland part of the area and to have remained there as local potential sources of contamination.

Much of this disposal of industrial wastes into the Los Angeles River has been stopped (as of 1945). Thus, at low flow in 1941–42, as it entered the coastal zone at Artesia Street the water of the Los Angeles River ordinarily did not exceed 750 ppm of all dissolved solids, including 160 parts of chloride. This quality is suggested by the partial chemical analyses of samples taken by the Geological Survey at Olive Street and at Long Beach

Boulevard, respectively, about a mile upstream and a mile downstread from the inland boundary of the coastal zone (see table 32).

Within the reach downstream from Artesia Street, the Los Angeles River now (1945) receives its first large discharge of nonorganic wastes from the skimming sumps of Oil Operators, Inc., just upstream from Wardlow Road and 2.8 miles upstream beyond the reach of ordinary tides (see p. 63). This waste is essentially a connate brine whose chloride content has ranged from at least 9,000 to 16,000 ppm since 1932. Its daily volume, which has not fluctuated greatly, has been equivalent to a steady flow of 6.5 cfs as of 1933–34, of 4.2 cfs as of 1945, and of 4.4 cfs from 1928 through 1943. So far as known, industrial wastes never have been discharged into the river channel downstream from these skimming sumps.

Until 1940 or 1941, these waste fluids at times made up the greater part of the dry-season flow in the coastal reach of Los Angeles River, but intermittently they were greatly diluted during periods of storm runoff. Thus, as shown by samples taken by the city of Long Beach about monthly from 1932 into 1940 at State Street and monthly since 1938 at Willow Street, also infrequently in 1941–43 by the Geological Survey at State Street and at Anaheim Street (1½ miles and 1 mile from the coast, respectively; see table 32), the common range of the water in the river channel there has been from 2,500 to 30,000 ppm of all dissolved solids, including about 1,100 to 22,000 parts of chloride; the extreme range has been from 660 to 55,000 parts of total dissolved solids, including 98 to 31,000 parts of chloride. Since 1941, with the substantial minimum flow due to ground-water overflow from the San Fernando Valley, the range in chloride content has been from 950 to 3,200 ppm.

The saline wastes in the coastal reach of the Los Angeles River are of substantially greater density than fresh water and are under a head greater than that of the underlying and adjucent body of unconfined ground-water. Under these conditions, both by displacement due to greater density (irrespective of head) and by percolation induced by greater head, the wastes at times doubtless have entered and now (1945) are entering the ground-water body; also, some ultimately have reached or now can reach the underlying highly permeable Gaspur water-bearing zone. In other words, the concentrated nonorganic industrial wastes of the coastal area continue to be potential contaminants of the usable ground-water bodies after those wastes have been discharged into the river.

The Dominguez Channel (which traverses the extreme western part of the coastal area, and which discharges into the east basin of the harbor 2 miles west of Los Angeles River) has been the means for disposal of waste brines from the Dominguez and Rosecrans oil fields (p. 70); the Rosecrans field is northwest of the area described in this report) and of waste fluids from the several large oil refineries in its vicinity. The volume of these wastes has been and, as of 1945, is as great as or greater than that of wastes carried by the coastal reach of the Los Angeles River. According to reports assembled in 1932 in the pollution survey by the city of Long Beach, oil-field and refinery wastes were being discharged into the channel throughout its reach from the Laguna Dominguez (Main Street) to Watson Junction (Willow Street), that is, in the reach between 8 and 3½ miles from the coast. Effluent from the sewage-disposal plant of the Los Angeles County Sanitation District also entered the channel about three-fourths mile above the downstream end of the reach. Four samples taken from the channel for that survey between February and April 1932 showed a downstream range in chloride content from 1,314 ppm at Main Street (Laguna Dominguez) to 201 parts at Willow Street. The downstream sample was taken below the outfall from the sewage-disposal plant, whose effluent then ranged from 135 to 202 ppm of chloride. According to samples taken by the Geological Survey in 1942–43 (table 32), the water of the Dominguez Channel then ranged at least from 145 to 10,000 ppm of chloride and from 700 to 16,000 ppm of total dissolved solids at the Laguna Dominguez (Main Street), but only from 4,010 to 5,410 ppm of chloride and from 8,000 to 10,000 ppm of total solids at Wilmington Avenue (about 1¼ miles upstream from Willow Street). One sample taken by the Geological Survey at Willow Street contained about 60 percent as much chloride and total dissolved solids as those in the simultaneous sample at Wilmington Avenue.

Like those in Los Angeles River, the saline wastes of the Dominguez Channel are of substantially greater density than fresh water and usually are under a head greater than that of the underlying body of unconfined ground water. However, the channel is underlain at most places by deposits appreciably less permeable than the silt and fine sand that compose the flood-plain deposits along the Los Angeles River. Specifically, from the Laguna Dominguez downstream to about Wilmington Avenue the Dominguez Channel is underlain by playa deposits, which are essentially fine-grained silt and clay of low permeability. In the succeeding 2-mile reach downstream the former channel was underlain by deposits of Pleistocene age but of very low permeability. However, beginning about 3 miles from the coast the channel passes onto the flood-plain deposits of the Los Angeles River, and is alined roughly with the western edge of the underlying Gaspur water-bearing zone (pl. 6). In this reach nearest the coast, saline water from Dominguez Channel ultimately may reach the Gaspur water-bearing zone, but in the two reaches upstream probably very little of the saline water infiltrates the channel bed.

CHARACTER AND OCCURRENCE OF INTERIOR CONTAMINANTS

The native interior contaminants of the area, that is, from sources within the deposits of Recent and Pleistocene ages, are chiefly the native waters of inferior quality whose chemical character has been described (see p. 50). These include: (1) unconfined and semiperched waters in the upper division of the Recent deposits, which in the coastward half of the Downey Plain are extensively unfit for use, whose natural content of dissolved solids reaches a known maximum of 57,300 ppm (160 percent of ocean-water concentration), and whose native poor quality has been greatly aggravated by contamination in the Dominguez and Santa Ana Gaps; (2) certain confined waters of diverse but inferior quality that occur locally in the Pleistocene deposits beneath the inland margin of the Downey and Tustin Plains and ordinarily within 300 ft beneath the land surface, and that may include interstitial waters in deposits of low permeability; and (3) certain native saline waters confined in the San Pedro formation beneath the southeast flank of the Palos Verdes Hills, from the eastern part of the Dominguez Gap some 14 miles along the coast roughly to the far side of the Bolsa Gap, and also beneath the eastern part of the Santa Ana Gap and the adjacent central and southern parts of the Newport Mesa.

A fourth interior source of potential contamination includes the southernmost reaches of the Gaspur and Talbert water-bearing zones beneath the Dominguez and Santa Ana Gaps; under natural conditions these two zones contained water of good chemical quality but each has been invaded rather extensively by exterior contaminants (see pp. 167, 92).

Of these four interior sources of potential contamination the semiperched waters of the Recent deposits, and the confined waters in the Gaspur and Talbert water-bearing zones and those in the upper part of the Pleistocene deposits, all overlie native water bodies of good quality from which large amounts of water are withdrawn for use, and all must be penetrated by wells that tap the waters of good quality below. These interior contaminants can move downward only where or when their static pressure level is higher than the pressure level—either static level or pumping level—of the underlying water-bearing zone, and the potential rate of movement increases in proportion to this difference in head. Conditions thus favorable to downward movement of contaminants exist extensively in the area but are most serious by far in the Dominguez Gap, where as of 1945 the differential head is from 45 to 60 ft (p. 169). The remaining interior source of potential contamination—the saline-water bodies of the San Pedro formation—underlies water of good chemical quality and has been reached inadvertently by wells in the eastern part of the Santa Ana Gap and the adjacent part of the Newport Mesa. Contamination from this source can be prevented and controlled effectively by securely plugging the bottoms of all wells drilled into it.

MODIFICATIONS IN CHEMICAL CHARACTER OF THE CONTAMINATED WATERS

The simplest possible case of ground-water contamination would involve a mixture of the native ground water and the invading water, without chemical reaction of the waters with one another or with constituents of the water-bearing materials. If the contamination had been of this sort, the analysis of a depreciated water ordinarily would suffice to discriminate among the potential natural contaminants, whose chemical characters differ considerably (see table 8). Actually, however most of the contaminated waters of the area have been profoundly modified by chemical reactions which involve all the major constituents other than chloride, so that ordinarily the ratios of these major constituents one to another can not serve to discriminate between ocean water and connate water as the particular contaminant. The general nature of these reactions is described in the next paragraphs as a necessary background for the descriptions of contaminated waters and contaminated areas to follow.

BASE-EXCHANGE REACTIONS

PRINCIPLES

The exchange of bases between ground waters and their containing materials whereby the water is modified in its ratios of calcium, magnesium, and sodium to one another without substantial change in concentration has been offered by Renick

(1924) as the explanation of certain native soft waters in the interior United States, and by Foster (1942) to account for the softening of certain salty ground waters in coastal areas of the eastern and southeastern United States. That this process goes on extensively has become well established. Briefly, in the "glauconitic" minerals and in certain clay-forming minerals the bases (calcium, magnesium, sodium, and potassium) are held loosely in part, and can be held in variable proportions. In the presence of a natural water with whose chemical composition it is not in equilibrium, any of these particular minerals (and possibly some types of organic matter associated with sedimentary deposits) has the property of releasing to the water a part of the base or bases most loosely held and of adsorbing from the water an equivalent amount of the base or bases for which it has a stronger bond. This process of exchanging bases goes on until an equilibrium is reached between the proportions of the several bases in the mineral and in the water or until the exchangeable bases are exhausted in one or the other. The effect in the chemical character of the water is an increase in one or more bases and an ion-for-ion decrease in one or more of the remaining bases.

The degree and readiness of base exchange seem to follow the law of mass action—that is, if water or mineral holds some base in large excess the exchange of that base for another proceeds more readily (and ultimately to a greater degree?). Also, the several bases differ greatly in their "exchangeabilities." Thus, Kelley and Liebig (1934, p. 360) state that:

> The replacing power, or what is sometimes called the energy of replacement of the different metallic cations, differs widely. It is well established that calcium possesses high replacing power; magnesium stands next, followed by potassium and then by sodium. This means that sodium clay is relatively easily converted into calcium clay.

In other words, regarding readiness of displacement from an exchange-mineral by a natural water, the decreasing rank of the common bases is sodium, potassium, magnesium, then calcium. Other conditions being equal, a natural water is softened much more readily than hardened by base exchange, so that the relative abundance of naturally softened waters is not astonishing.

These principles explain statements by Kelley (1939, p. 455) to the effect that if a sediment containing exchange-minerals saturated in calcium is leached for a long time with a dilute solution of sodium chloride only a "limited" amount of the calcium is exchanged into the water, and that a fairly concentrated solution of sodium chloride is required to displace all the adsorbed and replaceable calcium of the sediment; but if a sodium-saturated sediment is subjected to prolonged leaching with a dilute solution of a calcium salt, practically all the exchangeable sodium ultimately will have passed into the water, provided the spent solution can drain off effectively. They offer an explanation of the seemingly anomalous results of recent base-exchange experiments by Spencer and Murata, which indicated that certain pure clays, when transported to the ocean by rivers, released 3 parts of calcium to the ocean water but adsorbed 1 part of magnesium and presumably 2 parts of sodium—amounts recomputed in terms of chemical equivalents (Bramlette and Bradley, 1940, pp. 20-21).

The seeming anomaly of these results is that the clay adsorbed half as much magnesium as sodium, whereas the large relative excess of sodium in the ocean water might casually be taken to indicate that magnesium should have been released rather than adsorbed. However, the exchange-minerals of the clay presumably had been in equilibrium with river water in which the ratio of calcium to magnesium presumably was greater than 1, and were transported into ocean water in which that ratio was about 0.2 (in terms of chemical equivalents). Thus, in comparison with ocean water the clay doubtless was substantially deficient in magnesium as well as obviously deficient in sodium. The results of these experiments bear directly on base-exchange modification of water in the area.

BASE-EXCHANGE IN CONTAMINATED WATERS

In certain strongly contaminated waters of the area the content of chloride reaches several thousand parts per million but among the bases the corresponding increase is largely in calcium rather than in sodium (for example, see pp. 105–107). Without known exception, these waters in which the contents of chloride and calcium both are abnormally large have been drawn only from wells that first yielded water of good chemical quality. Under these circumstances and because available analytical data seemingly are adequate to preclude any native calcium chloride water in a concentration sufficient to have caused the contamination by simple admixture, it is concluded tentatively that the ordinary contaminant is either ocean water or brine of connate origin, and that base-exchange reactions in the contaminated zones have substituted calcium (and locally some magnesium) for a large part of the sodium in the contaminating water. In other words, the strongly contaminated waters have been hardened by base-exchange reactions. The degree of hardening is extraordinarily great, as is brought out specifically in the following study of the contaminated-water areas. As background for this study, it is pertinent here to review certain geochemical features of the native uncontaminated waters.

Thus, among the native waters of good chemical quality, it has been brought out that calcium bicarbonate waters of meteoric origin occupy the deposits of Recent age, and the successively underlying latest Pleistocene and unnamed upper Pleistocene deposits; also that in the still deeper San Pedro formation calcium bicarbonate waters occupy two lobes which extend coastward from the Whittier Narrows and from the Santa Ana Canyon, and whose vertical range extends downward roughly through the upper half of the formation in the inland part of the area but only into the topmost part of the formation near the coast. At depths greater than this range of calcium bicarbonate waters, the native waters of good quality pass into sodium bicarbonate waters whose chemical quality is the result of natural softening. (See pp. 36–38). Table 9 suggests the average ratios between the several bases in the native waters according to water-quality ranges, and brings out the effects of natural softening in the Silverado zone and in the lower part of the San Pedro formation.

TABLE 9.—*Approximate average ratios between constituents in the native fresh waters of good chemical quality*

[In terms of equivalents; based on average chemical characters as shown in table 4]

Water-quality range	Ratios			
	Calcium to magnesium	Calcium to sodium	Magnesium to sodium	Bicarbonate to sulfate
Unconfined waters	2.4	1.9	0.8	3.6
Confined waters:				
Gaspur water-bearing zone (range 1)	3.5	1.9	.5	3.9
Talbert water-bearing zone (range 1)	3.1	1.7	.5	3.8
Uppermost Pleistocene deposits (range 2)	2.8	1.8	.6	3.6
Unnamed upper Pleistocene deposits (range 3)	2.6	1.7	.7	3.1
Uppermost part of San Pedro formation (range 4)	3.5	1.9	.5	4.7
Upper part of San Pedro formation, beyond the Silverado water-bearing zone (range 5)	2.9	1.7	.6	4.0
Upper part of Silverado water-bearing zone (range 5)	3.2	.7	.2	6.5
Lower part of San Pedro formation, beyond the Silverado zone (range 6)	2.6	.14	.06	13
Lower part of Silverado water-bearing zone (range 6)	4.9	.14	.03	11
Basal division of San Pedro formation (range 7)	6.7	.09	.01	68

Base-exchange materials doubtless exist in the water-bearing materials of the area, especially in the San Pedro formation, and under native conditions their exchangeable bases presumably have been in proportions essentially at equilibrium with those of the native waters as shown in table 9. Thus before influx of a contaminant, the existing base-exchange materials were at equilibrium with waters containing fewer than 500 ppm of dissolved solids, in which the calcium-to-magnesium-to-sodium ratio was 1.8 to 0.6 to 1, ranging from the surface downward roughly to the Silverado water-bearing zone in the vicinity of Long Beach and Wilmington (see pl. 9), and elsewhere through approximately the upper half of the San Pedro formation. At increasingly greater depths this ratio passed to about 0.09 to 0.01 to 1 in the basal division of the San Pedro formation. (Ratios are in terms of equivalents.) In contrast, the corresponding ratio for standard ocean water is 0.04 to 0.2 to 1, and for the connate waters of table 29 the ratio is about 0.06 to 0.04 to 1 on the average but ranges from 0.15–0.02 to 0.12–0.002 to 1 among the 20 representative waters.

From these ratios it is inferred that with an influx of ocean water into the zone of native calcium bicarbonate waters the base-exchange minerals would release calcium in considerable amount, and magnesium in a much smaller amount or not at all, and they would adsorb sodium. Thus, the contaminated water would contain much more calcium and possibly more magnesium than the theoretical mixture of native water and contaminant, and its content of sodium would be less than the theoretical by the amount of the increase in calcium and magnesium (in terms of chemical equivalents). Likewise, if the sodium bicarbonate waters of the lower part of the San Pedro formation were contaminated by ocean water, less and less calcium and magnesium should be released from base-exchange minerals in successively deeper zones until in the basal division of the San Pedro formation the contaminated water would differ very little from the theoretical mixture and that difference would be mainly in loss of magnesium. On the other hand, with an influx of the connate water into the zone of calcium bicarbonate waters, the actual contaminated water should contain considerably more calcium and more magnesium than the theoretical mixture; and in those connate waters of least magnesium-to-sodium ratio, the gain in magnesium might be substantially more than the gain in calcium. At the other extreme, with influx of connate water into the basal division of the San Pedro formation, there would be only a moderate gain in calcium, from a small gain to a moderate loss of magnesium, and a compensating loss in sodium. Thus, it would seem that only connate water could have caused contamination in which the magnesium content of the product is substantially greater than that of the theoretical mixture, especially if the excess of magnesium is greater than the excess of calcium. However, the converse is not true: magnesium deficiency could occur with contamination either by ocean water or by certain of the connate waters.

SULFATE REDUCTION

Many contaminated waters in the area contain less sulfate and more bicarbonate than would result from simple mixture of native water and contaminant in the proportions indicated by the several amounts of chloride. This sulfate deficiency doubtless is due to sulfate reduction—a reaction which is not fully understood, but which goes on commonly in the waters of sediments that contain organic matter, and which has the effect of a molecule-for-molecule substitution of bicarbonate for sulfate in the water. Various aspects of this reaction have been treated by Bastin and others (1926, p. 21), Behre and Summerbell (1934, p. 39), Jenny (1903, p. 445), Rogers (1917, p. 99), and Foster (1942, pp. 848–850).

In the native waters of good quality the bicarbonate-to-sulfate ratio is about 3.8 in zones between land surface and about middepth in the San Pedro formation, that is, in the native calcium bicarbonate waters. In zones still deeper the ratio increases to nearly 70 in the basal division of the San Pedro. In contrast, the bicarbonate-to-sulfate ratio in standard ocean water is 0.04, and for the connate waters is 132 on the average but ranges from 1,190 to 1.1 among the 15 representative analyses which report sulfate in table 29. Three additional analyses in that table report no sulfate; in such waters the ratio equivalent would be very large. Even though the native waters and these principal native contaminants differ so much in their bicarbonate-to-sulfate ratios, in the contaminated waters the sulfate commonly has been reduced to the point that it cannot indicate the source of the contaminant.

CRITERIA FOR DISCRIMINATING CONTAMINANTS

Of the major dissolved constituents in the native fresh waters and native contaminants in the Long Beach-Santa Ana area, only chloride probably remains chemically inert in the zones of contamination. Hence, the amount of this constituent in a brine-contaminated water can be taken with assurance to indicate the proportion in which native water and brine have come together, provided the source of the brine and its chemical composition are known or reasonably can be inferred. In the contaminated water, owing largely to exchange of bases and reduction of sulfate, the amounts of all other major constituents commonly are so much greater or so much less than in a simple mixture of the proportions indicated by the amount of chloride, that no single major constituent or ratio between such constituents affords an infallible means of discriminating between ocean water and connate water as the particular contaminant.

In certain areas of small extent, bases have been exchanged or sulfate has been reduced only to a slight degree so that the identity of the contaminant is obvious from the composition of the contaminated water, but this condition is the exception rather than the rule. In contaminated waters that have been substantially modified, a content of magnesium considerably greater than that of the theoretical mixture may identify the contaminant as a connate brine, but this criterion must be applied discreetly. Likewise, sulfate may identify ocean water provided its amount is greater than could have been introduced by any connate water in the absence of reducing conditions.

Discordance in the minor constituents of ocean water and of connate brines affords some basis for discriminating these as contaminants (see table 8), as follows:

Barium (Ba) exceeding a few tens of parts per million in a contaminated water is presumptive evidence that the contaminant is a connate brine. However, so large a quantity of barium can not remain dissolved in the presence of plentiful sulfate and, following reduction of its sulfate, a water contaminated from the ocean might dissolve barium from the containing materials.

Borate (BO_3) in amounts such that in the constituents added by contamination the chloride-to-borate ratio is substantially less than 750 in terms of parts per million, or less than 415 in terms of equivalents, would be presumptive evidence of contamination by a connate water. However, the borate content in native waters of good quality ranges from 0.3 to 2.7 ppm, so that the amount of this constituent in a contaminated water is not a sensitive indicator of the source. Borate presumably is inert in the zones of contamination.

Iodide (I) exceeding a few tenths of a part per million would indicate contamination by connate brine. However, there is some disagreement as to whether iodide remains inert in the zone of contamination, and whether its virtual absence necessarily would indicate contamination by ocean water.

Bromide (Br) in amounts such that in the constituents introduced by contamination the chloride-to-bromide ratio is substantially less than 290 in terms of parts per million, or less than 650 in terms of equivalents likewise would be presumptive evidence of contamination by a connate brine. Because the bromide in standard ocean water is roughly a third of the greatest amount known in the connate brines, this constituent is not sensitive as an indicator of source of contamination. Presumably bromide is inert in the zones of contamination.

In this area the Geological Survey, by preliminary spectrographic determinations, explored the possibility that inert trace elements might afford a sharp distinction between ocean water and connate waters as sources of contamination. The procedure was unsuccessful, not only because the assemblages of trace elements in the two potential contaminants were found to be essentially identical in the particular samples studied, but especially because the native fresh water of good quality was found to contain by far the greatest variety of such elements.

Accordingly, for any further investigation of water contamination in the area or its vicinity it appears highly desirable to determine barium, borate, and iodide in all analyses of contaminated waters, as the most promising indicators for discriminating ocean water from brine of connate origin as the cause of contamination. For the purposes of this investigation, it is unfortunate that these three constituents had been determined in relatively few of the many analyses available for interpretation.

DEPRECIATION OF WATER QUALITY IN ORANGE COUNTY

CONTAMINATION IN SANTA ANA GAP

GEOLOGIC FEATURES

The Santa Ana Gap, the easterly of the most critical two districts of water-quality depreciation in the area, is floored by deposits of Recent age from land surface to a depth ranging from 120 to 160 ft. An upper division of these deposits consists of silt, clay, and fine sand in interfingered beds, is from 60 to 90 ft thick, and is of low permeability. It contains a body of semiperched water which is largely unconfined and natively of very inferior chemical quality near the coast, and which has essentially no hydraulic continuity with the main body of confined water below.

A lower division of the Recent deposits in this gap, the Talbert water-bearing zone, is composed chiefly of gravel but locally of sand in its upper part, ranges in thickness from 40 to 100 ft, and spans essentially the full width of the gap. (See pl. 11.) This water-bearing zone extends inland into the Santa Ana Canyon and under natural conditions has functioned as a ground-water artery which conveyed fresh water from its inland forebay area far into the gap and probably into the ocean.

The Talbert water-bearing zone rests directly on deposits of Pleistocene age, probably the San Pedro formation in large part, which within the gap includes permeable and impermeable beds in succession, and which are rather complexly deformed. Thus, certain faults* (pl. 11) here divide the Pleistocene into several distinct blocks which greatly affect water circulation and reach of contamination. The inferred or known faults fall into two sets, one trending southeast across the gap and the other trending somewhat east of north.

Of two known faults or fault zones that trend southeastward parallel to the coast, one which is about 1¼ miles inland passes through the intersection of Cannery and Atlanta Avenues and is believed to be the master fault of the Newport-Inglewood structural zone; the other is parallel, a mile to the south, and a third of a mile from the coast. Between these two, a mile-wide block of Pleistocene water-bearing deposits is downthrown to the south. A third fault which also strikes southeast is inferred to dislocate the Pleistocene of the Newport Mesa still farther inland, and to cross Adams Avenue near the south quarter corner of sec. 4, T. 6 S., R. 10 W.

Beneath the easternmost part of the gap the Pleistocene is cut by an inferred fault, or shear zone, which strikes roughly north nearly along Wright Street, and which extends some 2 miles in that direction from a point on the master fault in the southeast quadrant of Bushard and Hamilton Streets. The chemical character of waters suggests that this so-called Wright Street fault may extend southward beyond the terminus shown on plate 11. Along it the deposits of Pleistocene age are downthrown to the east, and the displacement is about the same as that at the master fault.

Each of the faults here described appears to be a zone of close shearing rather than a single plane of rupture; seemingly none extends into and dislocates the Talbert water-bearing zone above. Across them there is sensibly no physical continuity of water-bearing beds in the Pleistocene and there seems to be no hydraulic continuity except that afforded by the overlying and interconnecting regional ground-water artery, that is, the Talbert water-bearing zone. Thus, hydrologically the Santa Ana Gap is underlain by three distinct blocks.

In the mile-wide block on the coastward side of the master fault, the Talbert water-bearing zone rests upon beds of sand and gravel which there constitute the Pleistocene, which at the abandoned well field of the city of Newport Beach (6/10–18K) extend at least to 330 ft below land surface, and which over all the block extend to 300 ft on the average. Although these beds of sand and gravel alternate with silt and clay at least locally, all seem to be in essential hydraulic continuity with one another and with the Talbert zone above.

In the up-faulted block to the north, for about a mile inland from the master fault and westward from the north-trending fault near Wright Street, the Talbert water-bearing zone rests directly on impermeable rocks of Pleistocene age and these in turn on rocks of Pliocene age which contain no water-bearing beds at least to 1,000 ft below land surface. Here, therefore, is an effective barrier to inland movement of salt water through the Pleistocene, for across this mile-wide reach only the Talbert is water-bearing.

Still farther inland within this same block, beginning near the intersection of Cannery and Adams Avenues, the Talbert water-bearing zone rests on northward-dipping beds of sand and gravel, silt, and clay which are of Pleistocene age, and which thicken northward to 2,000 ft or more in the vicinity of Santa Ana. These Pleistocene deposits include productive water-bearing zones which probably have substantial hydraulic continuity with the overlying Talbert zone.

In the easternmost of the three blocks—that which extends eastward from the so-called Wright Street fault and which is down-faulted—the Talbert water-bearing zone seems to be underlain by successive water-bearing beds of Pleistocene age, of which the deepest reached by wells is about 300 ft below land surface. As is shown later, however, the native water in the several water-bearing zones here is markedly variable in chemical character, a condition suggesting that structural and stratigraphic traps—caused jointly by disconformities and by shearing in and near the fault zone—here impede free circulation of water within the Pleistocene and between the Pleistocene and the overlying Talbert zone. Thus, in this eastern block, the Talbert zone and the permeable deposits of the underlying Pleistocene do not constitute a single hydrologic zone as in the coastal block. Regarding the Pleistocene alone, however, it is believed that the permeable beds beneath this eastern segment of the Santa Ana Gap are in partial hydraulic continuity with those that underlie the central part of the Newport Mesa.

This general conception of the position, thickness, extent, and hydraulic continuity of water-bearing deposits beneath the Santa Ana Gap is fundamental to the detailed examination of chemical features that follows. Further details are presented in a separate report on geologic features (Poland Piper, and others).

CHARACTER AND OCCURENCE OF NATIVE FRESH WATERS AND OF INTERIOR CONTAMINANTS

It has been brought out that in the Talbert water-bearing zone (the regional ground-water artery which extends through the Santa Ana Gap to the ocean) the native or uncontaminated waters were of three types: (1) calcium bicarbonate water with dissolved solids from 250 to 350 ppm (see pl. 6 and table 4, analyses 5/10–32C1 and 6/10–6B1), from the inland forebay area coastward into the gap, or to within 1¼ miles of the master southeast-trending fault heretofore described; (2) calcium sodium bicarbonate water with about 250 parts of dissolved solids (pl. 6 and table 4, analyses 6/10–8D2 and –18C2, 6/11–12C2), onward to or nearly to the coast in the area west of the Santa Ana River and probably east of the river locally; and (3) salty water with dissolved solids at least as great as 6,250 ppm, locally and probably rather extensively east of the Santa Ana River southward from Adams Avenue, also locally west of the river from Hamilton Street toward the coast. The calcium bicarbonate water of the inland reach is that which enters the Talbert at its forebay area and thence moves oceanward, whereas the decidedly softer calcium sodium bicarbonate water in the coastal segment of the gap is believed to result from inblending of a small proportion of water from the underlying Pleistocene with the water of inland origin. In this connection, it is pertinent that the zone of transition within the Talbert from the harder, inland water to the softer, coastal water overlies north-dipping water-bearing zones in the upfaulted Pleistocene block, zones which have been described and inferred to be in hydraulic continuity with the overlying Talbert.

The salty water native in the Talbert water-bearing zone beneath the easternmost part of the gap was first recorded by the Mendenhall inventory of 1904. Thus, two wells then existing in the Santa Ana Gap and less than 100 ft deep—nos. 1323 and 1324 of the Santa Ana quadrangle (1905a, p. 135; see also pl. 2)—produced water with approximate total solids of 930 and 1,550 ppm, respectively; also presumably with several hundred parts of chloride. These two wells were respectively 1,200 ft and 2,500 ft south of Hamilton Street and both about 1,250 ft east of Bushard

Street. The more northerly well of the two was just east of the intersection of the Wright Street fault with the master fault of the Newport-Inglewood zone (pl. 11) and only a quarter of a mile southwest of the present well field of the Fairview Farms Water Co. and the Newport Mesa Irrigation District. (See pp. 112–120.) Both wells presumably tapped only the Talbert zone, and both flowed by artesian pressure. It is believed that the salty water of these wells probably was not of depreciated quality as of 1904 but was native in the Talbert of the vicinity, also that this occurrence of salty water in the Talbert under native conditions was due to the inblending of a small connate-water component from the underlying Pleistocene (see p. 61) with a large component from the coastward-moving water of forebay origin. Evidently, therefore, the head of the water in the Talbert, as of 1904, locally was insufficient to prevent upward movement of water from the underlying Pleistocene deposits, although sufficient to preclude all infiltration from the land surface or from unconfined, shallow ground water. Also, this condition probably existed before the natural pressure heads of the several water bodies had been disturbed by the construction of flowing wells, beginning about the seventies.

Within the mile-wide coastal block that lies south of the master fault, the Pleistocene deposits, which underlie and are there in hydraulic continuity with the Talbert water-bearing zone, evidently contained water of good quality under native conditions, at least locally. Thus, certain wells of the initial public-supply field of Newport Beach (now abandoned), in the southeast angle of Bushard and Hamilton Streets, there tapped the Pleistocene and in 1925 under native conditions produced sodium bicarbonate water containing only 248 ppm of dissolved solids and 13 parts of chloride. Water of the same general chemical character also has been found in the Pleistocene of the down-faulted block to the northeast—specifically, in well 6/10–8D4 (city of Newport Beach, well 8); a bailed sample, taken in December 1934, while the well was under construction and 232 ft deep, was of sodium bicarbonate water with 355 ppm of dissolved solids and 53 parts of chloride (table 30). Soft, sodium bicarbonate waters such as encountered in the two wells just described are presumed to be or to have been native and extensive in the uppermost part of the Pleistocene that is in hydraulic continuity with the overlying Talbert water-bearing zone beneath the greater part of the Santa Ana Gap.

However, within the down-faulted block east of the Wright

Street fault the native waters in the Pleistocene deposits are generally of variable and somewhat inferior quality. Thus, in the southwest angle of Hamilton Street and the Santa Ana River, well 6/10–18J6 (well 1 of the Newport Mesa Irrigation District, about 1,200 ft west of the river and just south of Hamilton Street) was drilled 332 ft deep in 1918 or 1919 and its casing was then perforated from 194 to 222 and from 265 to 314 ft below land surface, or wholly in Pleistocene deposits. According to an analysis of February 1921, the water presumably there drawn from the Pleistocene contained 255 ppm of chloride and 679 parts of dissolved solids. (See table 30.) Subsequently these perforations have been plugged off and the casing reperforated from 65 to 101 ft below land surface, or wholly in the Talbert zone, presumably to obtain water of better quality. At almost the same location, well 6/10–18J9 (Fairview Farms Water Co., well 1) in 1925 produced water with a chloride content of 121 parts per million; the total-solids content was 436 ppm, or essentially identical with that of 1904 at the same place (see pl. 2). This well is reported to have been perforated from 150 to 300 ft below land surface, largely in the Pleistocene but probably partly in the Talbert water-bearing zone. Also, well 6/10–18J8 (Newport Mesa Irrigation District, well 3) was drilled to a depth of 165 ft about 1931; its casing never was perforated because its water was "salty as ocean," according to unconfirmed report.

About half a mile to the southeast, roughly a mile from the coast and 0.1 mile east of the Santa Ana River, well 6/10–20D1 was drilled in 1924 and is reported to have tapped salty water from 220 to 240 ft below land surface.

East of the Santa Ana River and north of Hamilton Street, two wells are reported to have been drilled in 1913 for the Fairview Farms Water Co. (6/10–17C1 and –17E1), but at that time were not placed in service owing to the high salt content in the water. (See p. 126.) A third and adjacent well completed in 1922 to a depth of 161½ ft produced water with 548 ppm of chloride, and a sample from its water surface in early 1932 contained 682 parts of chloride. This third well tapped gravel from 124 to 159 ft below land surface, and presumably derived at least part of its water from Pleistocene deposits.

About a mile still farther north and just east from the north terminus of the Wright Street fault as drawn on plate 11, well 6/10–8D4 (city of Newport Beach, well 8) in 1934 encountered sodium sulfate water in a concentration of 3,250 ppm of total solids—at a depth of 270 ft below land surface and in the Pleistocene, but at a depth only 38 ft below the soft, sodium bicarbonate water already described. (See table 30.)

About 0.65 mile to the east, well 6/10–8B2 has its casing perforated only in the San Pedro formation and produces water containing nearly 100 ppm of chloride. Evidently, the boundary of the native water of inferior quality in the Talbert water-bearing zone and in the uppermost part of the underlying San Pedro formation passes between this well and well 8D4 to the west.

With the single exception of well 6/10–8D4, which is in an area of waters not now contaminated, these reported instances of salty water tapped by wells in the Santa Ana Gap antedate by several years the earliest incipient depreciation of water quality known to have been caused by influx of saline contaminant. Thus, all are believed to pertain wholly to native conditions of water occurrence. All apply to the down-faulted block of the Pleistocene east of the Wright Street fault, and analogous conditions are not known to have occurred elsewhere within the gap.

These native salty waters, which do not range widely in chemical composition, must exist because water circulation is impeded in the block of the San Pedro formation by which they are contained, and is impeded by structural traps along the margins of the block and by lithologic discontinuities within the block. Essentially, however, they are believed to be the somewhat diluted "top waters" and "edge waters" associated with a body of more salty water that seems to be relatively extensive beneath the central and southern parts of the Newport Mesa. The extent of this more salty body is suggested in the data by Mendenhall in 1904, which are summarized on plate 2 and which indicate native waters containing 1,000 ppm or more of dissolved solids in the area generally east of the Santa Ana River and south of Adams Avenue. That is, the body is roughly coextensive with the down-faulted block here recognized. The chemical character of this saltier body is suggested, though probably not shown in all its variations, by the analyses of a formational sample taken from the San Pedro (?) formation in well 6/10–8D4 (table 30, analysis 3) and of a sample bailed from the bottom of well 6/10–18J2 on April 12, 1945 (table 30, also). These two wells are in the eastern part of the Santa Ana Gap; both are only a few hundred feet east of the so-called Wright Street fault, and near either end of that fault as shown on plate 11. Flowing well 6/11–13Q1, which is midway across the gap and near the coast, taps a body of salt water whose chemical character is inferred to be similar to that of some part of the salt-water body locally native in the Pleistocene deposits beneath the Santa Ana Gap and the Newport Mesa. (See analysis in table 29.)

This body of native salt water beneath the eastern part of the Santa Ana Gap and beneath the adjacent central and southern parts of the Newport Mesa has been inferred (p. 61) to be derived from connate water trapped by the faults here described, never wholly displaced by land-derived water, but diluted and locally modified in composition since trapped. At least in part it was first under an artesian pressure head somewhat greater than that on the Talbert water-bearing zone, so that wherever there was hydraulic continuity its waters would have tended to move westward and upward into the Talbert of the Santa Ana Gap, as in the vicinity of wells 1323 and 1324 of the report by Mendenhall. However, such movement presumably would be effectively checked at the Wright Street fault, along which water-bearing zones in the block to the east butt against impermeable rocks in the mile-wide reach inland from the intersection of Bushard and Hamilton Streets, and across which there appears to be little hydraulic continuity at any place. This natural movement of salt water would be quickened by any drawdown of the fresh-water head incident to withdrawals, and has been quickened in this way by the sustained withdrawals from the Talbert zone over several decades. Under these conditions the main body of trapped salty water, also its top and edge waters of inferior quality, all constitute an interior source of contamination in the Santa Ana Gap.

Certain features of the occurrence of native water along the east side of the Santa Ana Gap are especially well shown by data from the active well field of the city of Newport Beach, which is in sec. 8, T. 6 S., R. 10 W., in the southeast angle of Adams Avenue and Wright Street. During construction of well 6/10–8D4 (city no. 8) of this field in December 1934 and early 1935, samples of water were taken from successive permeable zones and at various stages of the development work, and under service conditions the well has been sampled recurrently since March 1935. Analytical data and conditions of sampling are set forth in table 30 and most of the analyses are shown graphically on figure 8.

A sample from the San Pedro formation in this well at 270 ft below land surface (fig. 8 and table 30, analysis 3) was a sodium-sulfate water containing 3,253 ppm of dissolved solids (among the few for which comprehensive analyses are available, only one other water of modified connate origin from the Pleistocene of the Santa Ana Gap and vicinity contains more dissolved solids).

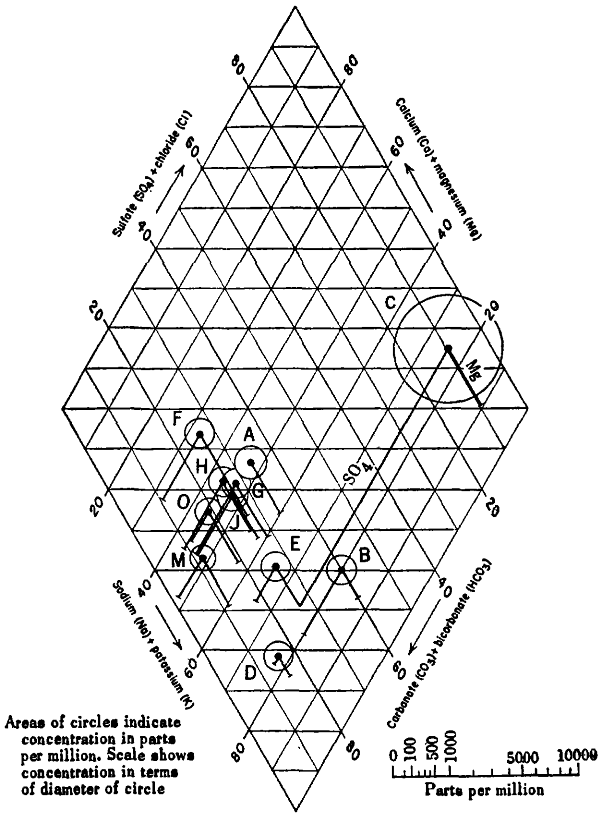


FIGURE 8.—Chemical character of waters from well 6/10–8D4 (city of Newport Beach, well 8). Area of circles is proportional to total dissolved solids in the various samples. Letters refer to analytical data and to statement of conditions of sampling in table 30. (After analyses by city of Long Beach Chemical and Physical Testing Laboratory and by Dr. Carl Wilson, water technologist, of Los Angeles.)

In contrast, another sample from the San Pedro, after the casing of well 8D4 had been perforated through a 30-ft reach only 29 ft above this modified connate water was a sodium bicarbonate water containing only 26 ppm of chloride and 280 parts of all dissolved solids (analysis 4). Still another sample, taken after the well had been plugged back to a depth of 198 ft and its casing reperforated from 86 to 106 ft below land surface, or wholly in the Talbert zone (analysis F), was of calcium bicarbonate water containing 16 ppm of chloride and 229 ppm of all dissolved solids. All three of these waters are native at their respective depths below land surface.

Under subsequent variable conditions of service the chemical quality of water drawn from the well has fluctuated between that of the native water of the Talbert zone and that of the native sodium bicarbonate water in the underlying San Pedro formation; that is, between waters in which the sodium-to-calcium ratios are 0.70 and 4.27 (in terms of chemical equivalents). Evidently, some water has been withdrawn from the San Pedro owing to leakage past the plug at 198 ft, to movement of water upward along the well casing, or to some natural hydraulic continuity between the Talbert and the San Pedro close at hand. However, this variability in chemical character indicates only that waters native to the Talbert zone and to the San Pedro formation are drawn into the well in an inconstant proportion; in no sense does it indicate any depreciation in water quality within the water-bearing beds, and probably does not indicate that sustained withdrawal has caused water of the San Pedro to migrate beyond its native zone. As of 1943–44, the contaminated water front in the Santa Ana Gap was more than a mile to the south.

GENERAL EXTENT OF THE CONTAMINATED WATERS

Data now available indicate that the chemical quality of the water withdrawn from wells in the Santa Ana Gap began to depreciate before 1927 when incipient depreciation occurred in certain wells about a mile inland from the coast. However, the extent and degree of water-quality depreciation at that time are not known. The earliest comprehensive analytical data on the waters of the gap were obtained by local agencies beginning about 1930, by which time waters containing more than about 50 ppm of chloride occupied roughly 1,900 acres in the Talbert water-bearing zone along the coast. (See pl. 11A.) In the area west of the Santa Ana River and north of Hamilton Street, also west of the Wright Street fault and south of Hamilton Street, these waters had been depreciated in quality by influx of a contaminant high in chloride content. In this area well 6/11–13P1, which is about 1½ miles southeast of Huntington Beach and 300 ft inland from the coast, in 1931 yielded water with a chloride content somewhat more than 18,000 ppm, that is, water with essentially the same chloride content as that of the ocean. Also, from the Huntington Beach Mesa eastward roughly to Cannery Avenue the inland fringe of the contaminated waters (approximately shown on plate 11 by the line of 50 ppm of chloride) was between 0.9 and 0.4 mile from the coast; beyond Cannery Avenue the fringe of contaminated waters swerved sharply inland and trended northeast to merge with that of the native inferior waters east of the Santa Ana River.

By 1944 the water produced from well 6/11–13K2 (about a quarter of a mile inland from well 13P1) had increased in chloride content to about 18,000 ppm; thus, it would seem that in the preceding 12 years water as salty as that of the ocean had advanced at least a quarter of a mile. Also, in those 12 yr the area of contaminated water in the Talbert zone had increased from 1,900 to 2,400 acres (see pl. 11*B*). From the Huntington Beach Mesa to within a quarter of a mile of Cannery Avenue, its fringe had moved inland between 0.1 and 0.35 mile, and from Cannery Avenue to Bushard Street had moved inland 0.7 mile. The greatest inland movement of the fringe, in the vicinity of Cannery Avenue and Bushard Street, coincided with the area of heaviest withdrawals in the Santa Ana Gap during the period. Still farther east, beyond Wright Street, the line of 50 ppm of chloride had been sensibly immobile; there, the line continued to represent the front of waters naturally inferior in chemical character.

PROGRESSIVE DEPRECIATION OF WATER QUALITY AT PUBLIC-SUPPLY WELL FIELDS

The most comprehensive information about the manner and degree of water-quality depreciation in the Santa Ana Gap is afforded by analytical data from three public-supply well fields: the abandoned field of the city of Newport Beach, in the southeast angle of Hamilton and Bushard Streets; the field of the Laguna Beach County Water District, about half a mile to the north, in the southwest angle of Bushard Street and Atlanta Avenue; and the common field of the Fairview Farms Water Co. and the Newport Mesa Irrigation District, in the southwest angle of Hamilton Street and the Santa Ana River. Water-quality depreciation in these fields is reviewed later, particularly to bring out a striking difference in the manner and degree of the depreciation on either side of the so-called Wright Street fault. Of these several fields the abandoned field of the city of Newport Beach and the field of the Laguna Beach County Water District are west of the fault, whereas the field of the Fairview Farms Water Co. and the Newport Mesa Irrigation District is east of the fault.

ABANDONED WELL FIELD OF THE CITY OF NEWPORT BEACH

For public supply at Newport Beach, withdrawal of water from the municipal well field in the southeast angle of Bushard and

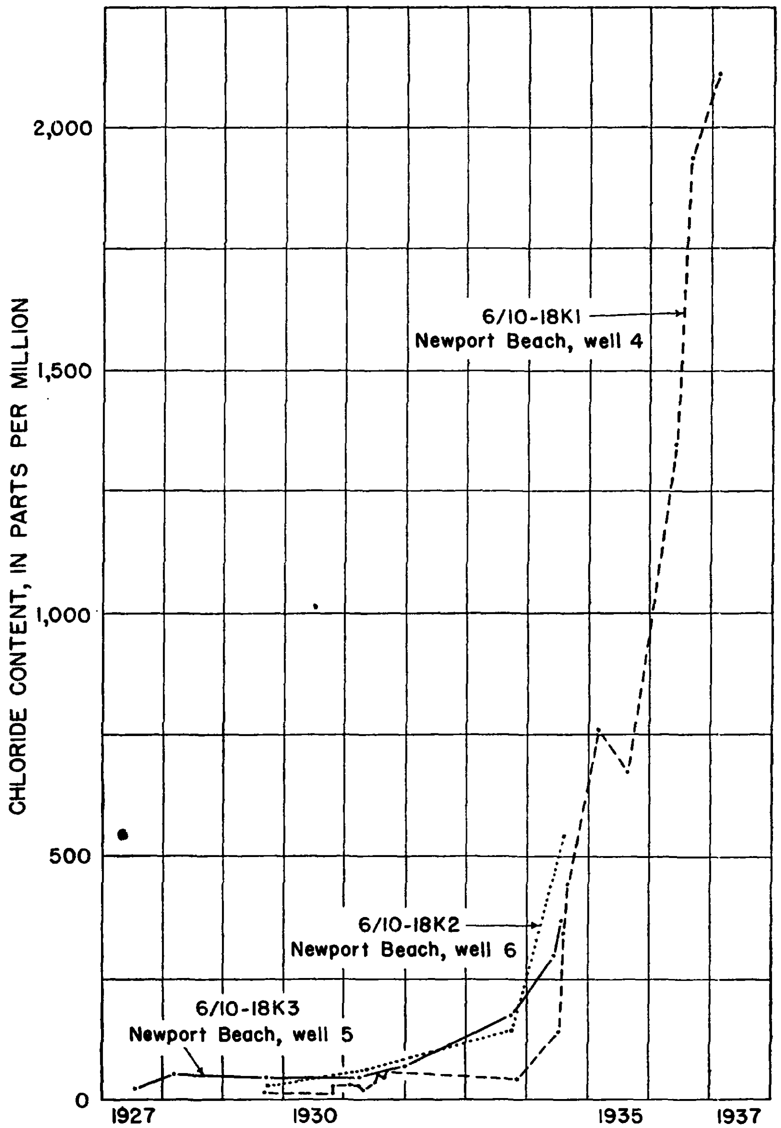


FIGURE 9.—Chloride content of water from three public-supply wells of the city of Newport Beach (abandoned field), 1927–1937.

Hamilton Streets began about 1914. Seven wells ultimately were included in the field and for three of these—6/10–18K1, –18K2, and –18K3 (Newport Beach, wells 4, 6, and 5, respectively)—recurrent chemical analyses are available. (See table 30.) From these analytical records and other data, figure 9 has been prepared to suggest the progressive depreciation in water quality which led to abandonment of the field about 1934.

Of these three wells for which recurrent chemical analyses are available, well 18K1 was 234 ft deep and drew its water largely from the Talbert water-bearing zone but in part from the underlying Pleistocene, probably the San Pedro formation; well 18K2 was 330 ft deep but drew only from the Talbert; and well 18K3 was 336 ft deep and draw only from the San Pedro. All three (also the remaining wells of the field) are in or immediately south of the shear zone that constitutes the master fault of the Newport-Inglewood structural zone and so, because details of stratigraphy and of geologic structure are not clear, the degree of hydraulic continuity among the several water-bearing zones tapped is uncertain: among the several zones of the San Pedro and among these and the Talbert alike. The native or uncontaminated waters first drawn from the wells differed somewhat in chemical character, as is shown in table 30 by the analyses for 18K3 as of August 1927 and for 18K1 as of September 1929. However, in the ensuing progressive depreciation the waters from all three trended toward a common chemical character, indicating contamination from a common source high in chloride content. Characteristically, the contamination has involved an increase in chloride and calcium in nearly equal proportions, and virtually complete removal of sulfate.

Figure 10 diagrams the general chemical character of the native and contaminated waters from well 18K1 from 1929 into 1935, and three potential contaminants. Specifically, the potential contaminants are taken to be represented by the waters of wells 6/11–13Q1 and 6/10–18J2 (bottom sample of April 1945; see table 30 and p. 119), also of the ocean (table 29). With the exception of the analysis of November 1933 and within limits of analytical error, the several waters from well 18K1 plot on this diagram in a straight line between the native, uncontaminated water of September 1929 and the most highly contaminated water of June 1936. This straight-line trend indicates progressive contamination from a single source and in a common manner. However, because their successive plottings do not trend toward the plotting of any one of the three potential chloride contaminants, the chemical characters of the contaminated waters can not have resulted from a simple mixture of native water with the contaminant. The principles of this manner of plotting are described in a separate paper (Piper, 1945, pp. 914–928).

The following table 10 compares the extremely contaminated

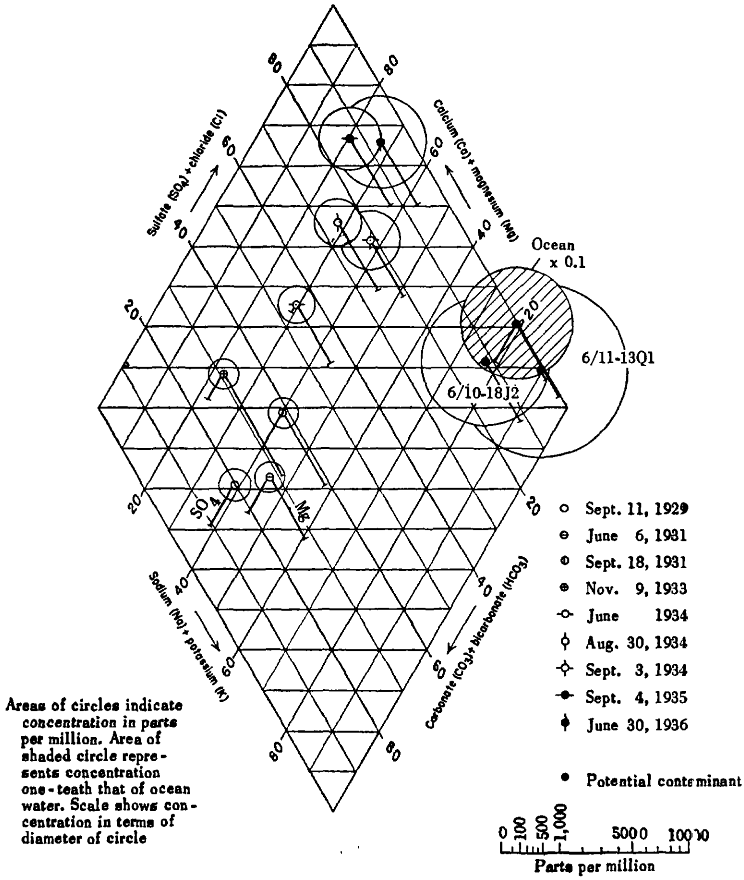


FIGURE 10.—Chemical character of native and contaminated waters from well 6/10–18K1 (Newport Beach, well 4) in 1929–1936, also of potential contaminants.

water from well 18K1 on June 30, 1936 and the hypothetical mixtures of a "standard" uncontaminated water of that well with three potential contaminants high in chloride content. For the purposes of this table and in lieu of the analysis of September 1929 for well 18K1, the standard uncontaminated water is taken to be represented best by the average of analyses for four adjacent wells in 1925 (wells 6/10–7D1 and –7F1, 6/11–12C2 and –12J1) before any known incipient contamination in the area. All three hypothetical mixtures have been calculated to a chloride content identical with that of the contaminated water, because chloride is the only major constituent not likely to be modified by chemical changes in the zone of contamination. Contaminants high in chloride content, other than ocean water, connate waters, and oil-field wastes (which are essentially brine of connate origin), are not known to exist in or near the Santa Ana Gap.

TABLE 10.—*Contaminated water from well 6/10–18K1 in comparison with hypothetical mixtures of the "standard" native water of that well with three potential contaminants*

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Standard native water of Talbert zone	42	5.1	44	205	32	10
Well 6/10–18K1, contaminated water of June 30, 1936 (table 30)	466	77	255	166	0	1,346
Standard native water mixed with bottom water of well 6/10–18J2	90	79	778	400	14	1,346
Standard native water mixed with brine of well 6/11–13Q1	97	11	811	158	24	1,346
Standard native water mixed with ocean water	67	94	799	206	217	1,346
Equivalents per million:						
6/10–18K1, June 30, 1936	23.26	6.33	11.09	2.72	0	37.96
Mixture with 18J2	4.47	6.51	33.84	6.56	.30	37.96
Mixture with 13Q1	4.84	.94	35.27	2.59	.50	37.96
Mixture with ocean water	3.36	7.76	34.73	3.38	4.51	37.96
Excess (+) or deficiency (–) of the contaminated water with respect to:						
Mixture with 18J2	+18.79	–.18	–22.75	–3.84	–.30	----------
Mixture with 13Q1	+18.42	+5.39	–24.18	+.13	–.50	----------
Mixture with ocean water	+19.90	–1.43	–23.64	–.66	–4.51	----------

[1] Includes equivalent of potassium (K).
[2] Includes equivalent of carbonate (CO_3) if any.

As figure 10 has indicated and as the table shows specifically, the contaminated water contains much more calcium and much less sodium than any of the three hypothetical mixtures. Its magnesium content is approximately equal to that of the mixture with the bottom water of well 6/10–18J2, is much more than that of the mixture with the connate water of well 6/11–13Q1, and is somewhat less than that of the mixture with ocean water. Regarding the mixture with the connate water of well 13Q1, the excesses in calcium and magnesium would be very nearly equivalent to the deficiency in sodium. In other words, an adequate exchange of bases would produce the actual contaminated water from that particular mixture almost precisely; the transformation would be precise if base-exchange were accompanied by reduction of sulfate or by precipitation of a small amount of calcium as the sulfate or carbonate, or both. Conversely, in comparison to the mixtures with bottom water of well 18J2 and with ocean water, the contaminated water has an excess of calcium but is deficient in all other major constituents. It could have been produced from either of these particular mixtures only by exchange of bases, accompanied by precipitation of calcium in a considerable amount, and possibly with very intensive reduction of sulfate in the mixture with ocean water.

Plate 12 depicts these chemical relations by columnar diagrams of the successive analyses of contaminated water from well 18K1. However, the arrangement of these diagrams is advisedly unconventional in four respects: (1) between left-hand and right-hand diagrams that represent the standard native water and a calculated mixture of that water with brine from well 13Q1, respectively, the diagrams of the several contaminated waters are spaced horizontally according to a linear scale for the percentage of native water in each, as calculated from the amounts of chloride; (2) only in the left- and right-hand diagrams are bases and acids balanced against one another in the conventional manner; (3) the several diagrams for the bases in the contaminated waters are placed vertically so that the sodium segments bottom along a straight line connecting the bottoms of the corresponding segments in the two marginal diagrams; and (4) the diagrams for the acids are placed with the bottoms (and tops) of the chloride segments alined likewise across the array.

With the contaminant correctly identified and the diagrams so arrayed, the sodium deficiency of a contaminated water is measured by the offset from the top of its chloride segment to the top of its sodium segment. A net excess of calcium and magnesium is measured by the amount that the bottom of the calcium segment runs below the base line of the two marginal diagrams. An excess or a deficiency in magnesium is measured by the overrun or underrun, respectively, of the magnesium segment with respect to a straight line connecting the bottoms of the corresponding segments in the two marginal diagrams. An excess or deficiency of sulfate is measured as is magnesium. Any underrun by a diagram of bases measures the net amount of analytical errors and of bases removed by precipitation. And any overrun by a diagram of bases measures the net amount of analytical error and of bases taken into solution.

Figure 11 shows the progressive contamination in a second well of the field abandoned in 1934 by the city of Newport Beach. Unlike the well whose contaminated waters have just been described and which at first yielded the native calcium bicarbonate water of the Talbert zone, this second well, 6/10–18K3, taps only the San Pedro (?) formation beneath the Talbert zone and at

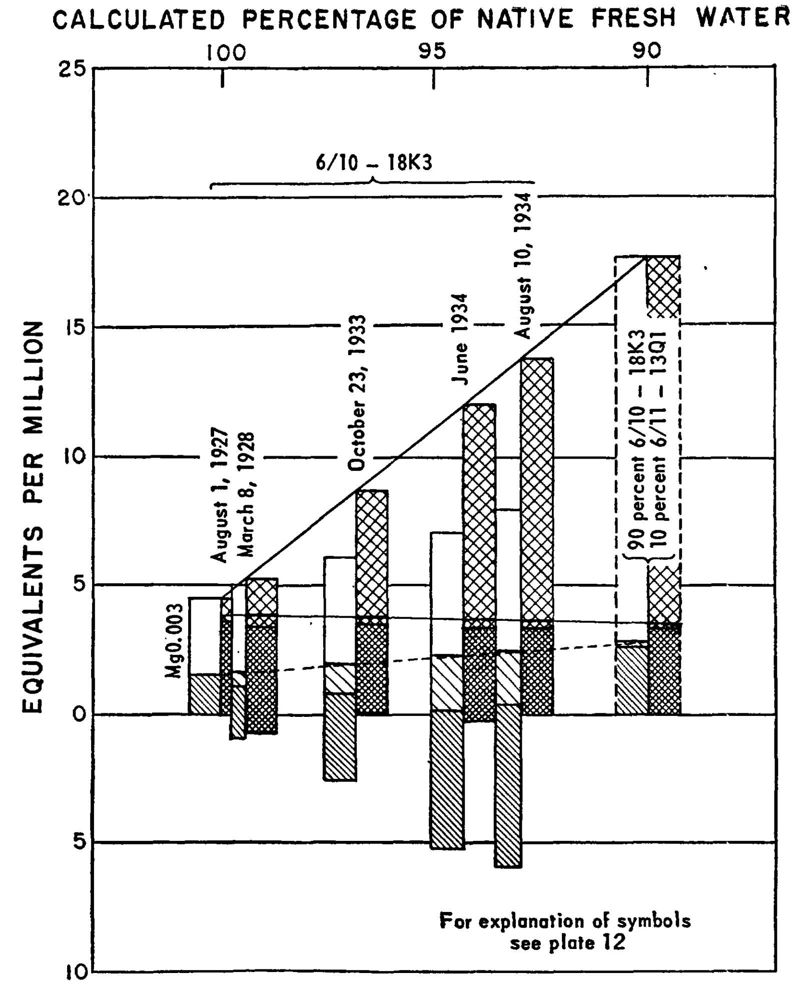


FIGURE 11.—Progressively contaminated water from well 6/10–18K3 (Newport Beach, well 5) in relation to hypothetical mixture of native water from that well with brine from well 6/11–13Q1.

first yielded the sodium bicarbonate water locally native to the uppermost part of that formation. Table 11 compares the most highly contaminated water of this second well with three hypothetical mixtures of native water and potential contaminants. The features shown by this table and figure are substantially identical with those developed by the foregoing table 10 and plate 12.

It is concluded tentatively that the immediate cause of the progressive contamination at the abandoned well field of the city of Newport Beach was an influx of connate water whose chemical composition was similar to that of brine 6/11–13Q1 or possibly that of bottom water 6/10–18J2. The basis for that conclusion and substantiating factual evidence are summarized under "Sources of the contaminants."

TABLE 11.—*Contaminated water from well 6/10–18K3 in comparison with hypothetical mixtures of the native water of that well with three potential contaminants*

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Well 6/10–18K3, native water of Aug. 1, 1927	31	0.4	65	225	12	23
Well 6/10–18K3, contaminated water of Aug. 10, 1934	128	25	125	207	11	364
Native water mixed with bottom water of well 6/10–18J2	45	20	252	268	10	364
Native water mixed with brine of well 6/11–13Q1	47	2.0	262	207	11	364
Native water mixed with ocean water	38	23	260	220	59	364
Equivalents per million:						
6/10–18K3, Aug. 10, 1934	6.38	2.06	5.44	3.39	.23	10.26
Mixture with 18J2	2.26	1.62	10.98	4.39	.21	10.26
Mixture with 13Q1	2.32	.16	11.40	3.39	.23	10.26
Mixture with ocean water	1.91	1.89	11.29	3.60	1.23	10.26
Excess (+) or deficiency (–) of the contaminated water with respect to:						
Mixture with 18J2	+4.12	+.44	–5.54	–1.00	+.02	----------
Mixture with 13Q1	+4.06	+1.90	–5.96	.00	.00	----------
Mixture with ocean water	+4.47	+.17	–5.85	–.21	–1.00	----------

[1] Includes equivalent of potassium (K).
[2] Includes equivalent of carbonate (CO_3) if any.

WELL FIELD OF THE LAGUNA BEACH COUNTY WATER DISTRICT

The Laguna Beach County Water District was formed in 1925 and in 1926 drilled two wells, 6/10–18C4 and –18C2, along the west side of Bushard Street about 950 ft and 700 ft, respectively, south of Atlanta Street. A third well, 6/10–18C1, was drilled in 1939 about 500 ft north of 18C2 and 200 ft south of Atlanta Street. All three wells tapped only the Talbert water-bearing zone; the underlying Pleistocene at this point is essentially nonwater-bearing.

Figure 12 shows the available data on the chloride content of the water from the three wells. Evidently in well 18C4 the chloride content had increased appreciably by 1934 and then rose sharply beginning in 1938, whereas in well 18C2 (about 250 ft to the north) the increase began after 1934 and first became rapid in 1939. Owing to this depreciation in water quality, withdrawal

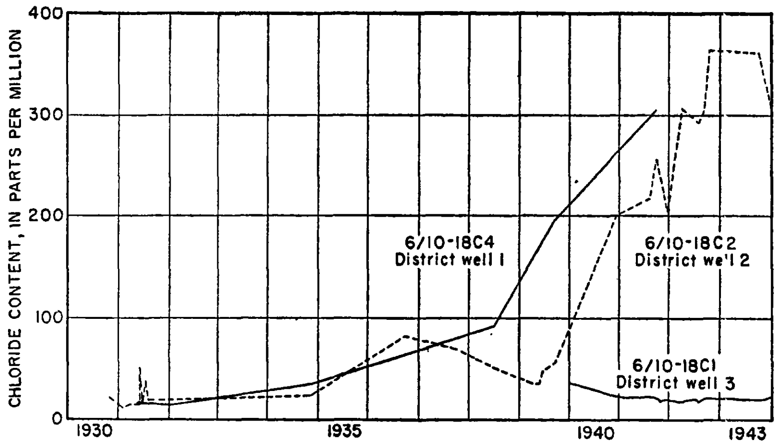


FIGURE 12.—Chloride content of water from three public-supply wells of the Laguna Beach County Water District, 1930–43.

for public supply ceased in mid-1938 at well 18C4 and in early 1944 at well 18C2. In well 18C1, the most northerly of the three, the chemical quality of the water had not depreciated when last sampled in February 1944.

Figure 13 shows the chemical character of the water in well 18C4 at 10-ft intervals from just below static level nearly to the bottom of the well. At the time these samples were taken the well had not been pumped heavily for about three years. This

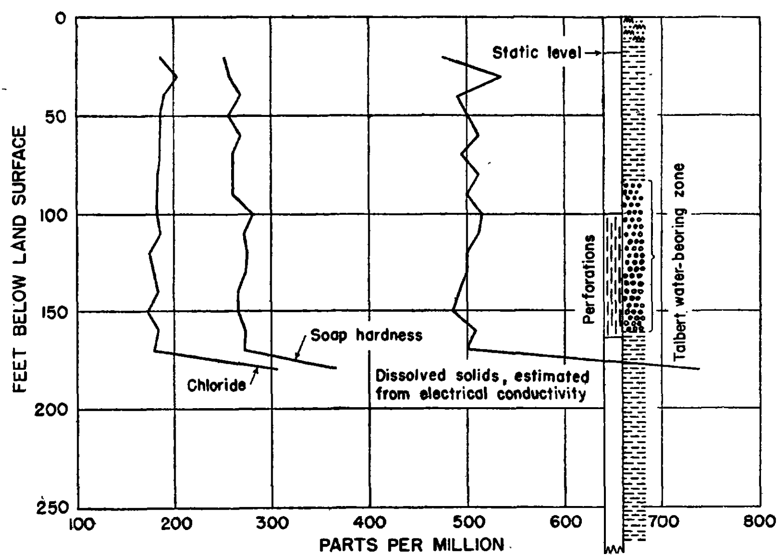


FIGURE 13.—Chemical character of water in well 6/10–18C4 (Laguna Beach County Water District, well 1) on September 19, 1941.

figure shows that throughout the reach of perforated casing, from 100 to 163 ft below land surface, the chemical character of the water was constant and sensibly the same as that of the sample last taken for analysis in August 1939 (see table 30); however, at a depth of 180 ft, 17 ft below the perforations, the salinity of the water increased sharply. Evidently in late 1941 the quality of the water in the aquifer was essentially identical with that drawn from the well in 1939, but in the interim, water of much poorer quality had accumulated in the bottom of the well, either from the Talbert water-bearing zone or from the overlying semiperched water of poor quality.

The following table 12 compares the contaminated water from well 18C2 on July 31, 1942, and hypothetical mixtures of the standard native water of the Talbert zone with the bottom water of well 6/10–18J2, with the brine of well 6/11–13Q1, and with ocean water. This comparison is analogous to those already made between wells 6/10–18K1 and –18K3 (Newport Beach, wells 4 and 5; see pp. 104–109). As at the abandoned Newport Beach field to the south, evidently the contamination at the field of the Laguna Beach County Water District has involved an increase in chloride

TABLE 12.—*Contaminated water from well 6/10–18C2 in comparison with hypothetical mixtures of the "standard" native water from that well with three potential contaminants*

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Standard native water of Talbert water-bearing zone	42	5.1	44	205	32	10
Well 6/10–18C2, contaminated water of July 31, 1942 (table 30)	138	24	76	201	19	300
Standard water mixed with bottom water of well 6/10–18J2	52	21	202	248	28	300
Standard native water mixed with brine of well 6/11–13Q1	54	6.5	209	195	30	300
Standard native water mixed with ocean water	48	24	206	206	72	300
Equivalents per million:						
6/10–18C2, July 31, 1942	6.89	1.97	3.30	3.30	.40	8.46
Mixture with 18J2	2.62	1.74	8.76	4.07	.59	8.46
Mixture with 13Q1	2.69	.53	9.07	3.20	.63	8.46
Mixture with ocean water	2.38	2.01	8.95	3.38	1.50	8.46
Excess (+) or deficiency (−) of the contaminated water with respect to:						
Mixture with 18J2	+4.27	+.23	−5.46	−.77	−.19	----------
Mixture with 13Q1	+4.20	+1.44	−5.77	+.10	−.23	----------
Mixture with ocean water	+4.51	−.04	−5.65	−.08	−1.10	----------

[1] Includes equivalent of potassium (K).
[2] Includes equivalent of carbonate (CO_3) if any.

and calcium in nearly equal proportions, and a slight decrease in sulfate. This can be most simply explained as being due to an influx of local connate water, together with exchange of bases and a precipitation of a nominal amount of calcium as the carbonate or sulfate.

WELL FIELDS OF THE FAIRVIEW FARMS WATER CO. AND THE NEWPORT MESA IRRIGATION DISTRICT

The well fields of the Fairview Farms Water Co. and the Newport Mesa Irrigation District are along the south side of Hamilton Street about 0.25 mile west of the Santa Ana River; they are 1,800 ft east of the abandoned Newport Beach field, and across the so-called Wright Street fault from that field. Altogether, eight wells had been drilled in the two fields between 1913 and 1930 but only three were in public-supply service as of 1944. These three afford critical information on contamination east of the Wright Street fault, and include:

6/10–18J1, Newport Mesa Irrigation District well 4, reportedly drilled in 1930 to a depth of 270 ft. and its casing perforated 145–245 ft. below land surface, entirely in Pleistocene deposits (probably San Pedro formation).

6/10–18J2, Fairview Farms Water Co. well 4, drilled in February 1930 to a depth of 270 ft.; casing reportedly perforated 156–256 feet below land surface, entirely in the San Pedro (?) formation. Analytical data indicate that some of its water is drawn from the overlying Talbert water-bearing zone.

6/10–18J3, Fairview Farms Water Co. well 2, drilled in 1913 to a depth of 290 ft. Casing reportedly perforated first about 150–300 ft. below land surface, that is, through a range wholly in the San Pedro (?) formation.

The well fields of these two organizations were largely developed by 1920 but withdrawal did not peak until the early thirties. Beginning in 1930, chemical analyses of the water withdrawn from the three active wells have been made at random intervals (see table 30); figure 14 graphs the available records of chloride content. These analytical data show not only that the general quality of the waters has worsened steadily throughout the term of the analytical records but also, especially in wells 18J2 and 18J3, that the chemical quality of the successive samples has fluctuated considerably. Of these two wells (which interfere mutually when pumped), it will be shown that this fluctuation in the quality of the water discharged by well 18J2 has been due to blending—in varying proportions under unlike conditions of pumping draft—of a local contaminant with waters from the

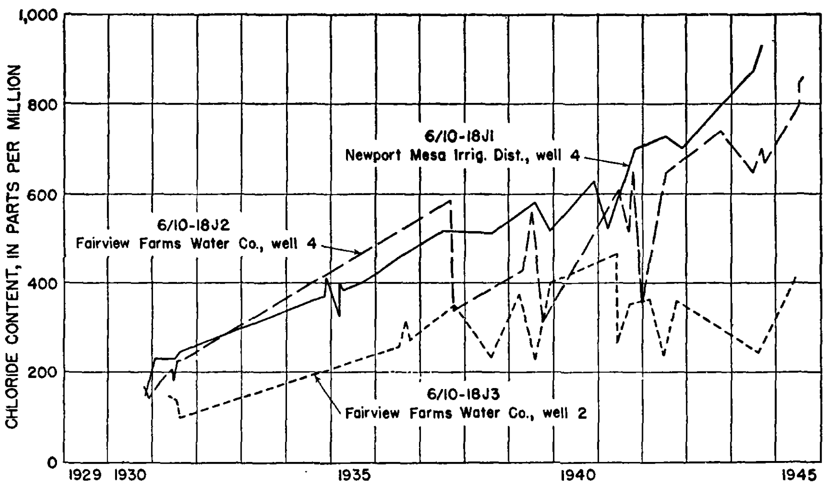


FIGURE 14.—Chloride content of water from three public-supply wells of the Fairview Farms Water Co. and the Newport Mesa Irrigation District, 1930–45.

Talbert water-bearing zone and from the San Pedro(?) formation. Thus, the fluctuation in quality of the successive water samples does not indicate necessarily that the contaminant repeatedly has surged into and then partially withdrawn from the vicinity of the well. (See p. 118.) This fluctuation has been least in the samples from well 18J1, which taps the San Pedro (?) formation not far from the fringe of the salt-water body native in that formation. It will be shown that the depreciation in water quality was incipient at the time of the earliest analytical data, 1930–31.

Critical information about the immediate source of the contaminant at well 18J2 is afforded by figure 15 and figure 16, which present data from tests of that well in August 1942 and April-May 1945. Pertinent conditions and procedures of the tests are as follows:

1. On August 27, 1942, water withdrawn by service pump at rate of 1,350 gallons a minute from 7:07 to 11:04 a.m., or for elapsed time 3 hrs., 57 min. Samples taken repeatedly from pump discharge for determination of chloride, soap hardness, and electrical conductivity. During test, bottom of pump intake was about 72 ft. below land surface, so that within all except the uppermost part of the well the water was drawn upward. Before this test, service pump had been operated several hours each day.

2. On August 28, 1942, with the pump idle, vertical traverse run to determine range in the character of water standing in well, in terms of electrical conductivity. (Poland and Morrison, 1940; Poland and Piper, 1942.) Before this traverse the pump had been idle about 45 min following the

second of two runs which intervened after the pump test of the preceding day, and whose total duration was 3½ hr.

3. On April 12, 1945, with the service pump removed for repairs after having been idle at least since April 5, another conductivity traverse run and a sample of water taken about 1 ft above bottom of well. The analysis of this sample is given in table 30; its chemical character is discussed on page 116.

4. On May 1, 1945, well having remained idle, water withdrawn at rate of 30 gpm for half an hour. Test unsuccessful because test pump failed owing to gas lock. However, two conductivity traverses run about 1½ and 4 hr. after test pump stopped.

5. On May 5, 1945, with air lift test pump, water withdrawn at rate between 200 and 300 gpm from 10 a. m. to 3:50 p. m., or for elapsed time 5 hrs., 50 min. Conductivity of water discharged was determined throughout test period; also, two conductivity traverses run to bottom of well after pump had been operating 1½ and 4 hr. During this test (also test of May 1), bottom of intake pipe set 250 ft. below land surface, to cause downward flow of water within the well to within about 11 ft. of its bottom (as determined by measurement).

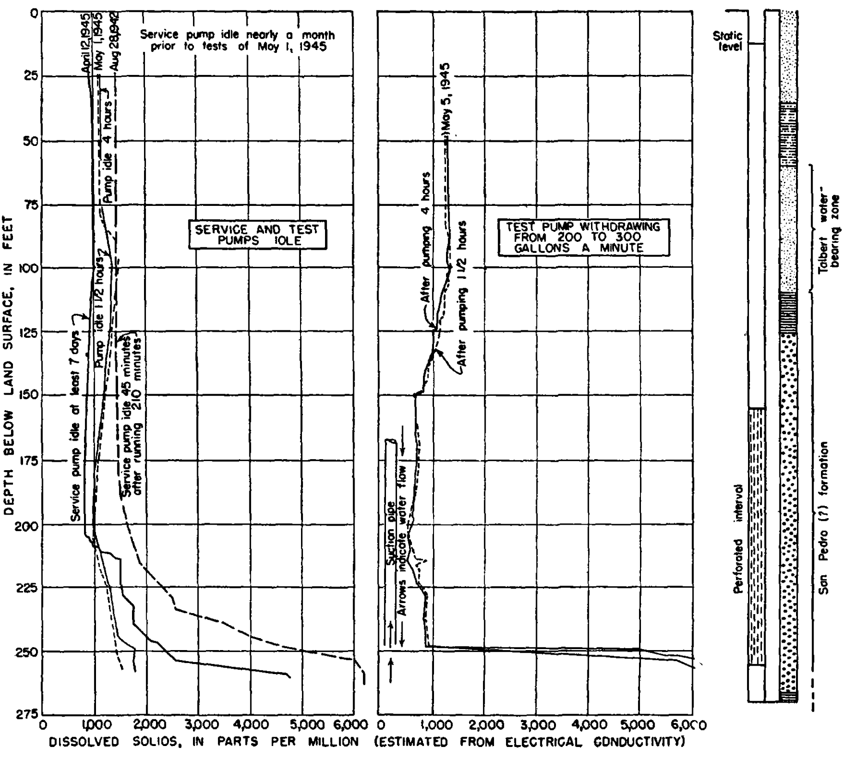


FIGURE 15.—Character of water in well 6/10-18J2 (Fairview Farms Water Co., well 4), August 1942 and April-May, 1945.

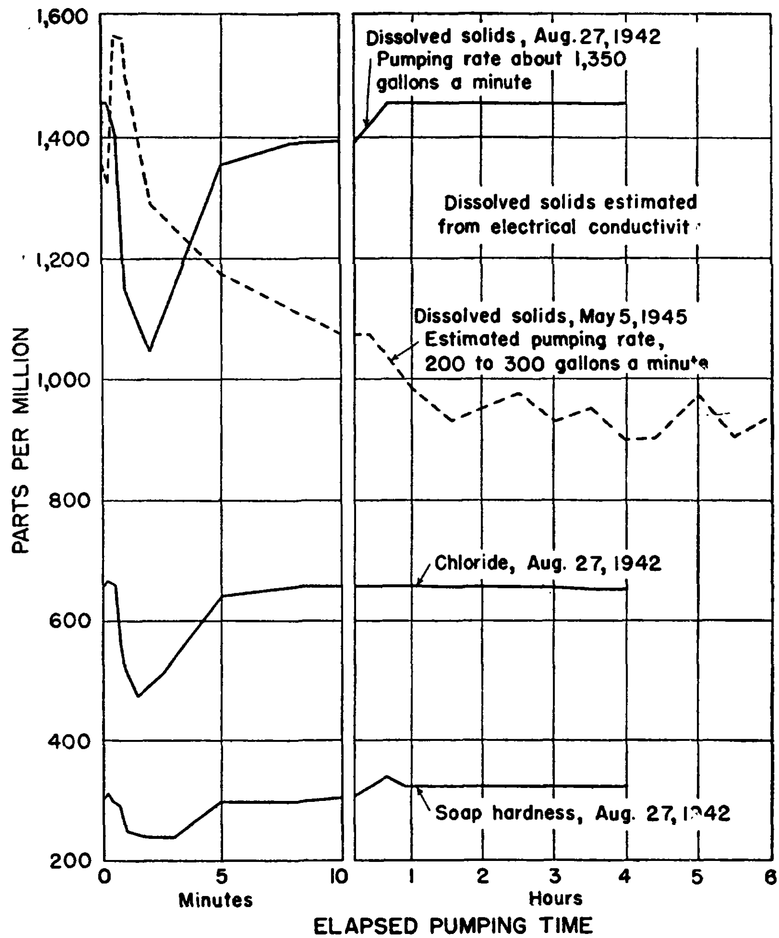


FIGURE 16.—Chemical character of water discharged from well 6/10–18T2 (Fairview Farms Water Co., well 4) during pumping tests of August 27, 1942, and May 5, 1945.

In the test of August 27, 1942, the chemical quality of the water withdrawn by the service pump was essentially constant during the first 30 sec of pumping, freshened somewhat from 30 sec to 2 min, regressed to the initial quality by the 38th minute, then remained constant through the last sample taken after nearly 4 hr of pumping. (See fig. 16.) In both the initial and terminal periods of uniform quality the chloride content was about 660 ppm, soap hardness was about 325 parts, and total dissolved solids (estimated from specific electrical conductivity) was about 1,450 parts; that is, the quality was essentially that shown by the analysis of October 16, 1941 (see table 30). During the initial 30-sec period the water discharged was probably that trapped in the pump column after an earlier period of draft; beyond the 38th minute the water discharged was a stable blend of the native water or waters with the contaminant. The fresher water of the 2d minute contained 475 parts of chloride, about 240 parts of hardness, and 1,050 parts of all dissolved solids; presumably it was drawn chiefly from the upper part of the aquifer, in which water of at least fair quality presumably existed. (See p. 117.) Such discharge of fresher water during the first few minutes of pumping probably has been characteristic of the well; under these conditions, if the samples for analysis had been taken at unlike intervals after the pump was started, those samples would have ranged widely in character even though the degree of contamination in the aquifer remained unchanged. This deduction is the basis for the interpretation of analytical data expressed in figure 14.

Among the four conductivity traverses with idle pumps (fig. 15), that of August 28, 1942, found the most concentrated waters at all depths. Specifically, to a depth of 34 ft below the topmost perforations which are 156 ft below land surface, the dissolved-solids content was uniformly about 1,400 ppm or about equal to that of the water discharged during the terminal period of the preceding day's test. At greater depth, however, the dissolved solids increased sharply to about 6,100 ppm at the bottom of the perforations (256 ft below land surface), and to about 6,250 parts near the bottom of the well. Thus, this bottom water is five times more concentrated than any water yet taken from the pump for chemical analysis (see table 30). Without doubt, it is the immediate local contaminant.

The conductivity traverse of April 1945 showed conditions analogous to those just described, except that at all depths the chemical quality of the water was much improved. Thus, to a depth of 100 ft below land surface the dissolved-solids content was essentially constant and about 950 ppm but from 100 to 200 ft in depth the dissolved solids diminished to 750 parts. Thus, through the upper half of the range of perforated casing, the water then standing in the well was no more depreciated in quality than samples taken as early as October 1937 (see table 30). Below 200 ft in depth, the dissolved-solids content increased unevenly to about 4,800 ppm. The sample for analysis taken at 260 ft in depth contained 4,520 parts of dissolved solids (table 30); thus, in this sample of "bottom" water from well 18J2, which affords the fullest information now available of the chemical character of the local contaminant, the dissolved solids were only about 70 percent of that in the bottom water of August 1942.

The most critical information is afforded by the two conductivity traverses (fig. 15) during the pump test of May 5, 1945. These two traverses disclosed essentially identical ranges in character of water within the casing of the well; the water discharged simultaneously by the test pump was nearly constant in quality and contained from 900 to 925 ppm of dissolved solids. Under the conditions of the test:

1. From 100 to 150 ft below land surface, that is, through roughly the full thickness of the Talbert water-bearing zone and through a reach in which the casing of the well reportedly is not perforated, the dissolved-solids content of the water in the well diminished progressively from 1,300 to 750 ppm. Evidently some water was entering the well from the Talbert zone, presumably through unreported perforations or through openings at the joints and seams of the stovepipe casing. Although doubtless contaminated, at least some of this Talbert water was of better quality than the blended water concurrently discharged from the test pump.

2. From 156 to about 180 ft below land surface, that is, through about the upper fourth of the reach of perforated casing, the dissolved-solids content was roughly constant and about 675 ppm. Either no water was being drawn from that reach, or the water drawn was of a quality identical with that blended from all the overlying Talbert zone.

3. From 180 to 210 ft, that is, through the next fourth of the downward reach of perforated casing, the dissolved-solids content diminished progressively to about 500 ppm. This water at 210 ft obviously blends all the waters entering the well to that depth. Therefore, it is evident that in the depth range here discussed, the water entering the well from the San Pedro (?) formation contained less than 500 ppm of dissolved solids in May 1945—in other words, that particular water at that time was of better quality than shown in table 30 by the analysis of June 1931. Thus, the latter analysis, the earliest available for well 18J2, presumably shows incipient contamination.

4. From 210 to 230 ft, or through about the third fourth of the perforated reach, the dissolved-solids content increased progressively from 500 to about 850 ppm, or nearly to that of the blend discharged by the test pump. In this reach, the water entering the well from the San Pedro (?) formation in May 1945

evidently contained at least a substantial percentage of the contaminating bottom water.

5. From 230 ft to the bottom of the suction pipe of the test pump at 250 ft, the dissolved-solids content increased to that of the pump discharge—about 900 ppm. In that reach, evidently very little additional contaminant was entering the well.

6. Within 3 ft below the bottom of the suction pipe the total-solids content increased sharply to at least 4,500 ppm and then to about 6,250 parts at 5 ft below the bottom perforations. However, little or none of this concentrated bottom water was being drawn upward into the suction pipe of the test pump.

From all the data available (and largely presented in fig. 15) it is concluded that an interface between uncontaminated or very slightly contaminated fresh water and the bottom contaminant exists in the San Pedro (?) formation within the reach of perforated casing in well 18J2. This interface has fluctuated upward and downward, probably depending upon natural fluctuations in the heads of the two waters, and upon the draw-down of those heads induced by pumping. With no draft from the well, the interface tends to stabilize currently at or a few feet above the lowest perforations in the casing, and under service draft at the rate of 1,350 gpm, the interface may have been as much as 55 ft above the lowest perforations, that is, about 210 ft below land surface.

It is concluded further that the water discharged from the service pump during the life of the well has been blended from (1) water of the Talbert zone, which locally has become contaminated progressively; (2) water of the San Pedro (?) formation, which in the upper part of that formation is contaminated only moderately or possibly not at all, even as of 1945; and (3) the bottom water, whose chemical character in April 1945 is shown by the analysis in table 30. The proportionate parts of water drawn from the three sources have varied continually, largely in accord with the rate and duration of draft.

Concerning well 18J1, plate 13 shows that the contaminated waters of 1931–44 could have been caused primarily by an influx of the bottom water of well 6/10–18J2 in various proportions, accompanied by (1) moderate gain in calcium and loss in sodium by exchange of bases, excepting the analysis of November 1935; (2) essentially neither loss nor gain of magnesium by exchange of bases; and (3) possibly a small decrease in dissolved solids owing to precipitation of calcium carbonate and perhaps calcium sulfate. This plate shows further that all the waters of well

18J1 could have been derived likewise from mixtures of the bottom water of well 18J2 with the sodium bicarbonate water that was native in the San Pedro (?) formation at well 6/10–18K3 (see p. 107). Plate 14 shows that the contaminated waters of well 18J2 could have been caused likewise, but with only a slight rather than a moderate gain in calcium and loss in sodium by exchange of bases, and with no more than a nominal decrease in dissolved solids owing to precipitation. Analytical data substantiate the same fundamental explanation for the contaminated waters of well 18J3, except that those waters have been slightly softened rather than hardened by exchange of bases—specifically, they have gained slightly in sodium and lost about commensurately in magnesium. Three fundamental generalizations follow:

1. In and near the joint well field of the Fairview Farms Water Co. and the Newport Mesa Irrigation District, the native water in the upper part of the San Pedro (?) formation very probably was of good chemical quality, very similar to that of the sodium bicarbonate water drawn from well 6/10–18K3 in August 1927 (containing only about 250 parts per million of dissolved solids). Also, as of 1945, water of good quality still exists in that formation, at least within the strata tapped by well 6/10–18J2 from 180 to 210 ft below land surface.

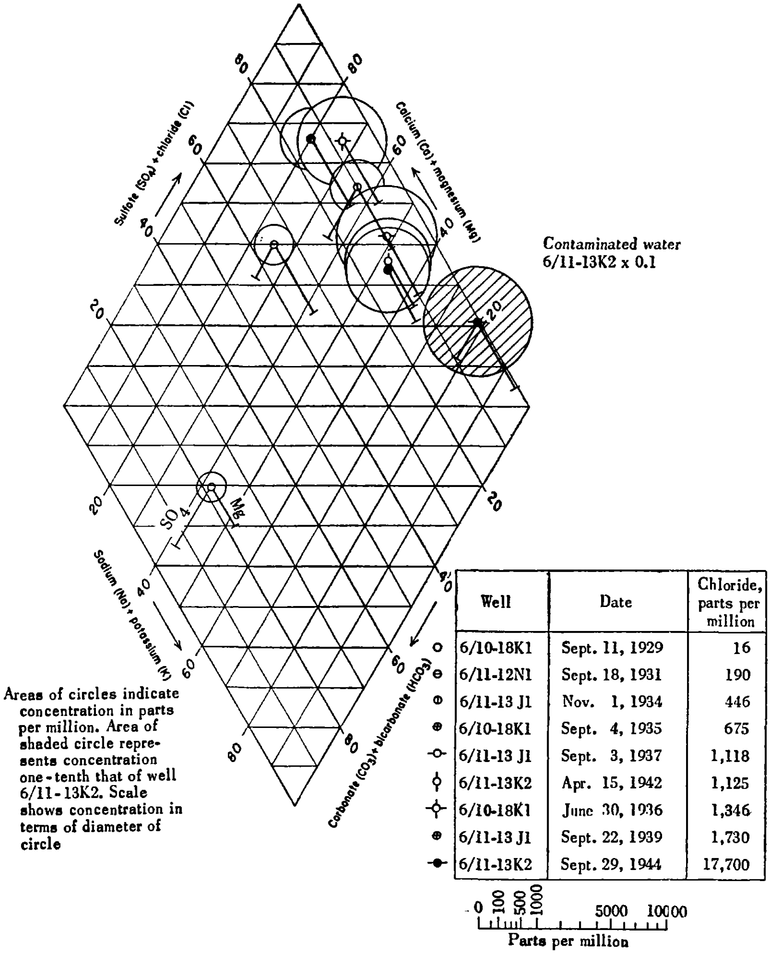
2. The principal immediate contaminant has been the high-chloride bottom water of well 18J2. As represented by the analysis of April 1945, in this bottom water the calcium-to-magnesium-to-sodium ratio is 0.11 to 0.19 to 1, whereas in ocean water that ratio is 0.04 to 0.22 to 1 (in terms of chemical equivalents). Also, the bottom water contains about 20 times as much iodide and nearly twice as much strontium as ocean water. Thus, the bottom water of well 18J2 is considered to be definitely of connate origin. Natively, doubtless it is essentially a top or edge water of the connate body that exists locally in the lower part of the San Pedro (?) formation from the so-called Wright Street fault eastward to and beneath at least the central part of the Newport Mesa (see p. 61). It is not known whether that connate body existed natively in the lower strata tapped by the perforations of well 6/10–18J2 or only in some underlying zone with which those strata are in hydraulic continuity; whatever the initial upward reach of the body, its water of high chloride content has been drawn upward with the heavy draft from the overlying well field, but at no time has it yet been drawn across the full thickness of the native fresh-water zone. As has been shown, the bottom water of the well in August 1942 contained nearly one and

one-half times the dissolved solids in the bottom water of April 1945. At that earlier date, the top of the connate-water body had been drawn higher above the bottom of the well; in other words, the well then disclosed the character of connate water that subsequently receded beyond the reach of sampling in 1945. It is estimated that in the bottom water of 1942 the chloride content was roughly 3,500 ppm or somewhat more than that in the saline water reached but plugged off at the bottom of well 6/10–10D3 on the Newport Mesa nearly 3 miles to the northeast. This bottom water of 1942 has the greatest chloride content yet disclosed for the connate-water body of the San Pedro (?) formation.

3. Chemical modification of the contaminated waters by exchange of bases has been shown to involve moderate enrichment in calcium at well 18J1, slight enrichment in calcium at well 18J2, but possibly some enrichment in sodium rather than in calcium at well 18J3. This seemingly anomaly of calcium enrichment at one well and of sodium enrichment at another, among wells that tap a common water-bearing zone, probably is related to the impeded circulation of water in the San Pedro (?) formation east of the Wright Street fault (see p. 94). Thus, only where water of meteoric origin has circulated most freely have the base-exchange media in the aquifer been enriched in calcium sufficiently now to release calcium abundantly in the presence of the contaminating connate water. Erratic differences in the degree of base-exchange modification presumably would characterize any contamination in the area east of the Wright Street fault.

PROGRESSIVE DEPRECIATION OF WATER QUALITY AT MISCELLANEOUS WELLS

Other than those of the several public-supply fields, the wells in the Santa Ana Gap are used chiefly for irrigation and relatively few chemical analyses of their waters are available. However, analyses for several wells in the area of contamination since 1931 bring out another relation which is believed to be typical and which is critical. Thus, figure 17 shows the chemical character of six additional contaminated waters, in comparison with the native water and the most contaminated two waters of well 6/10–18K1, already described. These additional waters include one from well 6/11–12N1 at the west flank of the gap and half a mile from the coast, three from well 6/11–13J1 in the center of the gap and 0.6 mile from the coast, and two from well 6/11–13K2 in the center of the gap and 0.4 mile from the coast. From the data there plotted it is inferred that in a first stage, contaminated waters in the gap commonly progress through the range of chemical compositions spanned by the analytical data for well 6/10–



Well	Date	Chloride, parts per million
6/10-18K1	Sept. 11, 1929	16
6/11-12N1	Sept. 18, 1931	190
6/11-13 J1	Nov. 1, 1934	446
6/10-18K1	Sept. 4, 1935	675
6/11-13 J1	Sept. 3, 1937	1,118
6/11-13K2	Apr. 15, 1942	1,125
6/10-18K1	June 30, 1936	1,346
6/11-13 J1	Sept. 22, 1939	1,730
6/11-13K2	Sept. 29, 1944	17,700

FIGURE 17.—Chemical character of a typical native water and of certain contaminated waters from wells in the Santa Ana Gap.

18K1 (pp. 104–106, fig. 10, pl. 12), but then become essentially of the composition of ocean water, as in well 6/11–13K2 (see table 29, analysis of September 1944).

In the first stage the mixture of native water and contaminant is hardened by the process of calcium enrichment already explained; also, sulfate diminishes to the vanishing point, presumably owing either to reduction (p. 90) or to precipitation in compound with barium or calcium. Presumably, the first stage ends as base-exchange media in the aquifer become saturated with sodium in the presence of the contaminant, and no longer release calcium (and possibly magnesium) in exchange. This terminal condition seems to be reached commonly when the contaminated water contains about 2,000 ppm of dissolved solids and 1,000 parts of chloride. In the second stage, further admixture of the contaminant seems to go on without substantial modification by exchange of bases; however, at least in the early part of the stage, admixed sulfate seems largely or wholly to be removed by reduction or precipitation.

The two-stage contamination here described seems to apply rather widely to the contamination by waters of high chloride content in the Santa Ana Gap. Yet, certain potential contaminants in and near the gap are sulfate waters rather than chloride waters; for example, the water encountered at 270 ft below land surface in well 6/10–8D4 (table 30, analysis 3). Contamination by such high-sulfate-content waters has not been discriminated clearly, but is suggested by the water from well 6/11–13J1 in November 1934. (See fig. 17.) With a contaminant of this sort, sulfate probably would not be removed fully by reduction or precipitation but, other conditions being equal, modification by base exchange might proceed quite as here described.

SOURCES OF THE CONTAMINANTS

As has been stated, the potential contaminants of the waters of the Santa Ana Gap include ocean water, the unconfined shallow ground water, connate waters from the deposits of Pleistocene age, and connate waters from the underlying rocks of Tertiary age. Among these, the ocean and certain connate-water bodies of the Pleistocene deposits are naturally in hydraulic continuity with the aquifers that natively contained fresh water and that now are contaminated, and so could have invaded the area as the fresh-water head was lowered by heavy withdrawals. However, it is believed that none of the remaining potential sources could have been responsible for a substantial part of the known voluminous contamination, because:

1. In the unconfined shallow body, water of inferior quality reaches inland a considerable distance beyond the area of contamination but exists in and is separated from the underlying contaminated aquifers by materials that are very slightly permeable and several tens of feet thick. Even with the fresh-water head depleted, movement of the unconfined water downward across the stratification of the fine-grained materials by which that water is contained would have been slow but widespread—probably much too slow and too widespread for conformity with the extent and degree of contamination heretofore described. Some water of the unconfined body may have reached the under-

lying aquifers by way of wells whose casings are inadequate or deteriorated, but contamination so caused would have been discontinuous rather than of somewhat uniform intensity over an extensive area.

2. The connate waters in the Tertiary rocks are confined by siltstone and shale at least several hundred feet thick, through which permeable conduits conceivably would be afforded only by the faults and minor fractures of the Newport-Inglewood structural zone. However, in all the 18-mile reach of that structural zone from the Santa Ana Gap northwestward to the Dominguez Hill, there is no evidence of connate waters moving upward along fault conduits. Thus, although in the Santa Ana Gap the inland front of the contaminated area has been between the principal two faults of the structural zone for more than a decade (pl. 11), it seems unlikely that those faults there and there only would transmit connate water from the Tertiary rocks in the volume required to satisfy the known contamination.

3. Essentially no oil-field waste brines are or have been held in sumps or dissipated promiscuously in and near the area contaminated. Thus, these connate waters of the Tertiary rocks have had little or no opportunity to infiltrate below the land surface after having been withdrawn with their associated oil.

4. A number of production oil wells have been drilled in the western part of the Santa Ana Gap, and several oil-test holes have been drilled and abandoned along the Newport-Inglewood structural zone across the gap. Of these, the area of contamination encompasses only a few abandoned test holes, for example, well 6/11–13Q1. Conceivably any such hole that had been inadequately cased or inadequately plugged might convey connate brine from the Tertiary rocks into the natively fresh-water aquifers. However, for even a minor part of the known contamination to have been so caused, each of the few test holes within the contaminated area would need have conveyed several tens or even a few hundreds of gallons a minute throughout the past 15 yr. Transmission of so great a quantity seems altogether unlikely.

In the foregoing discussion of first-stage contamination in the Santa Ana Gap, the evidence afforded by the major dissolved constituents of the waters has served to identify the immediate contaminant—connate water from Pleistocene deposits—only for the well field of the Fairview Farms Water Co. and the Newport Mesa Irrigation District. However, fairly competent supplementary evidence is found among the analytical data in the moderate member of borate determinations and a very few iodide determinations. Thus, for wells that have disclosed first-stage contamination, with few exceptions the pertinent analytical data indicate an increase in borate from two to eight times that which would have been introduced had the immediate contaminant been ocean water. In table 30, iodide is shown in two analyses of first-stage contaminated waters. In these, from wells 6/10–18J2 and 6/11–13K2, the iodide content of the contaminated water is respectively 8 and 20 times that of ocean water. Because both borate and iodide characteristically are many times more abundant in the connate waters than in ocean water (see table 8), this supplementary evidence agrees in indicating connate water as the first-stage contaminant. Because they are extensively in hydraulic continuity with the contaminated aquifers and those of the Tertiary rocks are not, it is concluded tentatively that in the Santa Ana Gap the connate-water bodies in the Pleistocene deposits, that is, in the San Pedro (?) formation, are and have been the principal if not the sole source of the first-stage contamination.

Second-stage contamination in the Santa Ana Gap (that in which base-exchange modifications are negligible) probably involves two contaminants: ocean water and connate water from the Pleistocene deposits. Only fragmentary analytical data are available to retrace this stage (see fig. 17) but the most highly contaminated water for which a comprehensive analysis is available—that of well 6/11–13K2 in September 1944—has substantially the composition of ocean water.

NATURE AND MOBILITY OF THE CONTAMINATION FRONT

As it has advanced inland in the Talbert water-bearing zone and in the underlying San Pedro (?) formation of the down-faulted block along the coast (p. 93, pl. 11), the inland reach of the contaminated waters has been and is exceedingly irregular. The greatest reach presumably is by fingers or tongues of the contaminant drawn toward the various centers of heavy withdrawal, probably in the lower part of the aquifer. Toward the coast, however, those fingers are believed to merge into a relatively continuous front behind which contaminated water occupies the aquifer from bottom to top. Within the inland-probing fingers and for a certain distance behind the front, in a belt now roughly from 0.2 to 0.5 mile wide, the contamination seems to have progressed only through the first stage; that is, the contaminant has been derived locally from the connate-water bodies of the San Pedro (?) formation, the chloride content is less than 1,000 parts per million, and calcium-enrichment by base exchange has increased proportionately with the influx of contaminant. Beyond that belt of first-stage contamination the waters currently seem to grade, locally within as little as 0.1 mile, into a composition essentially identical with that of ocean water. Available data suggest that this three-dimensional pattern has persisted during the inland march of the contamination front since the early thirties.

In the 12 yr ending with 1944 the contamination front progressed into the Santa Ana Gap as much as 0.7 mile and water of ocean composition progressed at least one-fourth mile. Thus, excepting the area east of the Wright Street fault, the average rate of advance was about 200 ft a year for the front as defined on plate 11 by the line for 50 ppm of chloride, and about 135 ft a year for the highly contaminated water as defined by the line for 10,000 parts of chloride. However, the rate of advance has been neither uniform nor constantly inland. For example, contamination sufficient to produce a chloride content of 100 ppm was reached in 1938 at well 6/10–18C4, about 6 yr later than in the wells of the abandoned field of Newport Beach about 1,800 ft to the south, and about 18 months earlier than in well 18C2 about 250 ft to the north. The apparent rate of inland movement of the front was locally about 300 ft a year until well 18C4 had been reached, 175 ft a year until well 18C2 had been reached, and then it slowed to some value less than 125 ft a year (because well 18C1 had not been reached in late 1943). Steady movement of any such front is not to be expected.

Analytical data by the Geological Survey have disclosed some advance by the contamination front in the Santa Ana Gap since 1941 in the vicinity of well 6/11–13G1 (table 31), and have indicated some retreat locally, around 1944. For example, well 6/11–13F2, which is 0.5 mile from the coast, in 1941 produced water containing 304 ppm of chloride but in May 1944, after having been pumped 8 hr, yielded water of essentially native quality containing only 13 parts of chloride. A mile to the east, periodic samples by the Geological Survey from well 6/10–18C2 have shown an increase in chloride content of the water from 200 ppm in late 1940 to 310 parts in 1942–43 (table 31). Owing to this increase in salinity, the well was abandoned for public supply early in 1944 and yet in February 1945, after it had been pumped for several days, the chloride content of its water had diminished to 91 parts. A seaward regression of the contamination front during 1944 apparently had occurred locally. However, this regression did not extend to the western edge of the gap, where water drawn from well 6/13–13C2 contained 860 ppm of chloride in September 1941 and 1,230 parts in September 1944. Neither did it extend to the most highly contaminated water near the coast, which at least locally continued to advance inland even as the front was regressing. Thus, at well 6/11–13K2 the chloride content of the water increased from 1,125 parts in April 1942 to 17,700 parts in September 1944.

In the part of the Santa Ana Gap that is east of the Wright Street fault, the contaminated area appears not to have extended itself inland appreciably during the 12 yr ending with 1944. There, water of at least fair and possibly undepreciated quality exists currently in the upper part of the San Pedro (?) formation, between water of depreciated (?) quality in the Talbert water-bearing zone above and a contaminating brine below. Probably no continuous contamination front exists across the full thickness of the aquifers. (See p. 119.) Rather, in accord with rates of draft, the body of contaminating brine rises into and recedes from the lower part of the zone natively occupied by fresh water and a variable amount of contaminant is drawn into the pumped wells. Thus, the quality of water yielded by certain wells, such as 6/10–18J2 (pp. 113–118), has depreciated considerably even though the area contaminated may not have enlarged. Yet, the water withdrawn seems to have improved in quality at least locally; for example, well 6/10–17C1 is reported to have encountered water "too salty" for public-supply use when drilled in 1913, but subsequently has been used for irrigation and has yielded waters containing 612 and about 560 ppm of all dissolved solids and 201 and 161 parts of chloride in 1932 and 1943, respectively. (See tables 30 and 31.)

CONTROL OF THE EXTENT AND DEGREE OF CONTAMINATION

The objectives of a program to constrain and, possibly, to reduce the extent of the contaminated area in the Santa Ana Gap would be to return overlying lands to irrigation from local wells and, more especially, to prevent ultimate contamination of the very productive fresh-water zones farther inland. Thus, west of the Wright Street fault the contamination front currently is roughly along Atlanta Avenue (see pl. 11) and there exists only in the Talbert water-bearing zone. This regional groundwater artery is uniformly about 50 ft thick. At and for about a mile inland from the master fault of the Newport-Inglewood zone, which passes near the intersection of Cannery and Atlanta Avenues, it rests directly on impermeable rocks which contain no water-bearing beds to at least 1,000 ft below land surface.

Therefore, so long as the front is constrained within this 1-mile reach, contamination cannot extend downward beyond the Talbert zone. Farther inland, beginning near the intersection of Cannery and Adams Avenues, northward-dipping water-bearing sand and gravel of Pleistocene age (probably the San Pedro formation) underlie and probably are in hydraulic continuity with the Talbert water-bearing zone. Together, the Talbert and the underlying Pleistocene there form essentially a single aquifer which thickens inland and is about 210 ft thick at the active well field of the city of Newport Beach, in the southeast angle of Adams Avenue and Wright Street. Under this condition, should the contamination front reach and pass inland beyond the intersection of Cannery and Adams Avenue, salt water could enter the inland-dipping permeable zones of the San Pedro (?) formation and then might spread widely and deeply because its density is greater than that of the native fresh water.

Fundamentally, the position of the contamination front in the Santa Ana Gap west of the Wright Street fault is determined by dynamic balance between the salt-water head of the ocean, the place and amount of fresh-water withdrawal, and the fresh-water head of the regional ground-water artery in the inland part of the gap, that is, in the Talbert water-bearing zone. (The local influx of connate water from the Pleistocene is believed to be actuated by ocean-water drive: connate water is merely displaced inland ahead of the invading ocean water.) In other words, the position of that front can be controlled with fair effectiveness by regulating the place and amount of fresh-water withdrawal, or by artificially replenishing the fresh-water head in the Talbert zone, or both. If withdrawal and replenishment (either natural or artificial) are held in such balance that the fresh-water head constantly is not lower than about 5 ft above sea level at the intersection of Cannery and Adams Avenues, then contamination should never extend beyond the regional ground-water artery in the coastward half of Santa Ana Gap. If these two controllable variables should be so balanced that a seaward hydraulic gradient again were established in the regional ground-water artery through the gap to the coast, then the contamination front should be forced back toward the coast, and over a term of years—probably several decades—a substantial part of the contaminated water now present (1945) should be displaced from the gap. Control of the contamination front as here briefly outlined is feasible, as is attested by the local natural regression in 1934–44 (p. 125) following some replenishment of the fresh-water head during a succession of wet years, and by somewhat lighter withdrawal. The hydraulics of such control are treated in some detail elsewhere (Poland and others).

If there is no objective other than constraining the area of contamination to its present extent, control of the front is not urgent currently (1945), because there has been no general advance of that front since about 1941. However, in this period there has been greater-than-average replenishment of the fresh-water head owing to excessive rainfall and to some reduction in the draft from the several public-supply well fields (following importation of water through the facilities of the Metropolitan Water District of Southern California). Also, in that period the fresh-water head in the contaminated area was intermittently drawn down below sea level, so that both local connate water and ocean water continued to move into the area behind the contamination front. The concentration of the contaminated waters continued to increase even though the front generally was stabilized and locally regressed during the period. Yet, if a succession of dry years should ensue, and if withdrawals within the gap should remain unregulated, the continuing influx of connate water and of ocean water would be accelerated and inland movement of the contamination front ultimately would resume. Under these conditions, artificial control of the front could become urgent within a very few years.

In the area east of the Wright Street fault, ocean-water drive is only a remote actuating force causing upward movement of the local connate water into the San Pedro (?) formation. Rather, at any particular well the upward reach of that contaminant fluctuates with and probably in rough proportion to the drawdown of water level under pumping. There, the proportionate amount of contaminant in the yield of an individual well can be controlled with substantial effectiveness through exploration such as that in well 6/10–18J2 (pp. 113–118), by determining the position of the interface between fresh-water and contaminant, and by securely plugging the well above that interface; also, by limiting the withdrawal sufficiently to keep the interface below the plug.

In addition, it would be necessary to plug all abandoned wells and repair existing wells in which inadequate or defective casings permit contaminants to circulate into the fresh-water aquifer from overlying or underlying zones. Even if a well is not pumped, a contaminant whose head is greater than that of the fresh water will pass through defects in the casing, circulate up or down the well, and invade the fresh-water aquifer locally. Also, if a contaminant is of greater density than fresh water even though its head is not greater, it can pass through casing defects, sink to the bottom of the well, and be withdrawn when pumping is resumed. In the Santa Ana Gap, the unconfined shallow ground water locally is as saline as ocean water, extensively has a head above that of the drawn-down Talbert water-bearing zone, and so potentially can contaminate the Talbert in the vicinity of any defectively cased well within an area that reaches inland beyond present contamination.

It is desirable for all abandoned wells when being plugged to be filled completely with impermeable material, so that even after the casing has disintegrated no permeable conduit exists to connect one water-bearing zone with another. In the construction of any new wells within the Santa Ana Gap, it is desirable for the water contained in each permeable zone to be adequately sampled and analyzed, so that top waters or bottom waters of poor chemical quality can be discriminated and cased off.

CONTAMINATION BENEATH HUNTINGTON BEACH MESA AND THE ADJACENT PART OF BOLSA GAP

SUMMARY OF GEOLOGIC FEATURES

The part of Huntington Beach Mesa which stands above the floors of the Santa Ana and Bolsa Gaps is formed wholly of Pleistocene deposits—possibly a thin mantle of the Palos Verdes sand, underlain in turn by unnamed upper Pleistocene (?) deposits and by the San Pedro formation. In the central part of the mesa these deposits extend about 575 ft below land surface. Logs of wells show that these deposits include an upper part composed of alternating thin layers of silt or clay, sand, and gravel, and a thicker lower part that is composed almost exclusively of sand and gravel. This lower zone apparently is immediately above the base of the San Pedro formation.

In general, these Pleistocene deposits contain three distinct and fairly extensive water-bearing zones. In well 5/11–35P3—on the central part of the mesa, 150 ft north of Garfield Avenue and 65 ft east of Holly Avenue—the upper zone of the three is encountered 60 feet below land surface and is 50 ft thick, the second or middle zone is reached at 187 ft below land surface and is 58 ft thick, and the top of the lower zone is found at 325 ft. The logs of adjacent wells indicate that here this lower or basal zone continues to a depth of about 575 ft and is about 250 ft thick.

Of these three zones which extensively are water-bearing, the uppermost is believed to crop out near and along the west edge of the mesa, in secs. 34 and 35, T. 5 S., R. 11 W. (projected); in sec. 26 it is at shallow depth and may crop out. In this west-central part of the mesa, the materials that compose the zone are exposed in several gravel pits which have been and to some extent still are used for disposal of oil-field wastes. Eastward, the zone extends across the full width of the mesa and butts against the alluvial deposits of Recent age which underlie the Santa Ana Gap—presumably against the relatively impermeable deposits of silt and fine sand which there overlie the Talbert water-bearing zone. Southward, the logs of wells show that the zone is continuous from the central part of the mesa at least to within 0.5 mile of the coast (at well 6/11–11E1), and that in this reach its top is about 50 ft below land surface. Still farther, quite possibly it extends beyond the mesa and crops out on the ocean floor a short distance offshore. In the opposite direction, or inland, its extent beyond the mesa is unknown. At most places, if not all, this upper permeable zone of Huntington Beach Mesa is underlain by silt about from 70 to 100 ft thick.

Like the upper zone, the middle water-bearing zone seems to underlie the greater part of the mesa (if not all), extends southward at least to within 0.5 mile of the coast and probably crops offshore, and is of unknown extent inland beyond the mesa. In the central part of the mesa its top is about 200 ft below land surface. On the west, and inland for at least a mile from the faults to be described, the zone probably is in hydraulic continuity with the "80-foot gravel" of the Recent alluvium in the Bolsa Gap. Along that west edge of the mesa and coastward from the faults, however, its continuity is not known. On the east, this middle zone may be in hydraulic continuity with the lower part of the Talbert water-bearing zone of the Santa Ana Gap.

The lower and relatively thick water-bearing zone is of decidedly different extent from that of the two overlying zones. Thus, it is known to extend southward from the central part of the mesa and to have an essentially uniform thickness of 250 ft, at least to the vicinity of well 6/11–2M2 which is a mile from the ocean. Still farther south, however, the zone appears to finger out into silt or clay, as at well 6/11–11E1 which is about 0.6 mile from the ocean and which reportedly penetrated blue clay with only streaks of coarse sand for 213 ft below the thin middle water-bearing zone (from 234 ft below land surface to the bottom of the well at 447 ft). Thus, near the coast the permeability of the lower zone diminishes greatly. Westward and northwestward the zone extends beneath and probably beyond the Bolsa Gap. On the southeast, it probably underlies and hydraulically is not in continuity with the Talbert water-bearing zone of the Santa Ana Gap; also, at least locally it fingers into or terminates against the impermeable Pleistocene deposits that underlie the Talbert zone for a mile inland from the intersection of Bushard and Hamilton Streets (p. 94). Thus, the permeability of the lower zone of the Huntington Beach Mesa probably diminishes or becomes very small beneath or near the western part of the Santa Ana Gap. Inland, this lower zone has been traced tentatively for about a mile beyond the mesa, or to well 5/11-22H1. Its extent beyond that well is unknown.

With respect to geologic structure, it is believed (Poland, Piper, and others) that at least two fault zones strike southeastward across the Huntington Beach Mesa, about parallel to and a mile and one-half mile from the coast. Evidence from the electric logs of certain oil wells shows that, although a zone of flexure exists at depth, the water-bearing deposits of Pleistocene age are displaced little if at all by these faults. Little is known about the physical character and continuity of the three water-bearing zones between the coast and the nearer fault zone, except that the log of well 6/11-11Q1 indicates that at least the upper and middle zones are essentially continuous across this nearer fault zone, and wells 6/11-11E1 and -11Q1, which are on opposite sides of this fault, both encounter materials of low permeability beginning about 235 ft below land surface, and so substantiate the previous conclusion that the lower water-bearing zone becomes increasingly less permeable near the coast.

CHARACTER AND CIRCULATION OF WATER UNDER NATIVE CONDITIONS

Available data, including those by Mendenhall (1905a, b) in 1904, suggest that the native fresh water in the upper zone of the Huntington Beach Mesa contained from 225 to 300 ppm of dissolved solids and from 12 to 20 parts of chloride, and in type ranged from the calcium bicarbonate to the calcium sodium bicarbonate. Hardness ranged from 115 to 175 ppm. Analyses 6/11-1C1 and -2J1 (table 30) are typical of the harder waters. The data by Mendenhall suggest very strongly that water of this character natively occupied all except the westernmost part of the upper zone inland from the two faults just described; the excepted part is that immediately east of the outcrop area, in which the zone obviously was not saturated to its top. Seemingly it could have been derived only by infiltration on the mesa and by percolation from shallow Pleistocene deposits farther inland. Water of the same type also extended natively to the coast, at least in the extreme southeastern part of the mesa, east of the present Main Street. There the water table was no more than about 10 ft above sea level in 1904, and there in particular the water evidently moved coastward rather freely and was not greatly impeded at either of the two faults.

However, from the inland fault to the coast, excepting the relatively small area east of Main Street, the chemical character of the water native to the upper zone remains obscure. There, only three water wells were found by the Geological Survey in 1940–41. This scarcity of water wells is not astonishing because the subarea is essentially coextensive with the city of Huntington Beach and adjacent oil-field developments. However, the investigation by Mendenhall in 1904 antedated the discovery of the oil field, but enumerated only two wells in the particular area. Neither investigation found any water wells in the southwest angle between the inland fault and Golden West Avenue, that is, on the western half of the subarea. This very absence of wells implies that early drilling may have found salty native water in the upper zone, as is known to occur along the coast farther northwest (pp. 58–61) and as would be consistent with certain chemical evidence to be introduced.

Fragmentary data concerning the middle zone of the Huntington Beach Mesa suggest that the native fresh water was of the calcium sodium bicarbonate type, with total dissolved solids possibly as much as 375 ppm, chloride content from 30 to 40 parts, and hardness at least as little as 55 parts. As of 1904, before it had been depleted greatly by withdrawals, the head of this water was several tens of feet above sea level in the southeastern part of the mesa, specifically, about 30 ft above sea level in well 254 (after Mendenhall) which was about 1,000 ft from the coast and near the southeast corner of the mesa, and about 60 ft above sea level in well 252 which was about 1.2 miles inland and near the present Huntington Beach Union High School. (See pl. 2.) Evidently the coastward circulation of water in the middle zone was impeded somewhat, possibly at the two faults. Because this middle water-bearing zone of the Huntington Beach Mesa locally is in hydraulic continuity with the "80-foot gravel" to the west and possibly with the Talbert water-bearing zone to the east, the fresh water natively contained in the middle zone of the mesa presumably has been derived largely from those two regional ground-water arteries, and its head has been imposed likewise. Available evidence does not preclude the possibility of native salty water in the middle zone within the southwest angle between the inland fault and Main Street.

The native water in the lower zone of the Huntington Beach Mesa is of the sodium bicarbonate type, with dissolved solids ranging from 250 to 300 ppm, chloride from 12 to 15 parts, and hardness from 20 to 35 parts. Analyses 5/11–26P1 and 6/11–1N1 are taken as typical. (See table 30.) Thus, it is decidedly softer than the water of the overlying two zones. As of 1904, its head was sufficient to produce flowing wells in the central part of sec. 2, T. 6 S., R. 11 W. (projected); that is, its static level was at least about 60 ft above sea level. Presumably the water of the lower zone is derived by percolation from Pleistocene deposits farther inland, and at best can be derived only remotely from the regional ground-water arteries.

GENERAL EXTENT OF CONTAMINATED WATERS

The earliest available chemical analyses (1925) show definite saline contamination at least locally in the waters of the Huntington Beach Mesa at that time—specifically, at wells 5/11–34F and –34H which tapped the middle water-bearing zone, also in well 6/11–11E1 which tapped both the upper and middle zones. (See table 30.) Of these three wells, the first two were about 1.7 miles from the coast, in the west-central part of the mesa; the third well, 6/11–11E1, is about 0.5 mile from the coast and just inland from the more southerly of the two faults. By 1931, when fairly comprehensive analytical data were obtained by local agencies, water of deteriorated quality had been withdrawn from several additional wells and at that time waters containing more than 50 ppm of chloride are inferred to have underlain 1,500 acres of the mesa. Within the next decade both the extent and intensity of contamination increased substantially until as of 1941–42, water containing more than 50 parts of chloride underlay about 2,100 acres.

As is shown on plate 11*B* by shaded areas, the natively fresh waters of the Huntington Beach Mesa now (1945) definitely are contaminated by salines about as follows:

1. Throughout the upper water-bearing zone beneath the extreme southeast part of the mesa, that is, from the coast inland across the nearer of the two faults and to Adams Avenue at least, but not east of Hampshire Avenue. Neither the northward nor the westward reach of this area of contamination in the upper zone is defined sharply, because water wells that might give pertinent factual information do not exist. Thus, beneath

the eastern part of the mesa and at least between Golden West and Huntington Avenues, this southeastern area of known contamination may reach northward to and merge with a central area of contamination to be described. Beneath the western half of the mesa, it is assumed that the upper zone now probably contains salty water from the coast inland roughly to the nearer of the two faults; here in particular, any salty water may not be due wholly to contamination, but at least in part may be native, as has been implied and as is true in the coastal segment of the Bolsa Chica Mesa to the northwest. (See analysis 5/11–29P1, table 30.)

2. In the middle water-bearing zone, at least locally in the southeastern area just described. Factual information now available does not indicate the reach of these contaminated waters, except that definitely they do not now reach to well 6/11–2M2, which is 1.2 miles inland. That well taps only the middle water-bearing zone, is pumped continually to supply the Huntington Beach Union High School, and yields water which had not increased appreciably in chloride content through October 1943. To the west, salty water due to contamination of the middle zone may grade into native saline water along the coast.

3. In the upper water-bearing zone and probably locally in the underlying middle zone, beneath an area of about 900 acres in the central and west-central parts of the mesa; also locally in an adjacent part of the "80-foot gravel" which underlies the Bolsa Gap, and which there is in hydraulic continuity with the middle zone of the mesa. The northeast and northwest margins of this particular contaminated area, but not the southwest margin, are rather sharply defined by available analytical data; those data do not preclude the possibility that contaminated waters occupy the upper water-bearing zone continuously from the coast inland across the two faults and into the area here described.

4. Possibly in the lower water-bearing zone, locally in the central part of the mesa in the vicinities of certain wells that are inadequately cased. However, that particular zone is not known to be contaminated extensively, as of 1941–43.

Thus, the upper water-bearing zone definitely is contaminated by salines in two distinct areas, beneath the southeastern and central parts of the mesa. Also, west of Huntington Avenue this zone may be contaminated in unbroken continuity from the coast to the farthest inland reach of the central area, that is, for about 2½ miles or nearly to Slater Avenue. The central area of definite contamination is wholly inland from any barrier features of the

Newport-Inglewood structural zone. At least locally, the middle water-bearing zone is contaminated within the same two areas but is not contaminated between those areas except possibly in the area west of Golden West Avenue.

CONTAMINATED WATERS BENEATH THE SOUTHEASTERN PART OF THE MESA

For the southeastern part of the mesa, analytical data are available only for ten wells in sec. 11, T. 6 S., R. 11 W., of which nine wells have yielded contaminated water. Two of these nine, wells 6/11–11E1 and –11Q1, tap both the upper and middle water-bearing zones but not the lower zone, five tap only the upper zone, and well 11G1, whose depth is unknown, is inferred to tap only the upper zone. Table 13 summarizes information and shows that as of 1931: (1) contamination was most intense in the upper water-bearing zone but commonly was only incipient in the topmost part of that zone, as in well 11J2 and in well 11Q1 at the 40-ft depth; (2) at least locally, contaminated waters of the upper zone contained about 75 percent as much chloride as ocean water, as at the 50- to 110-ft depth in well 11Q1; and (3) in this same well and at the 189- to 200-ft depth, the middle zone was moderately contaminated although in 1904 a 200-ft (?) well at nearly the same place then yielded water containing only about 350 ppm of all dissolved solids. The data tabulated for well 11J4 as of 1942 suggest that the contaminant is not dispersed uniformly throughout the vertical range of the water-bearing zones.

TABLE 13.—*Wells tapping contaminated water in southeastern part of Huntington Beach Mesa*

Well number on plate 11	Distance inland (miles)	Depth of well or of perforated casing (feet)	Water-bearing zone	Parts per million: Chloride	Parts per million: Dissolved solids	Date
6/11-11E1	0.55	50-66 84-100 216-234	Upper Middle	308	842	October 1925.
11G1	1.0	----------	Upper(?)	931	----------	October 1943.
11J2	.85	130	Upper	[1] 62	322	October 1931.
11J3	.65	144	----do----	542	1,069	October 1931.
11J4	.7	----------	[2]	3,390 578	---------- ----------	April 1942 October 1942.
11K1	.75	110	Upper	[1] 46	294	October 1931.
11K2	.7	90	----do----	[1] 60	251	October 1931.
11K3	.6	46	Upper(?)	98	280	October 1931.
11Q1	.35	40 50-110 189-200	---------- Upper Middle	[3] 120 [3] 14,400 [3] 1,440	---------- ---------- ----------	1931

[1] Contamination incipient.

[2] Probably taps upper zone, and possibly taps middle zone also.

[3] During construction of well.

Comprehensive chemical analyses of the contaminated waters are available only for six of the nine wells just described, and only for 1925 or 1931. Figure 18 shows the chemical character of the waters from these six wells in relation to the inferred

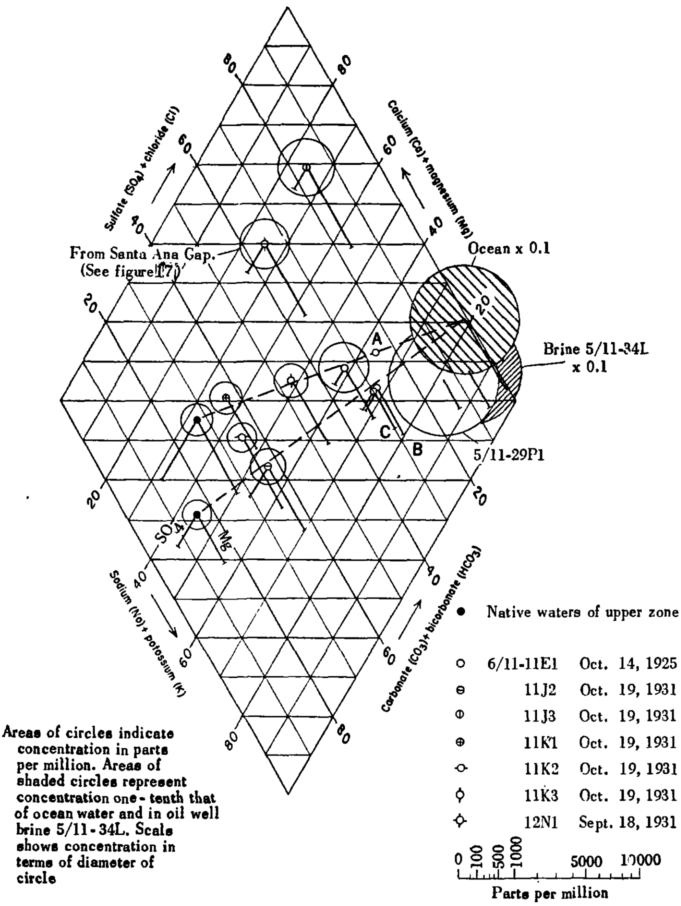


FIGURE 18.—Chemical character of native and contaminated waters from the upper and middle water-bearing zones in the southeastern part of the Huntington Beach Mesa, of potential contaminants, and of a contaminated water from the Santa Ana Gap. A, hypothetical mixture of the native water with ocean water, in proportions yielding a chloride content equal to that of contaminated water 6/11-11E1; B, a corresponding mixture with brine 5/11-34L; and C, a mixture with native salty water 5/11-29P1.

character of the native waters in the upper zone and to the character of three representative potential contaminants. The three potential contaminants are ocean water, brine 5/11-34L from a representative oil well in the Huntington Beach field, and native salty water 5/11–29P1 from a well in the coastal segment of the Bolsa Gap. Analytical data for the contaminated waters and for the native salty water are given in table 30; data for ocean water and for the brine, in table 29.

Excepting data from well 6/11–18J3, the analyses of the several contaminated waters of 1925 and 1931 plot on figure 18 very nearly in alinement with those of the native waters and of ocean water—just as they would plot were they simple mixtures of native water and ocean water. However, this alinement is fortuitous. If ocean water was the contaminant, moderate chemical modification has taken place after the admixture; also, with modifications no greater, the contaminated waters could have resulted from admixture of either brine 5/11–34L or native salty water 5/11–29P1. Thus, the plottings of three hypothetical mixtures on figure 18 and the data of the following table 14 show that contaminated water 11E1 could have resulted from admixture of any of the three representative potential contaminants, accompanied by some exchange of bases and reduction of sulfate and by further gain in both calcium and bicarbonate (perhaps by dissolving those constituents from the water-bearing material). Regarding the three hypothetical mixtures and in terms of chemical equivalents:

1. In all cases, the contaminated water has an excess of calcium and of bicarbonate, but a deficiency of sodium and of sulfate.

2. The sulfate deficiency (potentially due to reduction of this constituent) is only nominal in the cases of native salty water 29P1 and brine 34L, but is substantial in the case of ocean water. In all cases it is less than the bicarbonate excess.

3. In all three cases the sodium deficiency (potentially due to exchange of bases) is only moderate but is less than the calcium excess.

4. In the cases of native salty water and of brine, magnesium is in moderate excess but is in amounts less than the corresponding sodium deficiencies, as could result from a normal exchange of bases between either of the two potential contaminants and a material whose exchange media previously had been in equilibrium with the uncontaminated calcium bicarbonate water. In the case of ocean water, however, magnesium is deficient substantially and in an amount greater than the sodium deficiency. The greater deficiency in magnesium would be distinctly anomalous as an effect of base exchange. (See p. 89.)

Although far from conclusive, the weight of the foregoing chemical evidence seems to favor a native salty water or an oil-

TABLE 14.—*Contaminated water from well 6/11–11E1 in comparison with hypothetical mixtures of the presumed native water from that well with three potential contaminants*

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Standard native water of the upper zone of Huntington Beach Mesa	46	10	34	205	35	18
Well 6/11-11E1, contaminated water of Oct. 14, 1925 (table 30)	81	21	185	286	24	308
Standard native water mixed with:						
Native salty water of well 5/11-29P1	62	15	206	246	30	308
Brine of well 5/11-34L	54	19	207	235	35	308
Ocean water	51	30	198	205	75	308
Equivalents per million:						
6/11-11E1, Oct. 14, 1925	4.04	1.73	8.08	4.68	.50	8.67
Mixture with 29P1	3.10	1.26	8.96	4.03	.62	8.67
Mixture with 34L	2.69	1.55	9.02	3.85	.74	8.67
Mixture with ocean water	2.56	2.43	8.60	3.36	1.56	8.67
Excess (+) or deficiency (−) of the contaminated water with respect to:						
Mixture with 29P1	+.94	+.47	−.88	+.65	−.12	----------
Mixture with 34L	+1.35	+.18	−.94	+.83	−.24	----------
Mixture with ocean water	+1.48	−.70	−.52	+1.32	−1.06	----------

[1] Includes equivalent of potassium (K).
[2] Includes equivalent of carbonate (CO_3).

field brine as the contaminant at well 6/11–1-E1, but does not preclude ocean water. A similar showing can be made of the incipient contamination at other wells in the southeastern area (excepting well 6/11–11J3). Oil-field brines have been discharged promiscuously onto the permeable land surface of the mesa (p. 77), and could have percolated downward into the upper water-bearing zone. Salty waters or brine are not known to be native in either the upper or the middle water-bearing zone, but easily could exist in local structural traps along either or both of the two faults that parallel the coast.

The available fragmentary information suggests that beneath the southeastern part of the mesa, the contaminant or contaminants first have invaded the upper water-bearing zone and then have reached the middle zone by way of wells whose casings are inadequate or are perforated in both zones. This suggested path of invasion precludes none of the potential contaminants.

Neither are pertinent hydrologic data conclusive. Thus, as has been stated, the upper water-bearing zone presumably is continuously permeable to an offshore outcrop, at least in the extreme eastern part of the mesa, so that there the fresh waters of the land would have been in hydraulic continuity with the ocean. Also, if native salty waters exist in the upper zone to the northwest, they would have had some hydraulic continuity with the native fresh waters of the southeastern area. In well 6/11–12E1 (which penetrates only the upper water-bearing zone at the extreme eastern edge of the mesa) the fresh water head was 8.6 ft above sea level in 1924, had been drawn down to about 1 ft above sea level by late 1925, and remained about 1 ft above sea level through the latest measurements in 1930. In well 11E1, which is about a mile to the west and which has been described as penetrating both the upper and middle zones, the head has fluctuated slowly between 1.3 and 4.5 ft above sea level since 1931, with the greatest head in 1941. This range is known from monthly measurements by the Orange County Flood Control District. So substantial a depletion of the fresh water head could have caused brine to move inland from the ocean, or caused salty water native in the upper zone to have migrated from the northwest, or both.

In this treatment of the chemical aspects of water contamination beneath the southeastern part of the Huntington Beach Mesa, an exception has been made of well 6/11–11J3. In 1931, water from this well was more intensely contaminated than that from any other well of the particular area for which comprehensive analytical data are available. As table 15 shows it is unique for the area in that it resembles the first-stage contaminated waters of the Santa Ana Gap, such as that from well 6/11–12N1 (fig. 18, p. 120); also, it resembles contaminated waters beneath the central part of the mesa, which will be described later.

Table 15 draws the contrast between the contaminated water of well 18J3 and that of well 11E1, previously described. Regarding specifically the three hypothetical mixtures and in terms of chemical equivalents:

1. In all three, the contaminated water of 18J3 has relatively large excesses of both calcium and magnesium, but in amounts substantially less than the corresponding sodium deficiencies. (With 11E1, the excesses of calcium and magnesium were greater than the sodium deficiencies.) Evidently, a considerable exchange of bases, together with precipitation of calcium in moderate amount, would be necessary to produce this result.

2. With native salty water and with brine, sulfate is in moderate excess (rather than deficient in nominal amount, as with 11E1); evidently, this constituent would need be gained from

some source not indicated by available data. In the case of ocean water, sulfate is moderately deficient, a condition which could result from reduction of that constituent.

TABLE 15.—*Contaminated water from well 6/11–11J3 in comparison with hypothetical mixtures of the presumed native water from that well with three potential contaminants*

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Standard native water of the upper zone of Huntington Beach Mesa	46	10	34	205	35	18
Well 6/11-11J3, contaminated water of Oct. 19, 1931 (adjusted)	217	46	112	191	56	540
Standard native water mixed with:						
Native salty water of well 5/11-29P1	75	19	344	279	25	540
Brine of well 5/11-34L	60	26	347	259	35	540
Ocean water	56	45	330	205	107	540
Equivalents per million:						
6/11-11J3, Oct. 19, 1931	10.82	3.80	4.89	3.13	1.16	15.22
Mixture with 29P1	3.74	1.60	14.98	4.57	.53	15.22
Mixture with 34L	3.00	2.12	15.08	4.24	.74	15.22
Mixture with ocean water	2.78	3.70	14.33	3.36	2.23	15.22
Excess (+) or deficiency (−) of the contaminated water with respect to:						
Mixture with 29P1	+7.08	+2.20	−10.09	−1.44	+.63	----------
Mixture with 34L	+7.82	+1.68	−10.19	−1.11	+.42	----------
Mixture with ocean water	+8.04	+.10	−9.44	−.23	−1.07	----------

[1] Includes equivalent of potassium (K).
[2] Includes equivalent of carbonate (CO_3).

3. In all three mixtures, bicarbonate is deficient (whereas with 11E1 bicarbonate was in excess); the deficiency was only nominal in the mixture of ocean water, but moderate in the mixtures of native salty water and brine. This deficiency in bicarbonate would be accounted for in the precipitation of calcium as the carbonate. However, in the mixtures of native salty water and of brine, this deficiency would need be coupled with the gain in sulfate already cited. This is somewhat anomalous. In the mixture of ocean water, the over-all loss in bicarbonate would need be greater than the gain in bicarbonate through reduction of sulfate.

This chemical evidence for well 11J3 is even less conclusive than that for well 11E1 and precludes none of the three potential contaminants. In some respects, contamination largely by ocean water would be somewhat the more likely.

Among the four wells which penetrated substantially the full thickness of the upper water-bearing zone but did not reach the middle zone, and for which comprehensive analytical data are available (table 13, fig. 18), well 11J3 is deepest and nearest the coast. Thus, its more intense contamination, as of 1931, is not unusual if the contaminant was moving into the area at the very bottom of the water-bearing zone or from the direction of the coast.

The foregoing discussion has implied that, as of 1931, the native fresh waters of the upper zone in the southeastern part of the Huntington Beach Mesa may have been invaded both by a connate oil-field brine or a salty water native to the zone, and by ocean water. Neither chemical nor hydrologic data are available to demonstrate conclusively the actual source or sources of contamination at that time or subsequently.

CONTAMINATED WATERS BENEATH THE CENTRAL AND WEST-CENTRAL PARTS OF THE MESA

GENERAL FEATURES

As of 1931, definitely contaminated waters containing more than 50 ppm of chloride underlay about 550 acres in the central and west-central parts of the Huntington Beach Mesa, inland beyond any barrier features of the Newport-Inglewood structural zone. (See pl. 11*A*.) The most highly contaminated water then known in the area was in the NW¼ sec. 2, T. 6 S., R. 11 W., where a sample from 100 ft below land surface in unused well 6/11–2D1 contained 1,757 parts of chloride. To the southwest, in the central part of sec. 2, the four wells at the Clay plant of the Southern California Water Co. were not used after early 1931 because of excessive salinity. Samples bailed from these wells in April 1931 indicated a chloride content ranging from 75 to 815 ppm.

By 1941–42, this area of definitely contaminated waters covered about 900 acres—most of the 350-acre increase in the intervening decade occurred north of Garfield Avenue and east of Golden West Avenue, and about 125 acres reached beyond the mesa into the east flank of the Bolsa Gap. As in 1931, the most intense contamination was in the central part of sec. 2, where well 6/11–2G4 (Southern California Water Co., well 3) in 1941 produced water containing 1,800 ppm of chloride after 2½ hr of pumping. At the same time, bailed samples from two of the other three wells owned by the company contained 3,640 and 3,530 parts of chloride.

The following table 16 summarizes data and shows, as of 1945, that the most intensely contaminated waters were and are from wells that tap only the upper water-bearing zone; in waters from wells that tap the middle zone the contamination is moderate, but in those from the two wells that presumably tap the lower zone, the contamination is little more than incipient; and seemingly, through the decade ending with 1941–42, the intensity of contamination increased in all parts of the area and in waters from wells tapping all three water-bearing zones. It is inferred that contaminants are widely dispersed only in the upper zone, from which presumably they have reached the middle zone locally near wells with casings perforated in the two zones. Although incipiently contaminated water has been yielded by wells that

TABLE 16.—*Wells of know depth tapping contaminated water in central and west-central parts of Huntington Beach Mesa, also in the adjacent part of Bolsa Gap*

[In sequence of increasing depth to zones tapped]

Well number on plate 11	Depth of well (feet)	Depth of perforated casing (feet)	Water-bearing zone	Parts per million		Date
				Chloride	Dissolved solids	
6/11-2K1	53	------	Upper	342–27	------	1931.
5/11-26N1	54	------	Upper(?)	126–57	475–380	1941–42.
34A1	110	------	Upper	125–64	------	1930–31.
34A2	110	------	----do----	71	375	Sept. 18, 1931.
35N1	125	------	----do----	483	1,050	May 9, 1931.
6/11-2G1	252	80–118	----do----	103 617 [1] 3,640	402 1,320 6,200	Oct. 18, 1930. May 5, 1931. Mar. 26, 1941.
2G2	124	------	----do----	495 [1] 3,530	1,064 6,500	Aug. 11, 1930. Mar. 26, 1941.
2G4	263	90–111	----do----	73 408 [3] 1,845	361 918 3,570	Oct. 21, 1930. July 18, 1933. May 20, 1941.
2F1	150	------	----do----	[4] 1,530	3,050	Jan. 3, 1941.
5/11-35M1	150	------	----do----	392–227	850–740	1941–42.
34F	200(?)	------	Upper and middle(?)	129	489	Oct. 15, 1925.
6/11-2D1	203	------	Upper(?)	1,757 [4] 820–655	2,907 1,650–1,400	Oct. 21, 1931. 1941–42.
5/11-26M1	201	35–62 74–96 153–179	Alluvium 80-foot gravel Middle	29 208 [5] 13 [6] 213	277 695 220 640	Apr. 27, 1939. Jan. 20, 1943. Feb. 3, 1943. June 4, 1943.
26M2	282	60–85 175–180 254–256	80-foot gravel Middle	16 129	256 512	Sept. 18, 1931. Dec. 4, 1942.
6/11-2G3	258	100–118 214–224 242–254	Upper Middle	27 [2] 26	289 ------	Aug. 11, 1930. Mar. 26, 1941.
5/11-35L1	350	------	Upper and middle(?)	476–207 325	1,180–650 964	1941–42. Apr. 9, 1942.
35P1	391	213–246 337–367	Middle Lower(?)	16 91 92	247 334 375	Oct. 21, 1931. Sept. 3, 1937. Sept. 12, 1941.
6/11-2B2	------	------	Middle and lower(?)	64–111	320–640	1941–42.

[1] Bailed from near bottom of well or below perforations.
[2] Bailed from 44 ft below static water level.
[3] After pumping 1 hr.
[4] Bailed just below static water level in idle well.
[5] Well flowing.
[6] After pumping 6 hr.

tap the lower zone, it is altogether possible that contaminants have not yet invaded that zone but are drawn wholly from overlying zones as the few deep wells are pumped.

PROGRESSIVE DEPRECIATION OF WATER QUALITY AT WELLS OF THE SOUTHERN CALIFORNIA WATER CO., CLAY PLANT

As has been stated, the four public-supply wells at the Clay plant of the Southern California Water Co. (6/11–2G1, –2G2, –2G3, and –2G4) in the southwest angle of Clay Street and Huntington Avenue (see pl. 11), were taken out of service in early 1931, by which time the chloride content of their waters ranged from 400 to 600 ppm. Considerable contamination was then evident. Three of the four wells tapped only the upper water-bearing zone beneath the central part of the Huntington Beach Mesa; the fourth well, 2G3, tapped both upper and middle zones. In early 1941, samples bailed from wells 2G1 and 2G2, from below the perforations in their casings, contained 3,530 and 3,640 ppm of chloride, respectively; samples taken from the pump of well 2G4 contained 1,845 parts of chloride after 1 hr of draft, and 1,800 parts after 2½ hr of draft. (See table 16.) It is concluded that in the decade ending in 1941 the contaminant had continued its invasion of the area even though the draft from wells had almost ceased, and that the contaminant had not become dispersed uniformly through the upper water-bearing zone but was most concentrated in the lower part of that zone.

Figure 19, plate 15, and table 17 present available significant evidence of the chemical characters of the contaminated waters from the four wells, of the native fresh water, and of potential contaminants. On figure 19, a single analysis for well 6/11–2G3 is not plotted because that well taps both the upper and middle water-bearing zones; thus, the figure concerns only waters wholly from the upper zone. Three potential contaminants are considered specifically: ocean water and representative brines from two oil wells of the Huntington Beach field, 6/11–11A2 and 5/11–34L. This evidence indicates admixture of a contaminant of high-chloride content generally accompanied by considerable base-exchange hardening. Although not conclusive, the evidence favors admixture of an oil-well brine, gain in both calcium and magnesium by exchange of bases with the water-bearing material, virtually no reduction of sulfate, and precipitation of calcium carbonate in nominal amount. In contrast, if the admixed contaminant were ocean water it would be necessary that sulfate

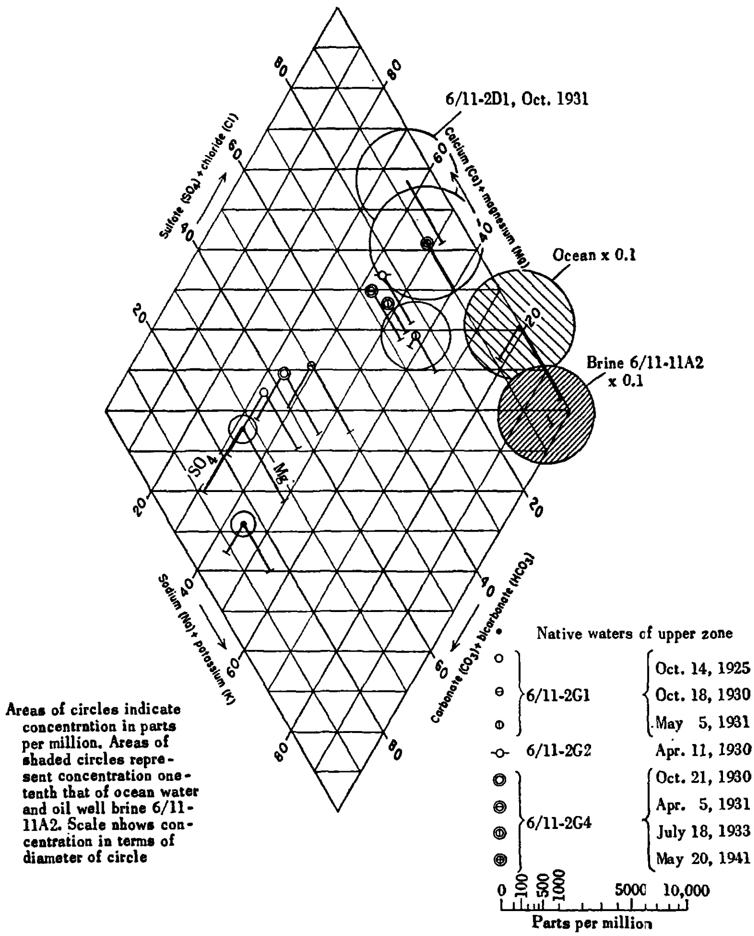


FIGURE 19.—Chemical character of native and contaminated waters from three wells of the Southern California Water Co. (Clay plant) in 1925–41, also of potential contaminants and of two other contaminated waters.

be reduced and calcium carbonate precipitated, both in considerable amount, but reduction and precipitation in the required amounts are believed unlikely. Admixture with ocean water would necessitate loss of magnesium by exchange of bases, but not in unreasonable quantity.

Evidently the contaminated water of well 6/11–2D1, half a mile northwest of the Clay plant, could have resulted from chemical processes identical with those here described.

This discussion of depreciated water quality at wells of the Southern California Water Co., Clay plant, has pertained only to the upper water-bearing zone. However, one of the four wells at

TABLE 17.—*Contaminated water from well 6/11–2G4 (Southern California Water Co., Clay plant, well 1) in comparison with hypothetical mixtures of the presumed native water from that well with three potential contaminants*

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Standard native water of the upper zone of Huntington Beach Mesa	46	10	34	205	35	18
Well 6/11–2G4, contaminated water of May 20, 1941 (adjusted)	454	87	649	334	37	1,838
Standard native water mixed with:						
Brine of well 6/11–11A2	64	25	1,225	369	31	1,838
Brine of well 5/11–34L	96	64	1,126	394	35	1,838
Ocean water	80	131	1,066	206	286	1,838
Equivalents per million:						
6/11–2G4, May 10, 1941	22.66	7.19	28.22	5.48	.77	51.82
Mixture with 11A2	3.19	2.06	53.26	6.05	.64	51.82
Mixture with 34L	4.77	5.29	48.96	6.46	.74	51.82
Mixture with ocean water	3.99	10.81	46.35	3.38	5.95	51.82
Excess (+) or deficiency (−) of he contaminated water with respect to:						
Mixture with 11A2	+19.47	+5.13	−25.04	−.57	+.13	----------
Mixture with 34L	+17.89	+1.90	−20.74	−.98	+.03	----------
Mixture with ocean water	+18.67	−3.62	−18.13	+2.10	−5.18	----------

[1] Includes equivalent of potassium (K).

[2] Includes equivalent of carbonate (CO_3).

that plant, 6/11–2G3, has been described as tapping both the upper and the middle water-bearing zones. Thus, that well and any others of like penetration and casing perforations afford conduits through which the contaminant might reach the middle zone. In this respect, paired measurements of water level made weekly by the Geological Survey from December 1940 to December 1942 shows that the head of the water in the upper zone (well 2G2) then ranged from 1 ft to 8 ft above sea level, and for most of that period was from 1 ft to 3 ft greater than the mean head of the upper and middle zones combined (well 2G3). It is reasonable to expect that similar conditions then prevailed and still prevail rather widely in this central part of the Huntington Beach Mesa. Thus, the relatively great density of the saline contaminant and the greater head in the upper water-bearing zone probably have acted and are acting jointly to transmit contaminated water from the upper zone downward to the middle zone, through wells such as 2G3 whose casing is perforated (as of 1945) in both zones. In other words, it is altogether probable that the middle water-bearing zone is being contaminated steadily from above.

INTERMITTENT DEPRECIATION OF WATER QUALITY AT WELLS OF THE SOUTHERN CALIFORNIA WATER CO., GOLDEN WEST PLANT

At the extreme northern reach of known contamination in the west-central part of the Huntington Beach Mesa, the two public-supply wells at the Golden West Plant of the Southern California Water Co. (5/11–26M1 and –26M2) in recent years intermittently have yielded water of depreciated quality. These two wells were drilled on the floor of the Bolsa Gap in or about 1931, in lieu of the abandoned wells of the Clay plant whose contaminated waters were just described. Their casings are perforated both in the "80-foot gravel" of the Recent alluvial deposits and in the northwestward extension of the middle water-bearing zone of the Huntington Beach Mesa. (See table 15.) These two wells have supplied water for the city of Huntington Beach since 1931 and, although it now is known that some incipient depreciation of quality occurred at least as early as 1938, water with an objectionably large content of chloride first was recognized by the operators in the discharge from well 26M1 late in the autumn of 1942. That well then was taken out of service temporarily.

Figure 20 graphs the chemical analyses for the two wells of the Golden West plant, and suggests that the contamination has progressed consistently toward water chemically similar to that of well 6/11–11J3, previously described. Table 18 compares the most intensely contaminated water of well 26M1 and hypothetical mixtures of the water native to the "80-foot gravel" with the representative brines of oil wells 6/11–11A2 and 5/11–34L, also with ocean water. Evidently the actual contaminated water could have resulted from admixture of either brine, coupled with moderate exchange of bases, and with moderate gain in both calcium and sulfate (from some unknown source); also, it could have resulted from admixture of ocean water coupled with moderate exchange of bases and gain in both calcium and bicarbonate. The admixture with ocean water would require the less extensive modification.

Critical information about hydrologic aspects of the intermittent contamination in these wells of the Golden West plant is afforded by certain pump tests and controlled operations in 1942–43, in sequence as follows:

1. As has been stated, well 26M1 was shut down in the late autumn of 1942 when substantially contaminated water first was detected by the operating agency. For several months previ-

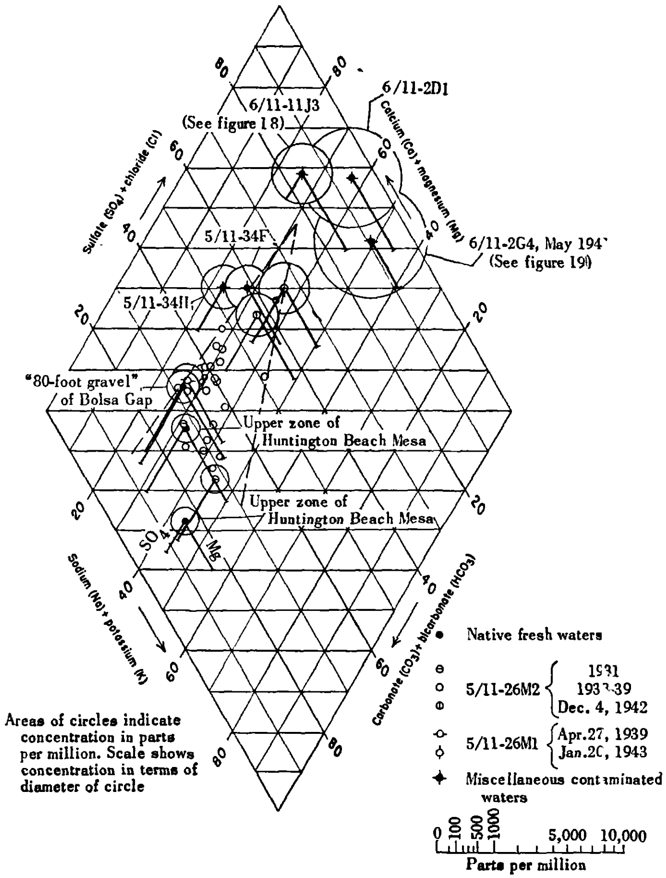


FIGURE 20.—Chemical character of native and contaminated waters from wells 5/11-26M1 and 26M2 (Southern California Water Co., Golden West plant, wells 2 and 1) in 1931–43, in comparison with miscellaneous contaminated waters.

ously the public-supply load had been divided equally between this well and 26M2, by pumping each well on alternate days. Subsequently, through December 29, 1942, the full load was carried by well 26M2 and the water from that well remained of usable quality; well 26M1 stood idle except for a pump test described next.

2. On December 10, 1942, a 4-hr pumping test at a withdrawal rate of 1,150 gallons a minute was made on well 26M1 by the Geological Survey. After the first minute and through 2 hr of draft, the quality of the water discharged was essentially constant—chloride, 12 or 13 ppm; hardness, 110 to 115 ppm; total dissolved solids (estimated from electrical conductivity), about

220 ppm. During the third and fourth hours of draft the amounts of these constituents increased slightly. (See fig. 18.)

TABLE 18.—*Contaminated water from well 5/11-26M1 (Southern California Water Co., Golden West plant, well 2) in comparison with hypothetical mixtures of the presumed native water from that well with three potential contaminants*

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Standard native water of the 80-foot gravel	56	11	32	212	47	23
Well 5/11-26M1, contaminated water of Jan. 20, 1943 (adjusted)	112	20	93	231	73	211
Standard native water mixed with:						
Brine of well 6/11-11A2	58	13	155	228	47	211
Brine of well 5/11-34L	61	17	145	231	47	211
Ocean water	60	24	138	212	73	211
Equivalents per million:						
5/11-26M1, Jan. 20, 1943	5.56	1.63	4.06	3.78	1.53	5.94
Mixture with 11A2	2.89	1.03	6.73	3.74	.97	5.94
Mixture with 34L	3.06	1.37	6.28	3.79	.98	5.94
Mixture with ocean water	2.98	1.94	6.01	3.47	1.52	5.94
Excess (+) or deficiency (−) of the contaminated water with respect to:						
Mixture with 11A2	+2.67	+.60	−2.67	+.04	+.56	-----------
Mixture with 34L	+2.50	+.26	−2.22	−.01	+.55	-----------
Mixture with ocean water	+2.58	−.31	−1.95	+.31	+.01	-----------

[1] Includes equivalent of potassium (K).
[2] Includes equivalent of carbonate (CO_3).

3. From December 29, 1942, to January 4, 1943, the two wells were rotated in service and were pumped from 16 to 19 hr each, on alternate days; 405,400 cu ft of water were pumped from well 26M1 and 246,900 cu ft from well 26M2. Samples taken at the end of each day's pumping showed that in the water from well 26M2 the dissolved solids remained essentially constant at about 380 ppm, but in the water from well 26M1 they increased progressively from 580 ppm on December 29 to 665 parts on January 2 and 4. Thus, after 17 to 19 hr of draft on each alternate day, the dissolved-solids content in the water from well 26M1 was between 2.5 and 2.9 times that at the end of the 4-hr test of December 10.

4. From January 4 through 11, well 26M2 was idle but well 26M1 was pumped daily; a total of 774,300 cu ft of water was withdrawn. At the end of this period the chloride content of the water was 243 ppm and soap hardness was 400 ppm; total

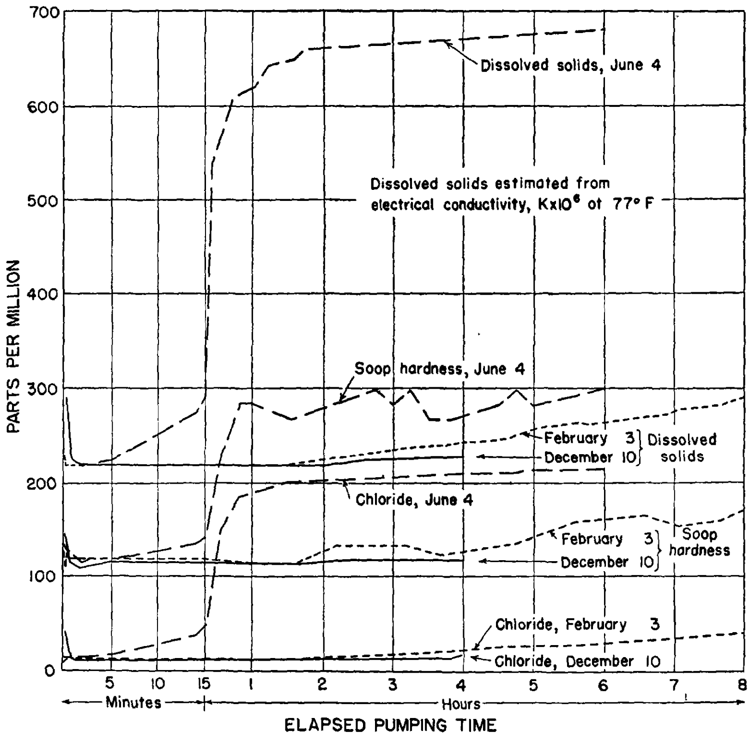


FIGURE 21.—Chemical character of water discharged from well 5/11-26M1 (Southern California Water Co., Golden West plant, well 2) during pumping tests of December 10, 1942, also February 3 and June 4, 1943.

dissolved solids were about 750 ppm, or 3.3 times that after the 4-hr test.

5. Through part of January 18 well 26M1 was idle and all the public service was carried by well 26M2; the draft for the period was 688,700 cu ft.

6. Well 26M1 again was pumped 36½ hr on January 18–20, and 207,800 cu ft of water withdrawn. A sample taken at or near the end of this period contained 208 ppm of chloride, 362 parts of hardness, and 695 parts of all dissolved solids (fig. 20, tables 18 and 30). Thus, following a week of idleness and then the draft described, the intensity of contamination was about the same as on January 11 after draft for a week. Subsequently, until February 3, well 26M1 was idle and well 26M2 alone was pumped for public supply.

7. On February 3 a second pumping test was made on well 26M1 by the Geological Survey. Its duration, which was limited by reservoir capacity, was 8 hr and 15 min; total metered draft

was 74,550 cu ft; average rate of draft was 1,130 gpm. At the start of the test the well was flowing by artesian pressure. As figure 21 shows, through about 1½ hrs of draft, the water discharged was essentially identical in quality with that during the corresponding interval of the test of December 10—the total-solids content was only 32 percent of that after the service pumping of January 18–20. Thereafter, the quality of the water depreciated steadily until at the end of the test the total-solids content was 295 ppm, but even then only 42 percent of that on January 20.

8. Well 26M1 was not pumped again until mid-April, except on February 15 and March 6–7; later it was pumped frequently in rotation with well 26M2 and was pumped from 18 to 20 hr daily on May 22–25 and 29–31. As shown by paired samples taken during the latter period, after 5 min of draft on each day the quality of the water was good and was essentially identical with that after a like term of draft in the tests of December 10 and February 3, but by the end of the pumping period it had depreciated to that of January 20. (See following table 19.)

TABLE 19.—*Chemical character of samples from well 5/11–26M1 during pumping, May 29–June 1, 1943*

	Elapsed pumping time	Draft (cu ft)	Parts per million		
			Chloride	Soap hardness	Dissolved solids (estimated from electrical conductivity)
May 29–30	5 min		14	110	220
	20 hr	148, 900	209	300	660
May 30–31	5 min		19	115	235
	20 hr	140, 800	222	290	690
May 31	5 min		14	120	220
June 1	18 hr	133, 200	214	320	680

9. Subsequently, well 26M1 was idle until June 4 when a final 6-hr pumping test was made by the Geological Survey; the rate of draft was 1,150 gpm. As figure 21 shows, only during the third minute of this test was the quality of the water like that of the two earlier tests; thereafter the quality depreciated steadily though not uniformly. After 14 min the total-solids content was 275 ppm or 40 percent of that after the pumping period of January 18–20, after 30 min was 77 percent, after 1¾ hr was 95 percent, and at the end of 6 hr was 98 percent (680 ppm).

During the 6-month term of these tests and observations, the water from well 26M2 remained about constant in quality although incipiently contaminated, whereas that from well 26M1 intermittently had been contaminated substantially and seemingly to about the same degree at the end of each day's service pumping. Evidently the contaminant was not then dispersed throughout the water-bearing materials tapped by the two wells, but was drawn into the wells in unequal proportions by the pumping draft. It is inferred that the contaminant is entering the casing of well 26M1 largely or exclusively through its uppermost perforations, which are 35 to 62 ft below land surface (table 16) and which presumably tap unconfined water in the alluvial deposits of the Bolsa Gap. Yet, well 26M2 is reported to have penetrated impermeable clay and "hardpan" from 38 to 60 ft below land surface, immediately above its topmost perforations of casing and in the depth range of the topmost perforations of well 26M1; accordingly, it does not tap the unconfined water body. Thus, it is believed that the contaminant can reach well 26M2 only by some devious path, either beyond the edge of its impermeable blanket or through well 26M1 and thence through a permeable zone tapped by both wells.

The immediate source of the contaminant is believed to be the unconfined water body tapped by well 26M1 but not by well 26M2. This body is contaminated, as of 1941–42, as is shown by samples from three test wells which are all less than 15 ft deep and which are just east of Golden West Avenue between well 26M1 and the foot of the mesa 1,300 ft to the south—specifically, by samples from well 5/11–26M3, chloride content 101 ppm; from well 26N2, chloride from 55 to 753 parts; and from well 26N3, chloride 2,070 parts. (See table 31.) Commonly, however, the head of this unconfined and contaminated body is less than that of the underlying essentially fresh water bodies that are confined and tapped in common by the two wells of the Golden West plant—except as the fresh-water head is drawn down by protracted draft. Under such conditions of head and the physical conditions previously described, equivalent draft would draw unequal quantities of the contaminant into the two pumped wells.

SOURCE OF THE CONTAMINANT

Although the available chemical evidence does not conclusively show the source of the saline contaminant in the central and west-central parts of the Huntington Beach Mesa, certain general supplemental evidence seems conclusive. Specifically:

1. Somewhat promiscuous disposal of waste oil-well brines onto

the surface of the Huntington Beach Mesa has been described briefly on pages 77 and 78.

2. Several sumps and ponds within a mile of the Golden West plant of the Southern California Water Co. contained brines with chloride contents ranging at least from 2,000 to 20,000 ppm; also, similar brine was being discharged at least intermittently by way of a gully which is several hundred feet east of Golden West Avenue and which discharges onto the floor of the Bolsa Gap near the plant.

3. Regarding ocean water as the possible contaminant, even the natural tidal overflow into the Bolsa Gap failed by about a mile to reach the vicinity of the Golden West plant, and currently (1945) the reach of the tides is controlled by dikes and a gate structure at the mouth of the Bolsa Bay (p. 65).

4. In the central part of the mesa, in the general vicinity of the Clay plant of the Southern California Water Co., waters in the upper productive zone have become extensively and grossly depreciated in quality even though their mean head is and has been sufficient to have precluded a widespread incursion of ocean water.

5. The earliest known contamination ensued within a few years after the discovery of the Huntington Beach oil field; also, the areal extent and the focus of contamination are roughly coincident with the extent and focus of the earlier oil-field development.

All this general evidence supports the conclusion that the contaminant of the central and west-central parts of the Huntington Beach Mesa is very largely (if not exclusively) oil-field brine which has been and, as of 1945, is being wasted onto the permeable land surface, which percolates downward to and laterally within the upper water-bearing zone, and which thence moves downward through wells into the middle and lower water-bearing zones.

CONTROL OF THE EXTENT AND DEGREE OF CONTAMINATION

As has been shown, the upper water-bearing zone of the Huntington Beach Mesa now is contaminated extensively and at some places rather intensely; also, at least in the central part of the mesa the ultimate source of contaminants lies very largely or exclusively in oil-field brines that have been, and to some extent still (1945) are discharged promiscuously onto the land surface. Near the coast, in the southeast part of the mesa, ultimate sources of contamination also may lie in the ocean or in a body of salty water native to the Pleistocene deposits. Whatever the ultimate sources may be, the contaminated waters cannot practicably be flushed from the area, nor can the reach of contamination be arrested generally by stabilizing the pumping levels in wells. Rather, even if waste brines all were piped to the ocean, the total quantity of contaminants heretofore accumulated below land surface would not be diminished and for many years those contaminants presumably will disperse themselves ever more widely in the upper water-bearing zone, even though little or no water should be pumped from that zone. Regarding such disposal, abandonment of the Clay plant of the Southern California Water Co. and virtual ending of heavy withdrawals elsewhere in the central part of the mesa about 1931, have not been followed by improvement of water quality in that vicinity. In fact, the intensity of contamination there seems to have increased greatly during the ensuing decade. Thus, over an area even more extensive than that now contaminated, the upper water-bearing zone in the future will constitute an immediate source for contamination of the underlying two water-bearing zones through any and all deep wells that are not adequately cased.

In the southeastern, central, and west-central parts of the mesa the middle water-bearing zone definitely is contaminated locally, but presumably the contaminants have reached that zone only from above and by way of many wells whose casings are perforated in both the upper and middle zones or have deteriorated in the upper zone. (See p. 145.) Thus, with appropriate repair of existing wells and adequate construction of future wells, as explained later, further influx of contaminants to the middle zone could be halted effectively. However, if pumping drafts should be increased, the contaminants now contained in this zone probably will become dispersed more widely.

Two wells which tap the lower water-bearing zone in the central part of the mesa have discharged slightly contaminated water. (See table 16.) Although the contaminants so discharged may have issued largely from one or both of the overlying two water-bearing zones only during pumping, and although the lower zone may be contaminated no more than incipiently at this time, there is a grave possibility that the zone is being contaminated steadily from above, through wells, just as the middle zone is being contaminated. This thick lower water-bearing zone beneath the Huntington Beach Mesa, which now is tapped by only a few industrial wells, constitutes a potentially productive reserve source of fresh water wherever the overlying two zones now are or may become contaminated (Poland and others). Obviously, it is urgent that contamination from above should be prevented if its potential yield of fresh water is to be realized.

Thus, on the Huntington Beach Mesa, control of the extent and degree of contamination is primarily a problem of adequately plugging abandoned wells, possibly of reconstructing some wells now in use, and of appropriately casing any new wells. In the lower zone, the problem is most pressing, as of 1945, in the area north of Garfield Avenue and west of Huntington Beach Boulevard (pl. 11); there, at least seven wells penetrate that zone, and five of the seven are known to have casings perforated in both the middle and lower zones.

For the ultimate withdrawal of the largest possible volume of fresh water from wells on the Huntington Beach Mesa, it is suggested that:

1. All discharge of oil-field waste fluids into permeable sumps, into natural drainage ways, or otherwise onto the land surface of the Huntington Beach Mesa be discontinued.

2. All wells abandoned permanently be filled with impermeable material through the middle and lower water-bearing zones, if penetrated, and then be securely plugged at the bottom of the upper zone.

3. Within and for half a mile beyond the several areas of known contamination in the upper zone, wells now in use be reconstructed if necessary, so that the casing of none will be perforated both in the upper zone and in either of the underlying two zones. As contamination in the upper zone becomes more widespread, the area of control by reconstruction of wells should be extended.

4. All wells which are within the areas of known contamination, and whose casings are perforated in both the middle and lower zones, be adequately tested to determine whether the water withdrawn is contaminated; then, if appreciable contamination is found, that all such wells be so reconstructed that their casings will take water from either one of the two zones, but not from both zones.

5. In the construction of each new well on the mesa, the water contained in each permeable zone be adequately sampled and analyzed as drilling progresses, and the casing not be perforated in more than one water-bearing zone unless the water of all such zones is found uncontaminated and of good quality.

6. The casings of all wells be maintained in constant good repair unless the well is filled and plugged in the manner just suggested.

CONTAMINATION AT AND NEAR LANDING HILL

Northwestward from the areas of contaminated water beneath the Huntingon Beach Mesa, to and beyond the boundary of Orange County, waters of high-chloride content seem to occupy nearly all the Pleistocene deposits between the coast and the principal fault or faults of the Newport-Inglewood structural zone. It has been concluded that these waters are native to that particular area, and not due to contamination. (See pp. 59–61.) Conversely, throughout this reach there are only two active wells along the inland side of the structural zone that have not yielded fresh water of good quality continuously. These two are (1) well 5/12–12P1, which is on the east flank of Landing Hill in the extreme western part of Orange County, which was pumped for domestic use and irrigation until 1942, and in whose water the chloride content had increased from fewer than 20 to 211 ppm during the preceding 12 years; and (2) well 5/12–11G1, which is in the Alamitos Gap about a mile to the northwest and just outside of Orange County, which is pumped actively for industrial use, and in whose water the chloride content has increased from 27 ppm in 1942 to 252 parts in 1945. As will be shown specifically, at these two wells the waters in the Pleistocene deposits have been contaminated.

The contaminated-water well on Landing Hill, 5/12–12P1, is on the inland side of and probably not more than 100 feet from the Seal Beach fault. In 1931 its water was of the excellent quality common to the main body of fresh ground water inland from the fault, and ranged between 17 and 19 ppm of chloride. However, on September 11, 1942, after the well had been pumped for 16 min in a test by the Geological Survey, the chloride content was 346 parts. No analyses are available for the period from 1931 to 1941. Reportedly, the well was drilled to an initial depth of about 400 ft, but in 1942 its measured depth was 185.3 ft; it taps the upper part of the San Pedro formation but presumably is sanded up so that only a short length of its perforated casing is open.

Figures 22 and 23 show the chemical character of the water discharged from the well during two pumping tests by the Geological Survey, and the vertical range in the chemical character of the water within the casing of the well during the second test. The two tests were made in September 1941 and 1942. Data shown in the two figures indicate that:

1. Even as of 1942, at least part of the aquifer contains water whose content of dissolved solids is about 250 ppm and whose

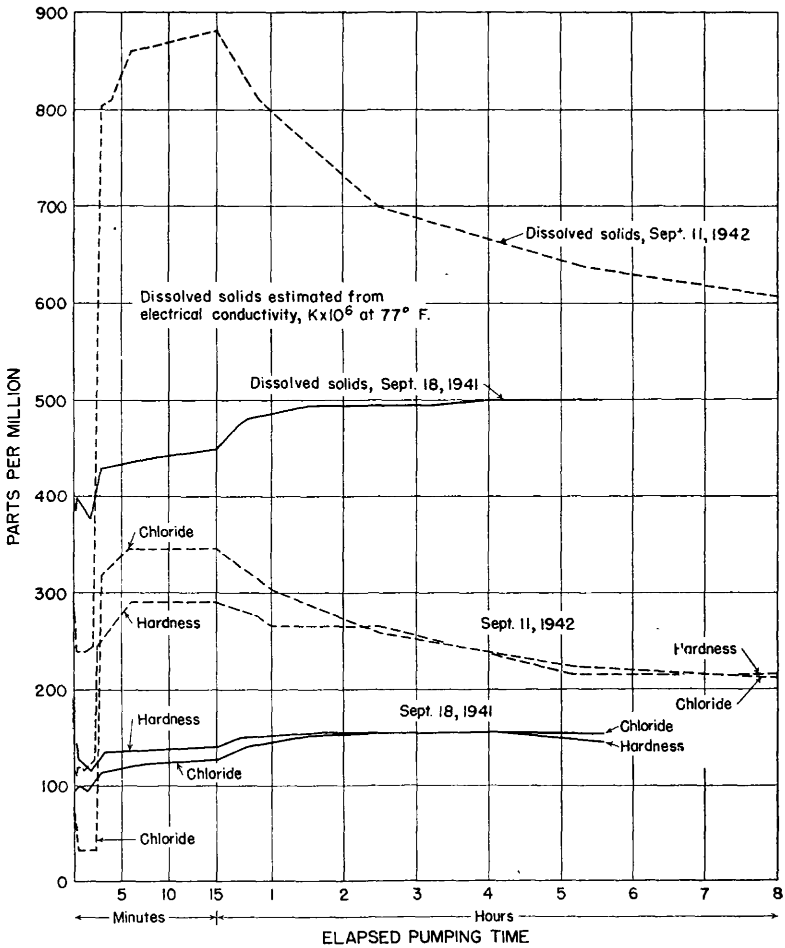


FIGURE 22.—Chemical character of water discharged from well 5/12-12P1 during pumping tests of September 18, 1941, and September 11, 1942.

head is greater than that of the contaminant. This water is fresh and of the excellent quality of that discharged from the well during the first 2 min of test pumping on Sept. 11, 1942; presumably it is native to the aquifer inland from the Seal Beach fault.

2. An interface between fresh water and a saline contaminant exists in the aquifer and is stabilized at a depth greater than 185 ft below land surface under nonpumping conditions, but rises into the well as the fresh-water head is drawn down by pumping.

3. The dissolved-solids content of the saline contaminant is at least 1,350 ppm, or about 150 percent of that of the most saline water known to have been discharged from the well.

4. Hydrologic conditions in the vicinity of the well are such that, during pumping, the native water of excellent quality moves toward the well more freely than the contaminant. Thus, while the pump is shut down for a long interval the contaminant accumulates at and near the well, but in the test of 1942 this ac-

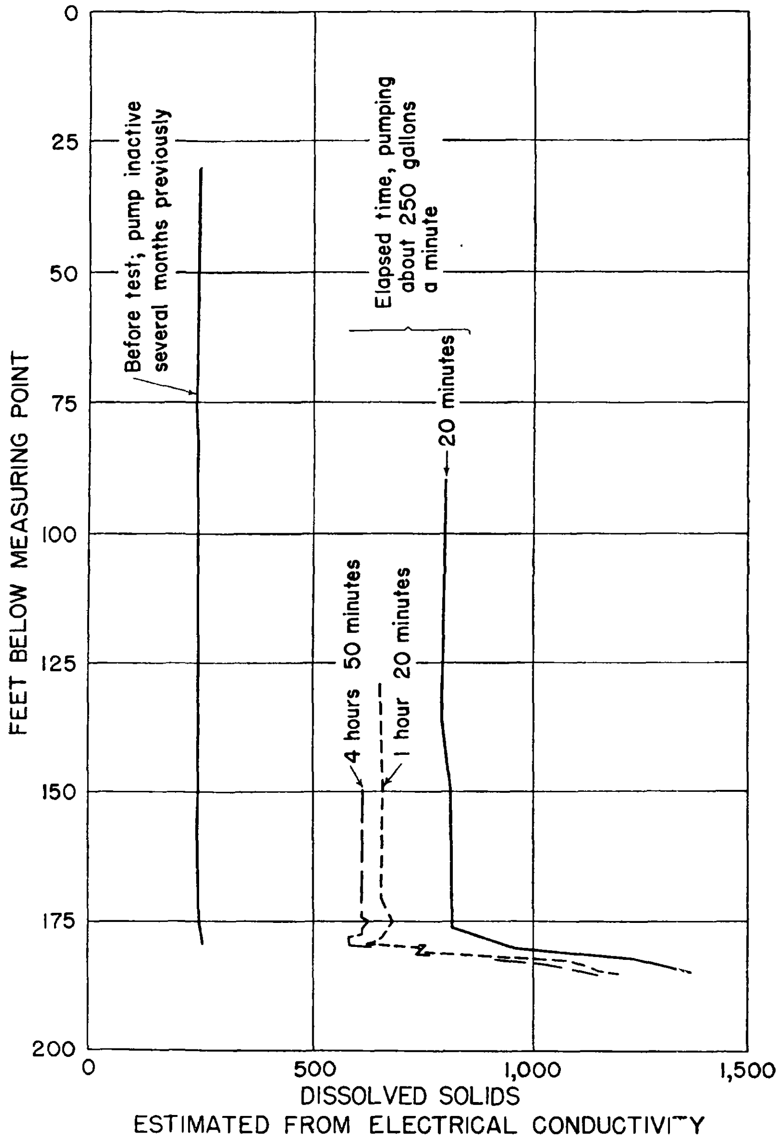


FIGURE 23.—Character of water in well 5/12-12P1 before and during pumping test of September 11, 1942.

cumulation was depleted within 15 min of draft. With protracted pumping, the quality of the contaminated water improves progressively and trends toward a blend of fresh water and contaminant in roughly stable proportions. In this stable blend, the dissolved-solids content, as of 1941–42, was about 500 ppm, and both chloride and hardness were about 160 parts.

Because neither a driller's log nor a record of casing perforations are available, it seems futile to attempt an explanation more explicit than the tentative conclusions just presented.

In this well, measurements of water level have been made weekly by the Orange County Flood Control District since 1930 (Meinzer, Wenzel, and others, 1944, p. 122; 1945, pp. 140–142). These measurements indicate that through 1943 the nonpumping level at the well has ranged from 6.1 to 19.7 ft below land surface, or from 9.9 ft above to 3.8 ft below sea level. The lowest levels were those of 1936. Because the draw-down commonly is from 8 to 12 ft, during periods of intensive draft for irrigation, the pumping level in the well probably has been depressed continuously to some 15 ft below sea level for as much as two months at a time. During the test of September 1942 the pumping level was about 8.5 ft below sea level. Because the well is not more than 100 ft inland from the Seal Beach fault, and because saline water nearly as concentrated as ocean water is known to be native in the water-bearing formations immediately across the fault, it is evident that the landward hydraulic gradient developed by intermittent draw-down below sea level at well 12P1—a gradient of about 20 percent—has been sufficient to induce some movement of salt water across the fault at this place.

About 300 ft northwest of well 5/12–12P1 but probably as much as 200 ft inland from the Seal Beach fault, the city of Seal Beach pumped water from wells 12P3 and 12P4 from 1936 until 1942. Water samples collected by the Geological Survey from well 12P4 indicated a decrease in chloride content from 47 ppm in April 1942 to 13 parts in July 1942 and 20 parts in October 1943. (See table 31.) After early 1942, when the public-supply draft was shifted principally to well 12P6 (city of Seal Beach, well 5) about 375 ft to the north, well 12P4 was maintained as a stand-by source only. It is inferred that in well 12P4 contamination was incipient as of 1941, but had been dissipated by mid-1942 owing to reduction of draft from 140 acre-ft in 1941 to a negligible quantity in 1942.

About a mile northwest of these wells on the southeast flank of Landing Hill, the second of the two active but contaminated wells here treated, 5/12–11G1, is in the Alamitos Gap about 1.2 miles from the coast and about 200 ft inland from the Seal Beach fault. This well was drilled 740 ft deep but probably taps only two water-bearing zones—one from 70 to 92 ft below land surface and in Recent (?) deposits, the other from 187 to 214 ft and in the upper part of the San Pedro formation.

Figure 24 shows that in the water drawn from this well the

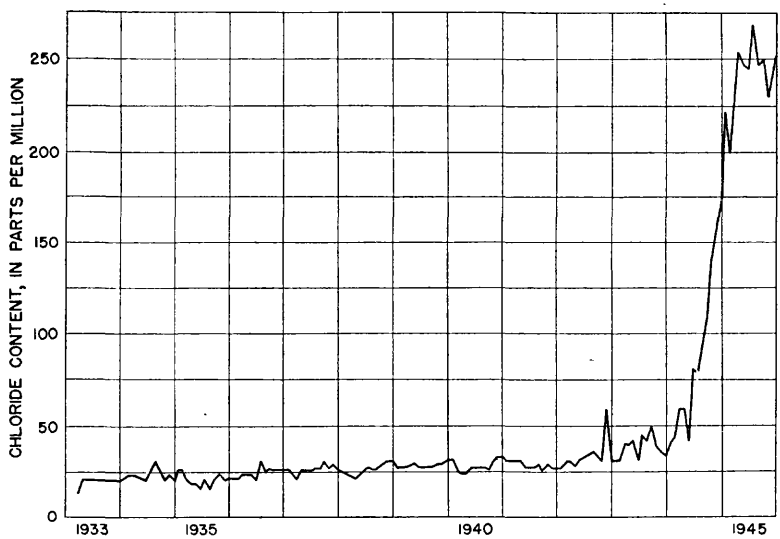


FIGURE 24.—Chloride content of water from well 5/12–11G1 in the Alamitos Gap, 1933–45. (After analyses by Los Angeles County Flood Control District.)

chloride increased from an average of 20 parts per million in 1933 to 30 parts in 1941, ranged between at least 27 and 59 parts in 1941–42, and by April 1945 was 252 parts. The high-chloride contaminant so indicated may have reached the well by percolation downward from the unconfined water body which is in the overlying surficial deposits, and which natively is of very inferior quality (pp. 59–61); from across the Seal Beach fault, owing to depletion of the fresh-water head by heavy draft inland from that fault; or from adjacent but unused well 5/12–11H1, which has encountered saline water as is described later.

Downward percolation from overlying native water of inferior quality is believed to be the least likely of these three possible sources of contamination. Had this been the sole or principal source, the water withdrawn probably would have increased notably in chloride content early in the life of well 11G1, and less abruptly than in 1944–45.

Indraft of saline water from across the Seal Beach fault can neither be proved nor disproved by the available evidence. Because well 11G1 is only about 200 ft inland from the main fault, because it was pumped heavily in the early thirties, and because water levels on the inland side of the fault generally were depressed the most during the early and middle thirties, it would be expected that any such indraft would have been most rapid at that time. Under those conditions, the very slow increase in chloride content of the water yielded by the well from 1933 to 1942 might be explained as incipient contamination. If so, substantially larger volumes of saline water have reached the well in the 3 yr since 1942 in spite of the regional increase in fresh-water head that has occurred in the forties.

Regarding the third possible source of contamination, adjacent well 5/12–11H1, it is pertinent that:

1. It is about 300 ft inland from the Seal Beach fault and a like distance southeast of active and contaminated well 11G1.

2. It was drilled in 1923 to a depth of 296 ft, reportedly found saline water, never has been used, and when first sampled by the Geological Survey in late June 1942 yielded water with 7,000 ppm of chloride. (See also paragraph 4).

3. Presumably it penetrates the two water-bearing zones tapped by well 11G1. Also, its water level is depressed as much as 3 ft by draft from well 11G1, and fluctuates in response to tidal changes in the natural channel of the San Gabriel River a few hundred feet to the west. These features imply that some hydraulic continuity exists between the water-bearing zones tapped by the two wells and that well 11H1 may act as a conduit for vertical movement of the contaminant.

4. Evidently there is some circulation of water through its casing because: The sample which was taken by the Geological Survey in late June 1942 and which contained 7,000 ppm of chloride was bailed at 20 ft below static level and contained about 11,300 ppm of all dissolved solids. A conductivity test by the Geological Survey in August 1942 showed that the water then standing in its casing ranged from 7,250 to 8,200 ppm of dissolved solids from static level to a depth of 142 ft below land surface (from 64 to 73 percent of the concentration at 20 ft below static level a month earlier), increased to 12,000 ppm at 155 ft, and then remained constant to the bottom of the well at 296 ft. A sample pumped in November 1943, after 1 min of draft and under a draw-down of 19 ft, contained 2,080 ppm of chloride and 3,900 ppm of all dissolved solids (concentration 35 percent of the bailed sample of August 1942).

5. A pumping test by the Geological Survey indicates that any perforations in its casing have become almost wholly closed by encrustation and corrosion—the water level drew down to the pump intake immediately and, when the residual draw-down was 3 ft, the casing refilled at the rate of only 1.6 gpm. Even so, because its water level currently is drawn down about 3 ft by the draft from well 11G1, under that same draft it now could yield contaminant to the fresh-water aquifers at a rate of a few gallons a minute (a few acre-feet per year of draft). In the late twenties and early thirties—presumably before the perforations in its casing had become so nearly closed, while the draft from well 11G1 was greatest, and while the fresh-water head generally was the lowest of record—its potential yield of contaminant could have been greater.

In order to eliminate it as a possible cause of local contamination, well 11H1 was plugged by the owner in October 1944, after the chloride content of water drawn from well 11G1 had begun to increase sharply (fig. 24). No improvement in the quality of water withdrawn had taken place by April 1945, nor would improvement be expected quickly if any substantial volume of contaminant previously had been drawn into the fresh-water aquifers. The ultimate source of the high-chloride-content water in well 11H1 is unknown; it may have been transmitted by subsurface flow from across the Seal Beach fault. However, the marked change in water quality that took place within the casing from June 1942 to November 1943, especially about 20 ft below land surface, suggests strongly that salty water of variable character was entering the well at shallow depth and then circulating downward.

Whatever its ultimate source, a contaminant of high chloride content may have accumulated in considerable volume in the eastern part of the Alamitos Gap and just inland from the Seal Beach fault, in the aquifers tapped by wells 5/12–11G1 and –11H1. Even if the immediate source has been cut off by the plugging of well 11H1, the contaminant probably will continue to disperse so that, over a term of months or a few years, the water from well 11G1 may become too saline for its present industrial use. Seemingly it is impracticable to arrest the contaminant by artificially replenishing the fresh-water head through recharge wells. Also, presumably it would be impracticable to withdraw the contaminant by continued pumping of well 11G1 or other wells constructed for that specific purpose. Obviously, if the contaminant is moving across the Seal Beach fault by underflow, such a pumping operation would maintain the water level continuously below sea level on the inland side of the fault and thus would induce greater inflow of saline water. Under such conditions, partial control over the reach and intensity of contamination can be sought only by appropriate plugging of abandoned wells, possibly by some reconstruction of active wells, and by whatever reduction of draft is feasible. (See p. 154.)

DEPRECIATED WATERS BENEATH THE NORTHEAST PART OF NEWPORT MESA

Thus far, the description of water-quality depreciation in Orange County has dealt with areas not more than 2½ miles from the coast. However, within the part of Orange County covered by this report, there are two small additional areas about 5 miles inland, on the northeast part of the Newport Mesa, within which certain wells have yielded water of inferior chemical quality. At some places, if not all, depreciation has been progressive. The two areas are in secs. 1, 2, and 3, T. 6 S., R. 10 W., and in blocks 5 and 6 of the Irvine tract, about a mile to the southeast. (See pl. 1.) For both areas, the data by Mendenhall in 1904 suggest that the native waters then yielded by active wells were of good quality. (See pl. 2.)

In the three sections of T. 6 S., R. 10 W., the waters of inferior quality are found only in certain wells which are less than 250 ft deep, and which tap upper Pleistocene deposits; type analysis 6/10–2H1 (table 30, pl. 10) is of a calcium, sodium sulfate water containing 2,730 ppm of dissolved solids. Waters of this sort have been described as native to the area (pp. 55–56) and they constitute potential contaminants of the waters of excellent quality that exist at greater depth, such as the sodium bicarbonate water of well 6/10–1E2. It is these inferior waters at shallow depth, not the underlying waters of good quality, that have depreciated in quality during the term of investigation by the Geological Survey. For example, seven samples taken periodically at well 6/10–2J1 between December 1940 and October 1942 have depreciated progressively, as follows: in chloride, from 238 to 341 ppm; in hardness, from 1,000 to 1,500 parts; and in total dissolved solids, from 1,500 to 2,100 parts. Three samples from type well 2H1 have ranged: in chloride, from 321 to 437 parts; in hardness, from 1,500 to 1,600 parts; and in total solids, from 1,600 to 2,100 parts. The greater set of values just cited is from the most concentrated of all these waters for which analytical data now are available.

As stated, the area of these inferior and currently depreciating waters is part of a larger district within which the wells yielded water of good quality in 1904. In 1904 Mendenhall listed 32 wells within the three sections, as follows: 16 wells less than 250 ft deep, dissolved solids about from 260 to 330 ppm; 7 wells more than 250 ft deep, dissolved solids from 210 to 360 parts; among 5 wells of unreported depth, dissolved solids from 270 to 330 parts in four wells and 440 parts in the fifth; and 4 wells, dissolved solids not reported. Thus, it would seem that the waters found to be of inferior quality to a depth not greater than 250 ft in 1940–43 have depreciated from an initial excellent quality in 1904. No analytical data are available to show the progress of depreciation in the 36-yr interim.

So far as the writers know, the underlying waters of excellent quality are not, and have not depreciated in quality within the particular area. Only two wells more than 300 ft deep are known to have yielded water containing more than 20 ppm of chloride or more than 360 parts of total dissolved solids (for the majority of wells, not more than 250 parts of total solids). One exception, well 6/10–2G1, is 516 ft deep and in December 1940 yielded a sample containing about 440 parts of dissolved solids but only 17 parts of chloride; evidently its water did not then contain a contaminant high in chloride content. The other exception, well 6/10–1E4, is 340 ft deep and has yielded very inferior water similar to the type from well 2H1; however, the depth of perforations in its casing is unknown and it may never have tapped water of good quality.

Because the underlying water is of excellent quality it was thought that the depreciation might have been caused by highly concentrated waters percolating from overlying surficial deposits. Accordingly, test holes 6/10–1E5 and 2J5, respectively 12.0 and 17.0 ft deep, were bored by the Geological Survey in 1944. These two holes produced water with 27 and 105 ppm of chloride, also 105 and 275 parts of hardness, respectively. Because the wells were drilled and sampled when the water table was near its high level for the year, the shallow water tapped probably had been derived from local rainfall and had not been concentrated appreciably by evaporation from the capillary fringe. Its relatively good quality precludes that surficial water as an adequate cause of the depreciation.

Available data do not afford a fully adequate explanation for the known depreciation of 1940–43 and for the much greater presumptive depreciation of 1904–40. Three incomplete and hypothetical explanations are offered tentatively, as follows:

1. The added salines have been dissolved from within the stratigraphic range and within the area occupied by the inferior waters; that is, the salines (but not the waters they have produced) are native to the stratigraphic range and area. This would constitute a process which might be termed autocontamination, for which no substantiating evidence has been recognized and of which the necessary magnitude is difficult to accept.

2. The added salines have been supplied by waters drawn from beyond the area but within an extension of the stratigraphic range. However, no native water with a content of sulfate and calcium at all sufficient for the known depreciation has been discriminated north of the inferred fault trap which passes roughly through the quarter corner between secs. 4 and 9 (pl. 11, p. 98), about a mile south of the depreciated area; also, for waters in the stratigraphic range and area of depreciation, the static level has declined somewhat since 1904, but from 1930 at least through 1943 has not declined appreciably below that of outlying areas, as would be expected with continuing in-movement of a competent calcium sulfate water.

3. The added salines have been derived from the ditch of the Delhi Drainage District, which trends southward across the eastern part of the area of depreciated waters, along Paularino Street. In the depreciated area, this ditch flows over earthy sand and gravel which is known locally to extend as much as 30 ft below land surface. Its floor is 1 or 2 ft below the ordinary high stage of the water table, but is a few feet above the ordinary low stage; under this condition, influent seepage from the ditch can pass to the water table during a large part of the year. Also, the ditch is known at times to have carried sodium sulfate water containing about 3,900 ppm of dissolved solids (1933, California Dept. of Public Works, Div. Water Resources Bull. 40–A, p. 116), but is not known to have carried calcium sulfate water or calcium sodium sulfate water as concentrated as that of well 6/10–2H1. If the known sodium-sulfate water of this ditch is the contaminant, that water is greatly hardened by exchange of bases as it percolates downward.

This third tentative explanation requires the contaminating saline to have percolated westward at least a mile from the ditch. It also requires the surficial water of relatively good quality (p. 163) to "float" above the contaminated water (one of the two test wells by which the surficial water was sampled in 1944, 6/10–1E5, is only 360 ft west of the ditch). It is not at all unlikely that the surficial water of good quality so overlies the depreciated water.

Demonstration of the cause of water-quality depreciation in this inland area on the Newport Mesa has been considered beyond the scope of the cooperative investigation reported in this paper. Regarding the possibility of contamination from the ditch of the Delhi Drainage District, the actual conditions probably could be demonstrated conclusively by a modest program maintained for at least one year and involving: (1) test wells arranged in several profiles normal to the ditch, and bored in groups of various depths to a maximum of a few tens of feet below the water table; (2) analyses of water samples from these test wells and periodically from the shallower wells; (3) periodic analyses of the ditch water; and (4) periodic measurement of water levels in the test wells and in the ditch, to establish the changes in hydraulic gradient. As for the more remote possibility of auto-contamination within the stratigraphic range of the depreciated waters, a program of demonstration would be more involved and in its first steps would include tests of available wells as much as 250 ft deep by analysis of samples taken successively during pumping, to obtain data such as those shown on figure 16, and by probes of the changes in water quality within the casings under both pumping and nonpumping conditions, such as those graphed on figure 15. Further investigation then could be planned according to results of these tests.

Under these conditions, the waters of depreciated and very inferior quality that now exist in parts of secs. 1, 2, and 3, T. 6 S., R. 10 W., to depths roughly not greater than 250 ft below land surface, obviously are potential contaminants of the underlying waters of good quality by way of any wells improperly constructed or cased. Quite possibly the depreciation will become more widely dispersed, to an extent unpredictable. Accordingly, the measures of control already suggested for the Huntington Beach Mesa would be applicable. (See p. 154.) In particular, in the construction of each new well it would be most advisable to sample and analyze the fluid contained in each water-bearing zone as it is reached by the drill, even though the zone is thin or not highly permeable; to avoid gravel-pack construction from top to bottom; and when the deepest zone of depreciated water has been fully penetrated, thoroughly to cement or mud-in an unperforated casing at that depth before drilling deeper.

In the southeastern area of the two on the inland part of the Newport Mesa (blocks 5 and 6, Irvine tract) four deep wells have yielded or now yield water whose chloride content seems abnormally large. At least two wells of the four tap the principal water-bearing zone of the mesa (Poland and others). Analysis I–6G1 (table 30) is taken as typical of the sodium bicarbonate water presumed to be native; chloride content is 23 ppm, hardness 33 parts, and total solids 422 parts. The four wells which have yielded water of seemingly abnormal character are I–5H1, –6D1, –6E1, and 6M1; table 20 summarizes pertinent data from all available sources and table 21 gives selected analytical data for the abnormal waters.

TABLE 20.—*Wells yielding water of depreciated (?) quality in blocks 5 and 6 of the Irvine Tract, on the northeast part of the Newport Mesa*

Well number on plate 2	Depth of well (feet)	Depth of perforated casing (feet)	Parts per million		Date
			Chloride	Dissolved solids	
I-5H2	412		143	567	1920.
			110	464	July 1932.
I-6D1	645		195	551	June 1931.
			156		August 1934
			165	620[1]	July 1941.
I-6E1	609	355–415	92	365	June 1931.
		480–515	76	324	September 1937.
			74	358	August 1939.
			83	347	May 1941.
			120	413	October 1941.
			84	380	July 1942.
			82	360[1]	October 1942.
			72	323	August 1944.
I-6M1	16		50	316	1920.
			138	643	April 1922.

[1] Estimated from electrical conductivity.

TABLE 21.—*Chemical character of presumed native water from well I–6G1 and certain depreciated (?) waters from well I–6E1*

[Quantities in equivalents per million]

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Presumed native water:	0.25	0.41	7.13	6.68	0.46	0.65
Depreciated waters (in order of decreasing chloride content):						
October 16, 1941	.05	.16	6.92	3.61	.15	3.37
August 15, 1930	.18	.08	6.98	3.74	.66	2.84
June 16, 1931	.28	.39	6.03	3.90	.06	2.74
July 31, 1942	.20	.08	6.22	3.60	.50	2.38
September 4, 1937	.25	.08	5.52	3.76	.00	2.11
August 14, 1944	.05	.25	5.30	3.40	.17	2.03

[1] Includes equivalent of potassium (K).
[2] Includes equivalent of carbonate (CO_3).

Obviously, the utility of the abnormal or depreciated (?) waters has not been impaired greatly. Lacking data on pumping tests such as those graphed on figure 22, it is not known whether the abnormally large content of chloride exists in the principal water-bearing zones tapped or has entered the wells from some other source; and whether the chloride content has tended to decrease since the early twenties, as is implied by the data of table 20. It is altogether likely that the water-bearing zones are not, as of 1945, appreciably contaminated. Further, it is not known whether the abnormal content of chloride is derived from ocean water, from a connate brine locally native in the Pliocene and Miocene rocks that underlie the water-bearing Pleistocene deposits, from the Delhi drainage ditch, or from some other source.

So far as is known to the writers, there is no reason to believe that the main water-bearing zone in this part of the Newport Mesa is threatened with intense contamination by high-chloride-content waters in the immediate future. However, owing to the abnormal chloride content in the waters from the four wells here treated it would be prudent for water users of the area to obtain chemical analyses periodically and, at the first indication of substantial further depreciation in water quality, to test their wells as necessary in order to devise adequate measures for control.

DEPRECIATION OF WATER QUALITY IN LOS ANGELES COUNTY

CONTAMINATED WATERS IN DOMINGUEZ GAP

SUMMARY OF GROUND-WATER OCCURRENCE

As explained elsewhere (Poland, Piper, and others), the Long Beach-Santa Ana area contains two regional arteries, which natively conveyed fresh ground water from inland forebay areas, across the coastal plain and the barrier features of the Newport-Inglewood structural zone, to the coast. The westerly of these two arteries, the Gaspur water-bearing zone of Los Angeles County, passes beneath the floor of the Dominguez Gap. There, its waters (as well as certain other waters) currently (1945) are contaminated by salines more extensively and more intensively than in any other part of the area treated in this report. Details of this most critical situation are given later. The area concerned is the tongue of the Downey Plain which is bordered on the east by the Signal Hill uplift and the Long Beach Plain, and on the west by the Dominguez Hill and the Torrance Plain, and which reaches from Victoria Street (projected) southward nearly 8 miles, to the coast. (See pl. 17.)

Within the Dominguez Gap, alluvial deposits of Recent age reach from land surface to depths ranging between 110 and 150 ft. There, as in the Santa Ana Gap of Orange County, these deposits include: an upper division which consists of silt, "clay" (see below), and fine sand, which is from 50 to 80 ft thick, and which contains a body of unconfined water natively of inferior quality (p. —) ; and a lower division which is composed of gravel and sand spanning nearly the full width of the gap, whose thickness ranges from 40 to 70 ft, and in which water is confined. This lower division constitutes the ground-water artery previously cited: the Gaspur water-bearing zone, which is the upper of two highly permeable zones that occur beneath the Dominguez Gap. The Gaspur zone is only imperfectly confined and, at least locally, probably there is some interchange of water between it and the overlying unconfined body. Thus, although the logs of most wells that tap the Gaspur zone report "clay" beds of various thicknesses in the overlying upper division of the Recent deposits, more detailed geologic evidence indicates that this material is largely flood-plain silt, which doubtless is somewhat permeable in part. These nominal confining beds presumably are least effective within approximately 2 miles of the coast, where their aggregate thickness is the least and where the proportion of sand in the deposits above the Gaspur zone is the greatest.

Under essentially natural conditions in 1903–4, the pressure level of the confined water in the Gaspur zone coincided very closely to the water table of the overlying unconfined body, ranged from 8 to 5 ft below land surface throughout the gap, and in the central reach of the gap was from 10 to 15 ft above sea level. Nowhere was it above the land surface. Under these conditions, the Gaspur zone at times may have discharged some water by leakage upward, but could not produce flowing wells. Owing to former heavy withdrawals locally and to continuing withdrawals inland, within the gap the pressure level of the Gaspur zone has been drawn down about 15 ft at Carson Street and about 12 ft at Willow Street, where now it is at sea level. South of Willow Street it was generally a few feet below sea level through the late twenties and early thirties, but since then has been about at sea level. Available information suggests that the water table of the unconfined body declined almost concurrently with and in the same amount as the pressure level of the Gaspur zone; in 1942, the pressure level and the water table coincided north of Spring Street, but farther south the water table was from 1 to 3 ft the higher. In other words, there must be appreciable hydraulic continuity between the unconfined water body and the confined body of the Gaspur zone, through a large part of the

Dominguez Gap. Thus, because its water is under the lower head, the Gaspur zone can and doubtless does receive water by percolation from the overlying unconfined water body in the area south of Spring Street, that is, in roughly the southern half of the gap. Also, because the overlying water body has become grossly contaminated (as will be described), its density has been substantially increased and so, even in the area north of Spring Street where the water levels for the two water bodies are essentially the same, the Gaspur zone can receive water by downward percolation from the unconfined body, owing to this very difference in density.

The Gaspur water-bearing zone is enclosed on both sides and beneath by deposits of Pleistocene age, at most places by the unnamed upper Pleistocene deposits but locally by the San Pedro formation. At a few places, these Pleistocene deposits in contact with the Gaspur zone contain lenses of gravel or coarse sand, but ordinarily they are composed of silt, clay, and fine sand of low average permeability. Beneath the Gaspur zone they are from 175 to 550 ft thick but along either flank of that zone, where they have not been thinned by erosion, they are from 150 to 200 ft thicker.

Beneath these fine-textured deposits is the Silverado water-bearing zone of the San Pedro formation, which is the deeper of the two highly permeable zones beneath the Dominguez Gap, and which long has sustained very heavy withdrawals from numerous public-supply and industrial wells. This water-bearing zone is a body of rather uniform gravel and coarse sand that ranges in thickness from 500 ft at well 4/13–23G2 (city of Long Beach, Silverado well 1) to as little as 180 ft between Anaheim Street and the coast (Poland, Piper, and others). Westward it extends for many miles beyond the shallower Gaspur zone but to the east, at least south of Willow Street, its reach is about the same as that of the Gaspur zone. The water of the Silverado zone is confined effectively by the overlying Pleistocene deposits of low permeability, and under native conditions was under sufficient head to sustain flowing wells at the inland and coastal ends of the Dominguez Gap, if not throughout the gap. However, its head has been drawn down progressively by the continuing heavy withdrawals, and currently (1945) is several tens of feet below sea level within a large part of the gap. Where the draw-down has been greatest, in the general vicinity of the intersection between Alameda and Carson Streets, in 1930 the nonpumping level of the water in the Silverado zone was from 30 to 35 ft below that of the Gaspur zone, in 1940 was from 40 to 45 ft below, and in 1944 was about 55 ft below.

In other words, there the pressure level of the water in the Silverado zone has receded in 14 yr from 30 to 55 ft below the pressure level of the water in the Gaspur zone. From 10 to 15 ft of this recession took place from 1940 to 1944, owing to a greatly accelerated withdrawal of water for purposes related to the war. Thus, under native conditions the Silverado zone would have discharged water upward if at all, but under the artificial condition of greatly and progressively depleted head the potential vertical movement of water now is reversed, or downward into the Silverado. As will be shown this condition poses an ever more serious threat that the productive Silverado water-bearing zone will become contaminated from above, through wells that are not tightly cased.

In turn, the Silverado water-bearing zone is underlain within the Dominguez Gap by (1) impermeable beds, chiefly silt and clay, which form the topmost part of the upper division of the Pico formation of Pliocene age and which range in thickness from 200 to 650 ft, and (2) by the remaining or lower part of the upper division of the Pico formation which includes several layers of medium- to coarse-grained sand of fair permeability. These permeable beds contain essentially fresh water not now tapped by wells. The deepest of them occurs from 1,600 to 2,700 ft below land surface here.

Of the deposits which contain the several water-bearing zones just described, all except those of Recent age are folded gently in the Wilmington anticline near the coast and are flexed rather sharply and probably are faulted in the Newport-Inglewood structural zone whose axis trends northwest across the Dominguez Gap near Del Amo Street. At the eastern flank of the gap, and probably beneath the gap, numerous planes of shearing in the fault zone have been tightly cemented by deposition of calcium carbonate and other substances. It is inferred from hydrologic evidence that the fault zone very greatly impedes movement of water in the Silverado and other water-bearing zones that underlie the deposits of Recent age. However, no such barrier exists in the upper of the two principal water-bearing zones in the Dominguez Gap, that is, in the Gaspur zone which constitutes the lower division of the Recent deposits.

GENERAL CHARACTER OF THE NATIVE GROUND WATERS

The data of Mendenhall in 1904 (pl. 2), together with analytical data on samples from numerous wells since 1923 (table 30), indicate that the native or uncontaminated ground waters of the Dominguez Gap and vicinity ranged somewhat widely in chemical character. Except possibly for a mile or less from the coast, waters of excellent quality were characteristic throughout the two principal water-bearing zones, the Gaspur and the deeper Silverado. Waters of excellent chemical quality also occurred locally but not generally in the upper Pleistocene deposits along either flank of the gap, and beneath the Gaspur zone within the gap. But waters of inferior chemical quality occurred at and below the water table in the upper division of the Recent deposits throughout the gap, and at various places and depths in the upper Pleistocene deposits to the east and to the west.

Of the waters of excellent quality, those in nearly the full reach of the Gaspur water-bearing zone were of the calcium bicarbonate type and ranged from 350 to 600 ppm of all dissolved solids, from 25 to 60 (or possibly somewhat more) parts of chloride, and from 190 to 275 parts of hardness. In general, each of these quantities increased southward, or toward the coast. In table 30 typical analyses are those from wells 3/13–36D1, 4/13–2P4, and 4/13–15A3 (analysis of 1931). Analysis 4/13–35M3 of 1923 possibly is typical for the reach within a mile or so of the coast; this analysis is of a sodium bicarbonate water with 318 ppm of all solids, 40 parts of chloride, and 113 parts of hardness. (See also pp. 26–28.)

In contrast to the native waters of the Gaspur zone, those of the Silverado water-bearing zone are characteristically of the sodium bicarbonate type. Dissolved solids ordinarily range from 200 to 325 ppm and chloride ranges from 20 to 30 parts. Hardness is from 120 to 80 ppm in waters from the upper part of the zone, but about 80 to 35 parts in waters from the central and lower parts of the zone. In table 30, typical analyses are 4/13–1F1, –15A2 (in 1931), and –22E1. Southwestward beyond the Dominguez Gap and toward the Palos Verdes Hills, in the waters native to the Silverado zone, the dissolved-solids content increases to 400 ppm and the chloride content increases to at least 100 parts; analyses for well 4/13–33E2 are typical. (Also, see pp. 35, 57.)

Along either flank of the Dominguez Gap, in minor water-bearing zones that exist in the Pleistocene deposits and that are more than 300 ft beneath land-surface, all known native waters contain between 225 and 375 ppm of dissolved solids and presumably range from calcium bicarbonate to sodium bicarbonate in type. To the east, these waters of good quality have been tapped by wells on the Los Cerritos segment of the Signal Hill uplift (Mendenhall, 1905b, pp. 71–73 wells 864, 922, 923, and 924), and along the south flank of Signal Hill itself (Mendenhall, well 927). On the other hand, native waters that have been encountered by wells less than 200 ft deep in the outlying Pleistocene deposits commonly contain 350 or more ppm of dissolved solids and, as will be described, are of decidedly inferior quality in certain parts of the area.

In the waters of inferior quality native in the upper division of the Recent deposits, the dissolved-solids content was as little as 600 ppm at the inland end of the gap between Dominguez Hill and Los Cerritos, but midway toward the coast was commonly 1,000 to 2,000 parts or more. Here the waters presumably were relatively high in sulfate and chloride content. It is inferred that near the coast and within the reach of tide channels the native ground water at shallow depth commonly was similar to ocean water in its chemical composition, and locally was even more concentrated than ocean water.

In the upper Pleistocene deposits, waters of inferior quality are inferred to be native beneath all the Long Beach Plain to the east of the Dominguez Gap. There, in 1904, nine wells from 15 to 120 ft deep yielded water containing from 800 to more than 2,000 ppm of dissolved solids (nos. 913, 925, 926, and 996–1000, inclusive, Mendenhall, 1905b, pp. 73, 76). Subsequent analytical data now available suggest that these are essentially sodium chloride waters. In the same area and also in 1904, the water from one additional well (Mendenhall no. 1001) contained 2,000 ppm of dissolved solids; this well is reported to have been 920 ft deep, but the depth of its aquifer or aquifers is not known. To the west of the gap, inferior waters are native in the upper part of the Pleistocene deposits rather extensively south and west of the Dominguez Hill and north and east of the Palos Verdes Hills. (See pl. 17.) In those two areas, wells less than 100 ft deep commonly yield water whose dissolved-solids content ranges from 405 to at least 1,050 ppm, and whose chloride content is from 85 to at least 410 ppm. In the northern area of the two, certain wells between 100 and 275 ft deep yield inferior waters whose dissolved solids reach 900 parts, and whose chloride reaches at least to 205 parts.

So far as is known, none of these inferior waters locally native in the upper part of the outlying Pleistocene deposits is in hydraulic continuity with the Gaspur water-bearing zone or with the Silverado water-bearing zone. But the natively inferior (and currently depreciated) waters in the upper division of the Recent deposits are in hydraulic continuity with the Gaspur zone at least locally and, as will be shown, have contaminated that underlying zone.

CONTAMINATION OF THE UNCONFINED, SEMIPERCHED BODY

Although of inferior chemical quality natively, the unconfined water body in the upper division of the Recent deposits long has been contaminated within the greater part of the Dominguez Gap, presumably by industrial and oil-field waste fluids discharged overland, discharged into the Los Angeles River, or discharged into the Dominguez Channel. (See pp. 80–84.) In table 30, typical analyses of the unconfined water are those of samples taken just below the water table from wells 4/13–8L1 and –10F1, sodium sulphate waters; also from well 4/13–14F1, a calcium chloride sulphate water. Among the four analyses from these three wells the total dissolved solids range from 3,454 to 12,900 ppm, chloride ranges from 870 to 2,231 parts, and sulfate ranges from 1,130 to 6,910 parts. These concentrations of dissolved constituents probably are several times greater than those of native unconfined waters at the several places. The conditions represented are those of 1932 (analysis 8L1) and 1942 (analyses 10F1 and 14P1). Plate 16 shows the chemical character of contaminated waters from these three wells and of native waters from the unconfined, semiperched body at well 3/12–30C1 in the alluvial deposits of Recent age, about 1½ miles inland from the head of the Dominguez Gap, and at well 4/13–6J1 in the unnamed upper Pleistocene deposits, at the margin of the Torrance Plain southwest of the Dominguez Hill.

Figure 25 summarizes the data on chloride content of the unconfined waters as explored by 38 shallow test wells constructed by the city of Long Branch (Brown, 1935, p. 175), in late 1931 and in 1932, and sampled periodically by that agency until as late as March 1935; also by 18 additional test wells constructed and sampled by the Geological Survey in 1941–42. Among the 56 test wells, those bored in or near the channel of the Los Angeles River produced water with chloride content between 50 and 312 ppm upstream from the outfall at the brine sumps of Oil Operators, Inc., near 223d Street (see fig. 7), but wells farther downstream produced water with chloride content ranging between 950 and 11,985 ppm. In each of the reaches, the greatest chloride content of unconfined ground water was roughly equal to the chloride content of river water during periods of low flow (pp. 81–82). The ground waters were somewhat

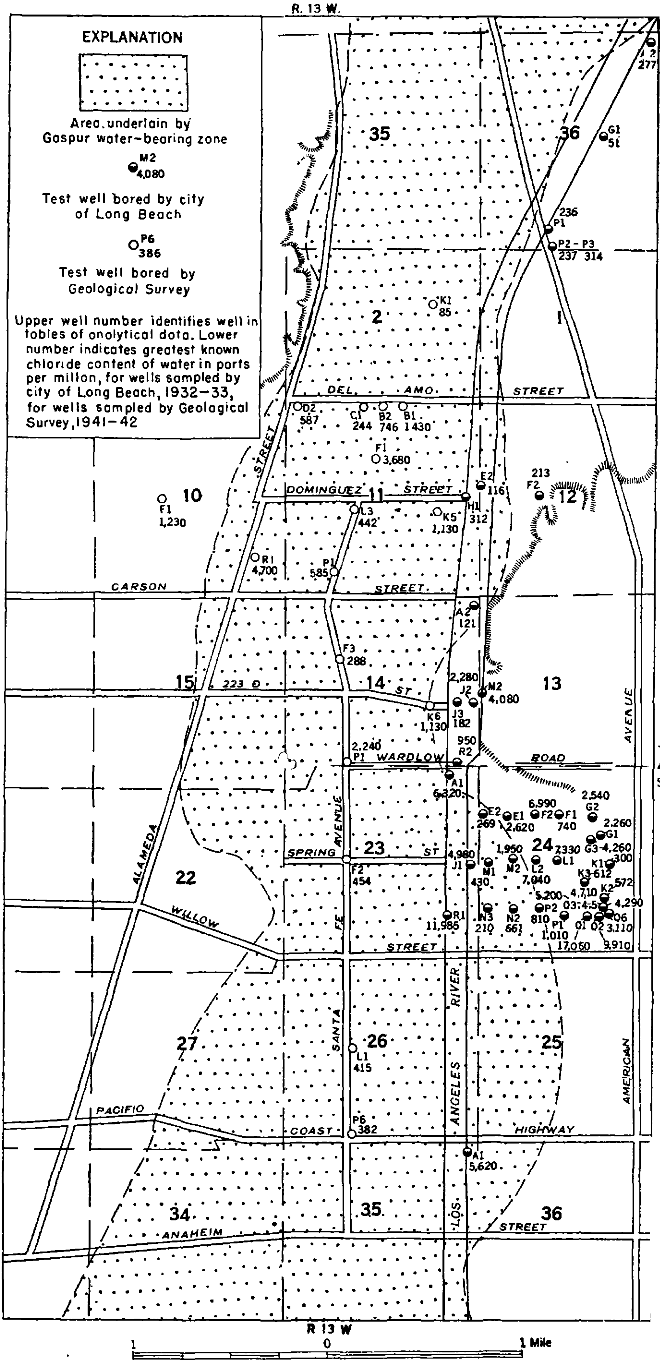


FIGURE 25.—Map showing location of test wells tapping the semiperched water body in the Dominguez Gap, also the greatest known chloride content of waters from those wells in 1932–33 and 1941–42.

contaminated in the upstream reach, but were grossly contaminated only in the downstream reach. Gross contamination in the unconfined waters also was disclosed, as of 1941–42, west of the Los Angeles River and adjacent to the flank of Dominguez Hill in secs. 10 and 11, T. 4 S., R. 13 W. (projected), and as of 1932–33, east of the river in sec. 24. The latter area is reported (Brown, 1935) to have been traversed by ditches carrying oil-field brine; the analyses by the city of Long Beach show that the chloride content of the brines in certain of those ditches ranged from 9,200 to 14,800 ppm in 1932–33.

Only general conclusions about the source or sources of contamination are warranted by the data now (1945) available. Thus, certain samples of high-chloride-content water from the test wells in sec. 24 are reported to have contained iodide in appreciable quantity. Presumably, therefore, the contaminant of those wells has not been ocean water but might have been oil-field brine. (See p. 91.) However, it is significant that in the three contaminated waters graphed on pl. 16: (1) the presumed gains in calcium, magnesium, bicarbonate, and sulfate all are greater than can be ascribed wholly to an influx of either ocean water or oil-field brine such as that discharged in 1941 from the sumps of Oil Operators, Inc., for which an analysis is given in table 29; (2) in the contaminated water of well 4/13-14P1, the calcium gain is roughly twice the calcium content of ocean water or of the brine; (3) in the contaminated waters of 14P1 and 10F1, the bicarbonate gain is many times the bicarbonate content of ocean water; and (4) in all three contaminated waters the sulfate gain is many times greater than the sulfate content of the oil-field brine, and in well 10F1 is nearly three times the sulfate content of ocean water.

In this connection, it will be recalled (p. 72) that Oil Operators, Inc., formerly acidulated their brines with sulfuric acid for the extraction of iodine and discharged the acidulated effluent into the channel of the Los Angeles River. If it infiltrated below the bed of the channel, any such acidulated waste would dissolve carbonates of calcium and magnesium rather freely from the alluvial deposits and probably would not precipitate any large proportion of its sulfate. In other words, the end product of chemical reaction between the acidulated brine and the alluvial deposits would be similar in constitution to these high-calcium contaminated waters. It will be recalled further that brines from the Dominguez oil field also have been treated with sulfuric acid for extraction of iodine, but that the waste fluid reportedly has been discharged into the Dominguez Channel (p. 70). Sodium sulfate waste fluids have been discharged into the channel of the Los Angeles River, upstream from the area here considered, although those for which analyses are available to the writers (table 29) have been much more dilute than the contaminated water of well 10F1. For that particular water, no specific source of a competent contaminant is known.

Waste fluids from industrial plants of the area are diverse in chemical character and currently (1945) are disposed of chiefly into a regional industrial-sewer system; the writers do not know of promiscuous disposal onto the land surface but it once may have been practiced. Reportedly, some oil-field and refinery wastes formerly were discharged onto the poorly drained area at the southwest flank of Dominguez Hill during periods of storm runoff; even though those high-chloride-content wastes were diluted by surface water at the time, all did not drain into the Dominguez Channel and evaporation probably has led to accumulation of residual salines in substantial amount. Use of the natural and artificial channels of the area to convey concentrated industrial wastes is treated on page 80.

It seems obvious that the saline wastes discharged onto the land surface or into the channels of the Dominguez Gap can percolate and have percolated to the unconfined water body rather extensively. Because the surficial materials beneath the land surface and stream channels range from the moderately permeable to the nearly impermeable, and because the known points of waste disposal are widely scattered, the resulting contamination of the unconfined water body has not been of uniform intensity over the area. The known wide diversity in chemical character of the contaminated waters indicates equal diversity in the sources of the contaminants. However, the focal point of intense contamination in secs. 13 and 14 (see fig. 25), adjacent to the outfall from the sumps of Oil Operators, Inc., also the general area of intensive contamination in sec. 24, both are caused presumptively by overland discharge of waste fluids from the oil operations on the Signal Hill uplift. Although not shown specifically by analytical data, contamination is believed to be rather extensive in the unconfined water body at the southwest flank of Dominguez Hill, and there likewise to have been caused largely by oil-field waste fluids.

Regarding movement of the contaminated unconfined waters, as of 1944–45 the water table of the unconfined body within the Dominguez Gap slopes somewhat sharply downward east and west for a few hundred feet from the channel of the Los Angeles River. Also, it declines gently southward, or toward the coast. These features of water-table form probably are essentially native, although in some respects doubtless they have been accentuated by draw-down during the development of the area. Accordingly, it is concluded that: A contaminant infiltrating from any particular point along the Los Angeles River would diverge somewhat downstream; such movement would explain the high chloride content of the water from shallow well 4/13–14P1 in 1942, because that well is southwest from the outfall from the sumps of Oil Operators, Inc. Contaminants infiltrating from the land surface on the east side of the river or derived from shallow depth in Pleistocene deposits along the west flank of the Signal Hill uplift would disperse toward the coast but would be restrained from percolating quite to or across the channel of the Los Angeles River. Likewise, contaminants originating from Dominguez Hill or elsewhere to the west would be restrained from percolating to or across the river.

CONTAMINATION OF THE GASPUR WATER-BEARING ZONE

GENERAL FEATURES

In the Gaspur water-bearing zone of the Dominguez Gap, saline contamination may have begun as early as 1913 when well 5/13–3K1, 0.15 mile from the coast, was drilled to a depth of 1,200 ft and its casing was perforated 137–155 and 189–275 ft below land surface, presumably in deposits of Pleistocene age. By report, it was never used because its water was salty. Because under native conditions the Gaspur zone probably conveyed fresh water to offshore submarine springs (Poland and others), the salty water of well 3K1 as of 1913 presumably had resulted from contamination. By the middle twenties, water of depreciated quality had been drawn from numerous wells tapping the Gaspur zone near the coast. By 1929, the year of the earliest analytical data available to the writers, substantially depreciated waters existed nearly half a mile inland. In that year wells 4/13–35Q4 and 5/13–3D1, respectively about 300 and 2,000 ft from the coast, yielded water containing 4,924 and 1,250 ppm of chloride. After 1929, and especially after 1931, progressive depreciation of water quality in the Gaspur zone alarmed those agencies and individuals concerned with the integrity of water supplies (Brown, 1938, p. 173), and led to programs of sampling and chemical analysis by the city of Long Beach, the Los Angeles County Flood Control District, the California Division of Water Resources, and the

Los Angeles Department of Water and Power (see pp. 6–9). In particular, the comprehensive and continuing program by the city of Long Beach (which has involved determination of chloride roughly at monthly intervals for 75 wells beginning as early as 1932) has yielded data invaluable for the purposes of this treatment. In fact, without those particular data it would be impossible here to trace the progress of water-quality depreciation in the Gaspur zone.

Plate 17 shows the extent of areas in and near the Dominguez Gap in which confined water containing more than 100 ppm of chloride existed as of 1931–32 and as of 1943–44 in the Gaspur water-bearing zone and in Pleistocene deposits not more than about 200 ft below the land surface. Within the Gaspur zone, all such waters definitely were contaminated. However, in the outlying areas to the west and to the east, waters of inferior quality were and are native in the uppermost Pleistocene; except in a few areas of small extent and immediately adjacent to the Gaspur zone, they are not known to have depreciated in quality.

As plate 17 shows, both as of 1931–32 and as of 1943–44 there were two principal foci of saline contamination in the Gaspur water-bearing zone, namely, from the coast inland about a mile, or roughly to Anaheim Street; and along the eastern margin of the zone nearly 4 miles inland, between 223d Street and Wardlow Road, in and near the SE$\frac{1}{4}$ sec. 14. At the coast, the area of strongly contaminated waters in the Gaspur zone—those containing 500 or more ppm of chloride—was about 1,900 acres in 1931–32 and 2,200 acres in 1943–44. In the 12-year interim that area had encroached on 300 acres, largely west of Santa Fe Avenue and north of Anaheim Street. The inland area of equally depreciated waters in 1931–32 covered only about 300 acres; at that time, several wells in sec. 14 produced water containing more than 1,000 ppm of chloride and one well, 14Q2, produced water of 3,639 parts. Within the ensuing 12 yr (by 1943–44) this inland area had increased to 1,400 acres, by slight encroachment northward but very largely by extension for somewhat more than half a mile to the west and for nearly a mile and a half to the south.

As of 1931–32, a third but small area of strongly contaminated water existed along the west margin of the Gaspur zone near the intersection of Alameda and Dominguez Streets. There, well 4/13–10J1 produced water with 731 ppm of chloride and two adjacent wells produced water with more than 100 parts. As of 1943–44, that small area persisted and had become somewhat more extensive. Certain evidence suggests that the focus of contamination may lie to the west in upper Pleistocene deposits that probably are in local hydraulic continuity with the Gaspur zone.

Still farther inland, all the waters of the Gaspur zone seemingly were of undepreciated quality in 1931–32; however, as of 1943–44, slight depreciation was developing along the lower reach of Compton Creek, beginning at least a mile north of Del Amo Street and diverging downstream.

Perhaps the most significant feature of contamination in the Gaspur water-bearing zone shown on plate 17 involves a part of the area from Sepulveda Boulevard and Willow Street on the north to Anaheim Street on the south. There, in a transverse belt perhaps half a mile wide at the west margin of the Gaspur zone and fully a mile and a half wide at the east margin, water of substantially native quality (chloride content from 55 to 70 ppm) existed in 1932–33. By 1943–44, the belt had been closed on the west by encroachment of salines beyond Santa Fe Avenue. On the east, although the belt had been narrowed fully a third by substantial encroachment from the north and probably by slight encroachment from the south, nevertheless water virtually of native quality persisted locally, as at well 4/13–26P4. (See fig. 28, p. 183.) As here briefly described, this feature is fully substantiated by determination of chloride by the municipal water department of Long Beach, in samples taken from 5 to 13 times yearly at numerous wells beginning in 1932. As will be shown, contamination in the areas to the south and to the north of this transverse belt has originated from two distinct sources.

CONTAMINATION AT THE COAST

Figure 26 shows the progressive increase in intensity of contamination from 1929 to 1941 in two wells, 4/13–34K1 and –35M3, about a mile from the coast and 200 yards south of Anaheim Street; as of 1941, the chloride content of their waters was about 2,500 and 4,000 ppm respectively. At both wells the chloride content of the water had increased almost uniformly throughout the preceding 10 yr, even though withdrawals from the Gaspur zone had become very small in the vicinity because the water was usable only for cooling and for a few other industrial purposes. However, even greater depreciation of water quality occurred in other wells; the known extreme is well 4/13–35Q4, at which from 1929 to 1933 the chloride content of the water increased about from 4,900 to 11,600 ppm, and the total-solids content from 8,960 to 20,500 parts. (See analysis of 1933 in table 30.)

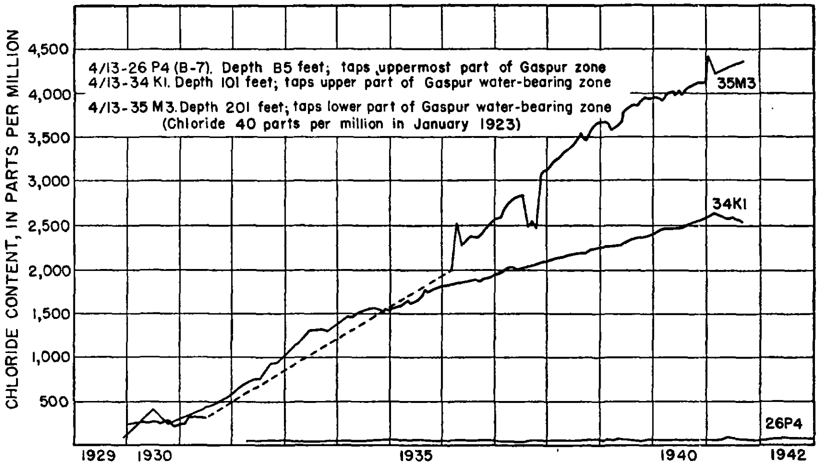


FIGURE 26.—Chloride content of waters from selected wells tapping the Gaspur water-bearing zone near the coast, 1929-42. (Analyses from California Division of Water Resources, Long Beach Water Department, and Los Angeles County Flood Control District.)

There seem to be two sources of brine competent to have caused the known depreciation in water quality: ocean water, which presumably is in hydraulic continuity with the water body of the Gaspur zone at an offshore outcrop, and which occupies dredged channels of the Long Beach Harbor within 125 yd of well 35Q4 and 300 yd of well 35M3; and oil-field brine, which long has been and currently (1945) is discharged into the channel of the Los Angeles River from the sumps of Oil Operators, Inc., which in dry seasons has supplied nearly all the summer flow in the lower reach of that channel, and which has passed about 250 yd to the east of well 35Q4. Analyses of ocean water and of the brine discharged by Oil Operators, Inc., (analysis 4/13–14R), are given in table 29. Conceivably, either of these competent potential contaminants could have been drawn into the Gaspur zone from above as the fresh-water head on that zone was depleted by former heavy withdrawals. Percolation from the river or from the channels of the harbor probably would not have been restrained completely by the deposits overlying the Gaspur zone, which here are sensibly permeable (p. 168) and into which the harbor channels have been dredged some two-thirds of the depth to the Gaspur zone.

In addition to these two competent sources, high-chloride-content waters locally are native in deposits of Pleistocene age (p. 59) and probably have some hydraulic continuity with the

Gaspur water-bearing zone from either side, but not from beneath. However, even the most concentrated of the known native waters of the Pleistocene contains far too little dissolved material to have depreciated the water of the Gaspur zone as severely as here described.

Plate 18 affords a graphic comparison between a group of analyses selected to span the known range of contamination in the area at the coast, and corresponding hypothetical mixtures of ocean water with the native water of the Gaspur zone, which is presumed to be represented approximately by the analysis of January 1923 from well 4/13–35M3. (See table 30.) The following tables 22 and 23 compare a moderately depreciated water from well 4/13–34K1 and the most severely depreciated water from well 4/13–35Q4, respectively, with hypothetical mixtures of the presumed native water of the Gaspur zone with two potential contaminants, ocean water and oil-field brine as represented by the discharge from the sumps of Oil Operators, Inc. In form, this plate and the two tables are analogous to others introduced in the description of water-quality depreciation in the Santa Ana Gap.

TABLE 22.—*Contaminated water from well 4/13–34K1 in comparison with hypothetical mixtures of the presumed native water and two potential contaminants*

	Constituents					
	Calcium (Ca)[1]	Magnesium (Mg)	Sodium (Na)[2]	Bicarbonate (HCO_3)[3]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Presumed native water of Gaspur zone	27	11	82	235	40	40
Well 4/13-34K1, contaminated water of January 4, 1933 (table 29, adjusted)	136	158	329	215	0	1,085
Native water mixed with ocean water	48	81	673	234	184	1,085
Native water mixed with brine 4/13-14R	64	30	701	285	39	1,085
Equivalents per million:						
4/13-34K1, January 4, 1933	6.80	13.01	14.32	3.53	0	30.60
Mixture with ocean water	2.38	6.63	29.26	3.84	3.83	30.60
Mixture with brine 14R	3.18	2.44	30.47	4.67	.82	30.60
Excess (+) or deficiency (−) of the contaminated water with respect to:						
Mixture with ocean water	+4.42	+6.38	−14.94	−.31	−3.83	----------
Mixture with brine 14R	+3.62	+10.57	−16.15	−1.14	−.82	----------

[1] Includes equivalents of barium (Ba) and strontium (Sr) if any.

[2] Includes equivalent of potassium (K).

[3] Includes equivalent of carbonate (CO_3).

TABLE 23.—*Contaminated water from well 4/13–35Q4 in comparison with hypothetical mixtures of the presumed native water and two potential contaminants*

	Constituents					
	Calcium (Ca)[1]	Magnesium (Mg)	Sodium (Na)[2]	Bicarbonate (HCO_3)[3]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Presumed native water of Gaspur water-bearing zone	27	11	82	235	40	40
Well 4/13-35Q4, contaminated water of January 4, 1933 (table 29, adjusted)	492	823	6,107	476	1,263	11,477
Native water mixed with ocean water	253	773	6,549	225	1,616	11,477
Native water mixed with brine 4/13-14R	429	216	6,853	782	31	11,477
Equivalents per million:						
4/13-35Q4, January 4, 1933	24.55	67.69	265.54	7.81	26.29	323.68
Mixture with ocean water	12.60	63.61	284.79	3.68	33.64	323.68
Mixture with brine 14R	21.41	17.73	298.01	12.82	.65	323.68
Excess (+) or deficiency (−) of the contaminated water with respect to:						
Mixture with ocean water	+11.95	+4.08	−19.25	+4.13	−7.35	----------
Mixture with brine 14R	+3.14	+49.96	−32.47	−5.01	+25.64	----------

[1] Includes equivalents of barium (Ba) and strontium (Sr) if any.
[2] Includes equivalent of potassium (K).
[3] Includes equivalent of carbonate (CO_3).

From these data it is concluded, concerning the depreciated waters in the Gaspur water-bearing zone at the coast, that:

1. The contaminant is ocean water rather than oil-field brine.

2. In a first stage of the depreciation, the mixture of native water and ocean water is hardened by exchange of sodium from the mixture for calcium (and some magnesium) from the containing deposits. This stage ends when the base-exchange capacity of the deposits is exhausted; locally, this capacity seems to have been to displace about 22 equivalents (500 ppm) of the sodium brought in by the invading sea water. The analysis of August 1939 for well 4/13–34K1 approximately represents the end-product of this stage. Beyond this first stage, depreciation progresses by simple admixture of the contaminating ocean water without further exchange of bases in appreciable amount. Thus, in the Gaspur water-bearing zone of the Dominguez Gap, the extent of hardening by base-exchange is substantially equal to that in the Talbert water-bearing zone of the Santa Ana Gap (pl. 12 and p. 120) and in the upper water-bearing zone of the Huntington Beach Mesa (pl. 15).

3. The moderately depreciated waters are deficient in sulfate, presumably because that constituent has been reduced. Although

shown only approximately by the available data, the reduction capacity of the deposits seems to average about 3.5 equivalents (175 ppm) of sulfate.

4. From moderately depreciated and severely depreciated waters alike, a nominal amount of calcium may have been precipitated as the carbonate.

That the contaminant here is ocean water rather than oil-field brine is substantiated in a general way by the belt of nondepreciated waters which in 1931–32 extended across the full width of the Gaspur zone between Anaheim and Willow Streets, and which in 1943–44 persisted east of Santa Fe Avenue (pl. 17); also by certain data on borate in the contaminated waters from well 35Q4. Because the nondepreciated belt seemingly was continuous as of 1931–32, when contamination at well 35Q4 had progressed nearly to the extreme previously described, it follows that the contaminant probably had not been transmitted through the Gaspur zone to the coast from an inland source. Because nondepreciated waters existed roughly from Santa Fe Avenue eastward to and beyond the Los Angeles River as late as 1943–44 (at least), it follows that probably the contaminating fluid was not derived by percolation from the river channel south of State (Pacific Coast Highway). The data on borate content of contaminated waters from well 35Q4 include ten determinations in 1932 and through March 1933; those determinations ranged between 7.2 and 11 ppm for waters whose chloride content was from 7,300 to 11,600 parts. Because the borate content of ocean water is much less than that of the oil-field brines (2.5 ppm as against 169 parts in a sample of brine from the Los Angeles River in 1932 as reported in table 29), also because the borate content of the contaminated waters was somewhat less than the amount hypothetically available in a mixture with ocean water, it is concluded that no appreciable quantity of oil-well brine could have reached the depreciated area. Incidentally, the seeming deficiency in borate in the contaminated waters was from 2.3 to 4.7 ppm. That relatively constant deficiency may be fictitious, because it was computed on an assumed value for borate in the native fresh water; yet it is possible that borate has been removed from the depreciated waters by reaction with some constituent of the containing deposits.

CONTAMINATION BETWEEN CARSON STREET AND PACIFIC COAST HIGHWAY

Concerning the principal inland area of water-quality depreciation in the Gaspur water-bearing zone—that is, roughly between Carson Street on the north and the Pacific Coast Highway on

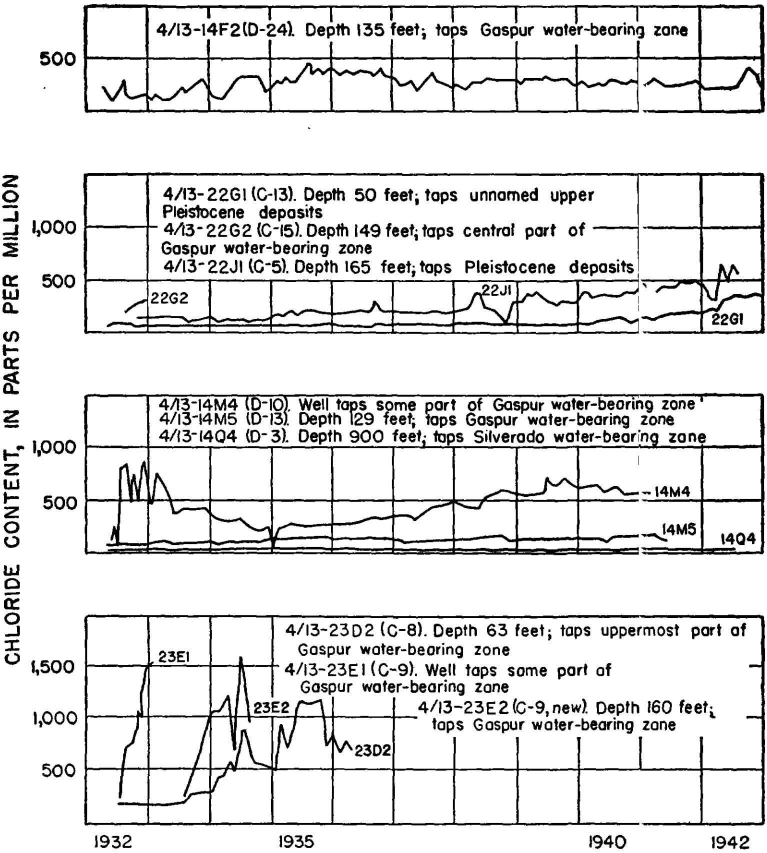


FIGURE 27.—Chloride content of waters from selected wells in the Dominguez Gap between Carson and Willow Streets. (After analyses by Long Beach Water Department. Numbers for wells shown in parentheses are those ascribed by city of Long Beach.)

the south—figures 27 and 28 graph the increase in chloride content at 14 wells from 1932 through 1942. Of the wells, 11 tap the Gaspur water-bearing zone, 2 tap the unnamed upper Pleistocene deposits close to the west margin of the Gaspur zone, and 1 taps the Silverado water-bearing zone at depth beneath the Gaspur. Although somewhat erratic, presumably owing in part to variable conditions of sampling, these graphic data on chloride content seem to indicate in general that (1) as of 1932, the water of the Gaspur zone contained more than 500 ppm of chloride over much of the S½ sec. 14 and the N½ sec. 23, at least west of the Los Angeles River (the greatest known chloride content in the area at that time, 3,639 ppm in well 14Q2, is not covered by figure 27); (2) in comparison with the focal area in sec. 14, the influx of contaminant lagged somewhat toward the north within the Gaspur zone and toward the west and southwest across the Gaspur zone and into the abutting Pleistocene deposits; and (3) southward, the contamination front advanced about a quarter of a mile a year on the average, and locally reached to the Pacific Coast Highway by 1939. Also, at least at and near the front, contamination seems to have been intense in the lower part of the Gaspur zone, as would be normal if all the saline contaminant had been transmitted through the zone from the focal area in sec. 14—normal because the density of the contaminant is substantially greater than that of the native fresh water.

However, exception to this last generalization is afforded by well 4/13–26Q2, which is just behind the front, 1,000 ft north of the highway, and 800 ft west of the Los Angeles River. This well is only 64 ft deep, and so taps only the uppermost part of the Gaspur zone. According to analyses by the city of Long Beach, of samples taken from this well at intervals of about

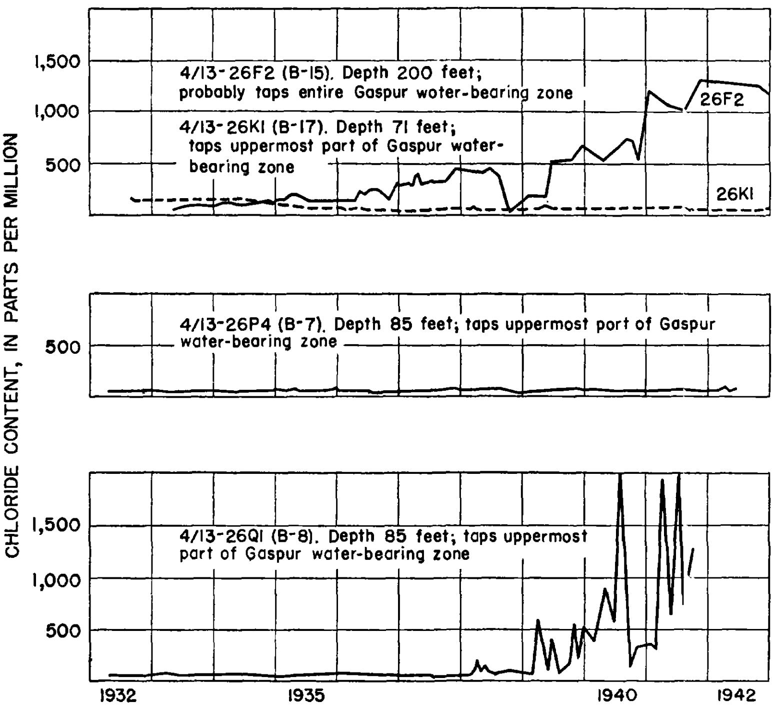


FIGURE 28.—Chloride content of waters from selected wells in the Dominguez Gap between Willow Street and the Pacific Coast Highway. (Analyses by Long Beach Water Department.)

five weeks since December 1932, the chloride content of its water ordinarily had been less than 500 ppm through October 1943, averaged about 660 parts in November and December 1943, increased sharply to 4,900 parts in January 1944, and subsequently has ranged ordinarily between 1,500 and 4,600 parts. Currently (1945) it yields the most intensely contaminated water known to be from the Gaspur zone within the area here considered. The well is equipped with a pump and windmill; if the analyses are on pumped samples, as seems probable, the data suggest very strongly that contaminating salines first reached the Gaspur zone in the vicinity of well 26Q2 by percolation from above rather than by transmission within the zone from the north.

General hydrologic evidence indicates that the source of contamination is not the ocean, and so must be within the immediate area. All the local area here considered is inland beyond the reach of the tides into the channel of the Los Angeles River or into any other passages, natural or artificial. The transverse belt of nondepreciated waters to the south, to which reference has been made, calls for an inland source. Finally, the general extent and focal point of the contamination coincide approximately with the corresponding features of contamination in the unconfined water body above.

Chemical evidence of the sources of contamination is graphed on plate 19, which compares representative depreciated waters from this central reach of the Gaspur zone with hypothetical mixtures of the native fresh water and brine from the Signal Hill oil field, as represented by the effluent from the skimming sumps of Oil Operators, Inc. (See table 29, analysis 4/13–14R.) Regarding such hypothetical mixtures, the actual depreciated waters fall into three general groups, as follows:

1. Depreciated waters in which there is a substantial deficiency of sodium, a corresponding excess of calcium and magnesium, and no more than a moderate excess of sulfate or of bicarbonate. These are represented in the right half of plate 19 by plottings of three waters from well 4/13–14L1 in 1932–33; the greatly depreciated water from well 4/13–14Q2, in 1931 (table 30) is of the same sort. So far as is disclosed by available data, such waters have been encountered only in wells at or near the focal area of contamination just west from the sumps of Oil Operators, Inc. Concerning ocean water and oil-field brine as alternative potential contaminants, table 24 shows that the depreciated water of well 14Q2 would involve very substantial hardening by exchange of bases, a considerable reduction of sulfate in the case

of ocean water, and precipitation of calcium (and magnesium?) as the carbonate (and sulfate?). The necessary precipitation of calcium compounds is much the less in the case of oil-field brine. This chemical evidence favors oil-field brine as the likely contaminant, but of itself does not preclude ocean water.

2. Depreciated waters in which there is not only a substantial deficiency of sodium but also an even greater excess of calcium and magnesium and considerable excesses in sulfate and in bicarbonate. The waters from wells 4/13–14M3 and –26B1 in 1942; and from well 4/13–14M8 in 1939 (pl. 19) show progressive stages of the depreciation. Waters of this general sort have been encountered widely and commonly to the west and to the south of the focal area in sec. 14, nearly to the far reach of the strongly contaminated area. Table 25 shows that the chemical composition of the waters in this group could be duplicated rather closely by unmodified mixture of the native fresh water with the contaminated water of well 4/13–14P1, that is, with the high-calcium-content type of depreciated water in the unconfined body which overlies the Gaspur zone.

3. Depreciated waters in which there is an excess rather than a deficiency of sodium, along with considerable excesses of calcium, sulfate, and bicarbonate. The water from well 4/13–14D2

TABLE 24.—*Contaminated water from well 4/13–14Q2 in comparison with hypothetical mixtures of the native fresh water and two potential contaminants*

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Standard native water of Gaspur water-bearing zone	58	9.7	50	218	64	35
Well 4/13–14Q2, contaminated water of October 5, 1931 (table 30, adjusted)	756	221	1,088	57	36	3,597
Native water mixed with ocean water	123	247	2,070	218	550	3,597
Native water mixed with brine 4/13–14R	176	74	2,166	392	55	3,597
Equivalents per million:						
4/13–14Q2, October 5, 1931	37.71	18.14	47.28	.94	.74	101.45
Mixture with ocean water	6.13	20.34	90.00	3.57	11.45	101.45
Mixture with brine 14R	8.80	6.06	94.17	6.43	1.15	101.45
Excess (+) or deficiency (−) of the contaminated water with respect to:						
Mixture with ocean water	+31.58	−2.20	−42.72	−2.63	−10.71	----------
Mixture with brine 14R	+28.91	+12.08	−46.89	−5.49	−.41	----------

[1] Includes equivalent of potassium (K).
[2] Includes equivalent of carbonate (CO_3).

TABLE 25.—*Contaminated water from well 4/13–14M8 in comparison with a hypothetical mixture of the fresh water native to the Gaspur water-bearing zone and the contaminated water of well 4/13–14P1*

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Well 4/13-14M8, contaminated water of August 7, 1939 (table 30, adjusted)	222	56	162	413	228	398
Mixture of 84.5 percent native fresh water and 16.5 percent contaminated water of well 4/13-14P1 as of April 22, 1942	205	50	177	354	240	398
Equivalents per million:						
4/13-14M8, August 7, 1939	11.08	4.62	7.03	6.77	4.75	11.21
Mixture	10.24	4.10	7.67	5.81	4.99	11.21
Excess (+) or deficiency (−) of the contaminated water with respect to the mixture	+.84	+.52	−.65	+.96	−.24	

[1] Includes equivalent of potassium (K).
[2] Includes equivalent of carbonate (CO_3).

in 1943 has the greatest known excess of sodium. The waters from well 23L3 in 1932 show progressive depreciation with proportionately less excess of sodium. Thus, waters of this type have been encountered rather widely in the contaminated area, seemingly near the outer fringe of that area. Table 26 shows that in chemical character the extreme water of this type (14D2) could be duplicated essentially by an unmodified mixture of the native fresh water of the Gaspur with the two known types of the unconfined depreciated water, the high-calcium-content water of well 14P1 and the high-sodium-content water of well 10F1.

Determinations of borate are available for contaminated waters from six wells in the depreciated area here considered; these range from 1.6 to 9.2 ppm. In proportion to the corresponding determinations of chloride, these amounts of borate are from two to five times that which would be expected had the contaminant been ocean water, but they are well within the range of borate gain that would result from contamination by oil-field brine. In this connection, the borate content of ocean water is 25 ppm but that of the oil-field brines is as much as 386 parts (table 8). In and near this area, the borate contents of oil-field waste in the Los Angeles River and of diluted waste in the Dominguez Channel are known to have been as much as 23 and 169 ppm, respectively. (See table 29.) In proportion to chloride content, these amounts of borate are roughly 10 times that in ocean water and so are ample to have caused the known borate gain in the contaminated waters of the area.

From this and other hydrologic and chemical evidence, it is concluded that:

1. In the reach between Carson Street and the Pacific Coast Highway the Gaspur water-bearing zone has been and in 1945 is being contaminated partly by oil-field brine such as that wasted from the sumps of Oil Operators, Inc., partly by overlying unconfined waters which themselves had been depreciated in chemical quality as previously described, and partly by miscellaneous industrial wastes that have been and, to some extent, still (1945) are being discharged into the channel of the Los Angeles River upstream from the outfall of Oil Operators, Inc.

2. Contaminants have reached and still are reaching the Gaspur zone by percolation downward through the overlying and slightly permeable deposits, that is, directly from the unconfined water body above but indirectly from the Los Angeles River, from the sumps of Oil Operators, Inc., and from other sources. Contaminants also have reached and probably still reach the Gaspur by circulation through defectively cased wells and by percolation westward from contiguous Pleistocene deposits in which waste oil-field brines doubtless have accumulated in considerable volume. For example in well 4/13–13N1 (which taps the Pleisto-

TABLE 26.—*Contaminated water from well 4/13–14D2 in comparison with a hypothetical mixture of the fresh water native to the Gaspur water-bearing zone and the contaminated waters of wells 4/13–10F1 and 14P1*

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Well 4/13-14D2, contaminated water of July 20, 1943 (table 30)	120	9.7	206	293	360	123
Mixture of 94.0 percent native fresh water, 3.9 percent contaminated water of well 4/13-10F1 as of April 21, 1942, and 2.1 percent contaminated water of well 4/13-14P1 as of April 22, 1942	85	27	202	270	351	123
Equivalents per million:						
4/13-14D2, July 20, 1943	5.99	.80	8.96	4.80	7.49	3.46
Mixture	4.22	2.21	8.77	4.42	7.32	3.46
Excess (+) or deficiency (−) of the contaminated water with respect to the mixture	+1.77	−1.41	+.19	+.38	+.17	----------

[1] Includes equivalent of potassium (K).
[2] Includes equivalent of carbonate (CO_3).

cene deposits about 200 yd east of the sumps of Oil Operators, Inc.) a traverse by the Geological Survey on May 9, 1941, found that the water more than 100 ft below land surface contained about 3,000 ppm of chloride. In the middle twenties this well had been used for domestic purposes, so that its water presumably was of at least fairly good quality at that time. The high salinity of 1941 almost certainly is due to contamination by waste brine from the Long Beach oil field.

3. Brine from the oil fields on the Signal Hill uplift has been and now (1945) is the principal contaminant by far; a focal point of such contamination has existed at the sumps of Oil Operators, Inc., since the early thirties, but dispersed contamination has been and doubtless is being derived from somewhat extensive accumulations of brine in sec. 24, to the south. Assuming for the purpose that oil-field brine has been the sole contaminant, it is calculated that as of 1943 about 1,500 acre-ft of that brine had infiltrated to the Gaspur water-bearing zone. This volume is equal to 3 percent of that which had been discharged from the sumps of Oil Operators, Inc., through 1943. The average rate of infiltration would have been about 90 acre-ft a year.

Thus, for the depreciated area between Carson Street and the Pacific Coast Highway the principal contaminant is concluded to be oil-field brine, whereas for the depreciated area near the coast the principal or sole contaminant has been concluded to be ocean water (p. 182). In these two areas only, one feature of chemical character seems to discriminate rather sharply the waters contaminated from the two sources. Specifically, and as figure 29 shows, in the waters contaminated from the ocean the

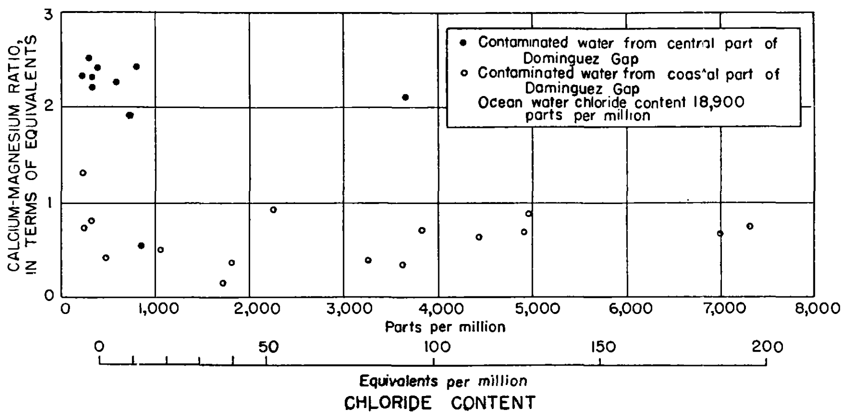


FIGURE 29.—Relation between calcium to magnesium ratio and chloride content of contaminated waters from the Gaspur water-bearing zone.

calcium-to-magnesium ratio averages about 0.6, whereas in those contaminated primarily by oil-field brine the corresponding ratio averages about 2.3, at least for chloride contents less than 1,000 ppm. For the Dominguez Gap at least, a calcium-to-magnesium ratio much greater than 0.6 would seem to indicate a contaminant other than ocean water.

CONTAMINATION INLAND FROM CARSON STREET

Near the head and along the west edge of the Dominguez Gap, moderate contamination of the Gaspur water-bearing zone was disclosed through the sampling program by the city of Long Beach, which began in 1932. At that time a small area of contamination existed near the intersection of Alameda and Dominguez Streets, in the E½ sec. 10, T. 4 S., R. 13 W. (projected). Subsequently that area has extended two tongues which have merged into the main area of strongly contaminated waters south of Carson Street. As of 1943–44, one tongue had reached southward fully 1½ miles along the west margin of the Gaspur zone; the other and broader tongue had spread widely, roughly from Del Amo Street on the north to Carson Street on the south. (See pl. 17.) Also, beginning about 1936, a third tongue of depreciated waters has developed beneath the lower reach of Compton Creek, in the SW¼ sec. 35, T. 3 S., R. 13 W. and in sec. 2, T. 4 S., R. 13 W.

Table 27 shows the increase in chloride content of samples from the observation wells in sec. 10, from 1936 through 1944. Its data suggest that chloride diminishes radially eastward away from a focus which is near the west margin of the Gaspur zone, and in the SW¼NE¼ of the section; and that the water in the upper part of the Gaspur may be somewhat more concentrated than that in the lowest part of the zone.

Only one comprehensive chemical analysis is available to show the character of the contaminated water in the Gaspur zone in this area. It is of a sample from well 4/13–10G3 in 1942 (see table 30). Table 28 compares that analysis to the composition of a hypothetical mixture of native Gaspur water with the contaminated water of well 10F1 (which taps the overlying, unconfined water body) and with typical oil-field brine of well 4/13–14R. The proportions of the three components are such that the concentration of the mixture is equal to that of contaminated water 10G3, in terms of equivalents. Evidently, this hypothetical mixture and a moderate gain in calcium and magnesium at the expense of sodium (base-exchange hardening) would very nearly duplicate the actual contaminated water. Thus, it is reasonable to assume that in the local area here considered the depreciated quality of the water in the Gaspur zone probably has been caused principally by downward percolation of contaminated water from above, but in part by an influx of oil-field brine (which very probably has accumulated in the Pleistocene deposits to the west; see p. 71). More comprehensive analytical data would be necessary to verify this assumption.

TABLE 27.—*Chloride content of contaminated waters from wells tapping the Gaspur water-bearing zone in sec. 10, T. 4 S., R. 13 W. (projected), in 1936 and 1944*

[From analytical record by city of Long Beach on observation wells sampled about monthly]

Well number on plate 17	Depth of well (feet)	Depth of perforated casing (feet)	Greatest known chloride content (ppm)	
			1936	1944
4/13-10A1	175		67	168
10A2	112		128	199
10B1	141	93-96, 120-130	222	326
10G1	185		109	575
10G2	90		419	646
10G3	80		594	[1] 626
10G4	115	93-96	(2)	[3] 497
10H1	370		126	174
10H2			176	698
10H3	85		229	435
10J1	157	105-157	[4] 752	
10J4			139	263

[1] In 1943.
[2] Well drilled in 1941.
[3] In 1942, by Geological Survey.
[4] In 1932.

Evidence of the contamination of the Gaspur zone beneath the lower reach of Compton Creek is afforded by two wells only: well 3/13-35N1, in whose water the chloride content first exceeded 100 ppm in 1936, and was as much as 276 parts in 1944 (after analytical records by the city of Long Beach) and well 4/13-2J2, in whose water the chloride content was from 110 to 130 ppm in 1942-43 (table 31). No comprehensive analyses are available.

FUTURE DISPERSAL OF CONTAMINATED WATERS WITHIN THE GASPUR WATER-BEARING ZONE

Further dispersal of contaminated waters within the Gaspur water-bearing zone will be determined largely by the areal pattern of sources from which contaminants are derived, and by long-term fluctuations of ground-water head and gradient in response to the cycle of wet periods and droughts. Because con-

TABLE 28.—*Contaminated water from well 4/13–10G3 in comparison with a hypothetical mixture of the fresh water native to the Gaspur water-bearing zone, the contaminated water of well 4/13–10F1, and oil-field brine 4/13–14R*

	Constituents					
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Bicarbonate (HCO_3)[2]	Sulfate (SO_4)	Chloride (Cl)
Parts per million:						
Well 4/13–10G3, contaminated water of April 13, 1942 (table 30, adjusted)	401	108	260	238	941	591
Mixture of 85.2 percent native fresh water, 12.2 percent contaminated water of well 4/13–10F1 as of April 21, 1942, and 2.6 percent oil-field brine 4/13–14R	96	55	711	346	895	564
Equivalents per million:						
4/13–10G3, April 13, 1942	20.00	8.86	11.31	3.90	19.59	16.68
Mixture	4.77	4.50	30.92	5.66	18.63	15.90
Excess (+) or deficiency (−) of the contaminated water with respect to the mixture	+15.23	+4.36	−19.61	−1.76	+.96	+.78

[1] Includes equivalent of potassium (K).
[2] Includes equivalent of carbonate (CO_3).

tamination is severe and extensive, the withdrawal of water from the Gaspur zone within the Dominguez Gap now is small and, except locally, presumably will not be a determining factor in the movement.

As has been explained piecemeal, the sources of contamination include: A focal point of intense contamination at the brine sumps of Oil Operators, Inc., along the east side of the Los Angeles River in the vicinity of 223d Street (fig. 7). At least three reaches along the margins of the Gaspur zone: across the mouth of the gap at the coast, where the Gaspur zone is in some hydraulic continuity with the ocean; along the east margin at the flank of the Signal Hill uplift, where waste oil-field brines doubtless have accumulated in the adjacent Pleistocene deposits, perhaps chiefly in sec. 24, T. 4 S., R. 13 W.; and along the west margin at and southward from the flank of the Dominguez Hill, where oil-field brines probably have accumulated likewise, perhaps chiefly in sec. 10. And third, the overlying body of unconfined water, grossly contaminated over nearly all the gap, whose contaminated waters range greatly in chemical character, and to which contaminants have been and (in 1945) are conveyed chiefly by the Los Angeles River, Compton Creek, and Dominguez Channel. In these channels the contaminants—oil-field brine, oil-refinery effluent, and various industrial wastes—have varied considerably in chemical character and in concentration.

Within the several areas which on plate 17 are enclosed by the lines representing a chloride content of 500 ppm—at the coast, and separately between Del Amo Street and the Pacific Coast Highway—strongly contaminated waters doubtless occupy the Gaspur zone from top to bottom. Beyond the margins of those areas, quite probably the contaminants are not dispersed uniformly through the zone and in part may form ramifying tongues.

In general, the reach of contaminants into the Gaspur zone inevitably will increase and ultimately will engulf the area in which waters of essentially native quality now (1945) exist between the Pacific Coast Highway and Anaheim Street, east of Santa Fe Avenue. Because the hydraulic gradient is generally southward, the most mobile front of contamination is that which currently is just north of the highway, and which is inferred to be moving continually toward the coast. (See p. 183.) In contrast, the north-facing fronts roughly along Anaheim Street and at 223d Street some 3 miles farther inland are much less mobile except as they may be drawn northward under the draft from adjacent wells. During a protracted drought, the normal seaward hydraulic gradient in the Gaspur zone would decrease through the Dominguez Gap, owing both to diminishing natural underflow and to increasing withdrawals inland. Such conditions presumably would slow or even stop the southward movement of the front at the Pacific Coast Highway and might induce or accelerate northward movement of the two fronts at Anaheim Street near the coast and near 223d Street farther inland. Also, they would tend to accelerate the inflow of oil-field brines from the accumulations along either flank of the Gaspur zone, in the contiguous Pleistocene deposits. Conversely, during a prolonged wet period the south-moving front at the highway would be accelerated, the two north-facing fronts would be slowed or might even regress toward the coast, and the inflow of brine from Pleistocene deposits would diminish.

In the future, if all saline and concentrated wastes of the area were piped to the ocean, and so long as the hydraulic gradient might be oceanward and relatively steep, both the intensity and the extent of contamination in the Gaspur zone of the Dominguez Gap probably would diminish gradually. Such improvement would be quickened by any artificial measures maintaining a substantial flow of fresh water in the Los Angeles River perennially. However, even under the most favorable circumstances it is extremely unlikely that the present contaminated waters could be displaced completely from the Gaspur zone. Also, the accumulations of oil-field brine along either flank of the zone in contiguous Pleistocene deposits will remain potential sources of contamination almost, if not quite, indefinitely.

POTENTIAL CONTAMINATION OF THE SILVERADO WATER-BEARING ZONE WITHIN DOMINGUEZ GAP

Within the Dominguez Gap the depreciation of water quality in the Gaspur water-bearing zone now (1945) is so intense and widespread as to have made that zone virtually worthless as a source of water, except in the small area between the Pacific Coast Highway and Anaheim Street, east of Santa Fe Avenue. This destruction of a formerly prolific source of fresh water at relatively shallow depth is serious, but far less serious than the current threat that grossly depreciated water of the Gaspur zone can reach and contaminate the deeper Silverado water-bearing zone (pp. 169–170). This deeper water-bearing zone is by far the most productive source of water now tapped by wells in the Long Beach-Santa Ana area. It sustains very heavy and continual withdrawal, chiefly for municipal supply and for industrial purposes, from many wells of large yield. Within the Dominguez Gap and south of Del Amo Street, that is, within the area of gross contamination in the overlying Gaspur water-bearing zone, the yearly withdrawal for these purposes is estimated to have been 19,000 acre-ft as of 1941 and, owing to the greatly increased demand of the war period, 28,000 acre-ft as of 1944 (Poland and others).

Silt, clay, and some fine sand, from 250 to 500 ft thick, and impermeable under hydraulic gradients of ordinary slope, intervene between the Silverado zone and the overlying bodies of grossly contaminated water in the Dominguez Gap. However, owing to the heavy and increasing withdrawals, the head on the Silverado zone has been drawn down until, as of 1944–45, it is extensively from 40 to nearly 60 ft below that of the Gaspur zone. So, every deep nonpumped well potentially is a conduit through which contaminated water can move downward from the Gaspur zone into the Silverado zone, currently under an average head of 50 ft, provided its casing is perforated opposite the Silverado and is not watertight above. Several such wells are known to exist within the Dominguez Gap.

So far as the writers know, the Silverado water-bearing zone has not been contaminated from the overlying Gaspur zone through inadequately cased wells. However, the possibility of such contamination exists, currently (1945) is increasing, and will continue to increase so long as the pressure head of water in the Silverado zone is progressively depleted. For assurance against such contamination in the future it is essential for all active wells tapping the Silverado zone to be maintained rigorously, with completely watertight casings from land surface to the top of that zone and for each well permanently abandoned to be securely plugged. For adequacy in plugging, it is recommended that the well be filled tightly with mud or other impermeable material from its bottom to some level opposite compact silt or clay at least 50 ft above the top of the Silverado zone, that a plug of cement at least 10 ft long then be placed in the casing, and that the remainder of the well then be filled. If the character of the materials above the Silverado zone is not known, probably it would be advisable first to fill the lower part of the well to the desired level, then to perforate the casing at that level and cement under pressure. As new wells are drilled to the Silverado zone (or to the underlying upper division of the Pico formation, which is believed to constitute an untapped source of essentially fresh water (Poland, Piper, and others), it is suggested that an outer casing be carried down through the Gaspur zone into the underlying impermeable Pleistocene deposits and there be tightly sealed by circulating drilling mud under pressure, or by driving the casing shoe into tough clay.

As for potential contamination from sources other than the overlying Gaspur zone, it will be recalled that in and near the southwestern part of the Dominguez Gap, along the flank of the Palos Verdes Hills and the margin of the Torrance Plain, the Silverado water-bearing zone locally contains native water of decidedly inferior quality, as in well 5/13–6D1, and presumed native waters of somewhat inferior quality, as in wells 4/13–31E3, –33E2, and –33E8 (pp. 57–58; also table 30). In these native waters the chloride content ranges from 70 to 500 ppm. Under continuing heavy withdrawal from the Silverado in this part of the area, the poor water of well 5/13–6D1 may be drawn northward and eastward to wells that now yield water of excellent quality.

In this area, incipiently contaminated waters have been drawn from a few wells that tap the Silverado zone: well 4/13–20L1, chloride 126 ppm in 1931; well 4/13–21R1, chloride 88 parts in 1938; and well 4/13–31E2, chloride 276 parts in 1938. (See analyses in table 30.) Presumably, these wells are self-contaminating because they are inadequately cased through native waters of inferior quality in the upper Pleistocene deposits which there overlie the Silverado zone. For control of such contamination, the obvious course is stricter maintenance of active wells and plugging of all abandoned wells.

As explained, in 1944–45 the head on the Silverado water-bearing zone had been drawn down to about 50 ft below sea level in the vicinity of Dominguez Street, which is 5 miles inland and within 2 miles of the head of the Dominguez Gap. Thus, a substantial hydraulic gradient exists and favors movement of ocean water inland through the Silverado zone, if there is hydraulic continuity. Even so, no contamination whatsoever is known to have occurred in that zone within the area of heavy draft, which extends inland from Anaheim Street and largely lies east of Wilmington Avenue (see pl. 17). South of Anaheim Street, within a mile of the coast, the water of the Silverado zone becomes progressively more saline eastward and southward on the flank of the Wilmington anticline. This is shown by the electric logs of many oil wells and by the record of well 5/13–3K1 which was drilled in 1913 at the plant of the Southern California Edison Company at the east end of Terminal Island, and which is reported to have encountered salty water. Data by Mendenhall in 1903–4 suggest that the higher salinity of the water here is at least in part a natural characteristic, and not due primarily to contamination during the period of water use. Thus, contamination of the Silverado zone because of in-draft of ocean water is not known to have occurred. Should such contamination ensue, quite probably the conditions of the Santa Ana Gap would be repeated; that is, the first stage of contamination would be caused by local connate waters displaced inland ahead of ocean water. (See pp. 122–124.)

CONTAMINATED WATERS BEYOND DOMINGUEZ GAP

Within the area of this report and west of the Dominguez Gap, available chemical evidence shows definite saline contamination of natively fresh ground waters at only a few additional wells on the edge of the Torrance Plain, just west of the Dominguez Hill. Here, well 3/13–31A1 penetrates the upper Pleistocene deposits to a depth of 200 ft; the chloride content of its water has increased from an average of 200 ppm in 1941 to 270 parts in November 1942 (table 31). For the area to the south and east along the flank of the Dominguez Hill, the few analytical data available do not indicate appreciable depreciation of quality since 1931 in the water from wells that tap the upper Pleistocene. However, it seems altogether likely that saline contamination here is more widespread than the available data show conclusively. In sec. 10, T. 4 S., R. 13 E. contamination likely extends farther west than is indicated on plate 17, and may extend beneath part of Dominguez Hill. (See pp. 191–193.)

East of the Dominguez Gap, contamination is known only for well 4/12–30B1 on the southwest flank of the Signal Hill uplift, along the south side of Willow Street and about 100 yd north of the Cherry Hill fault. That well is 254 ft deep and taps sand and gravel of the Silverado zone in an area whose native water contained about 300 ppm of all dissolved solids in 1904. (See pl. 2.) A sample from it analyzed by the Geological Survey in 1942 contained 261 parts of chloride and about 700 parts of total dissolved solids. A considerable volume of oil-field brine presumably has infiltrated below the land in the vicinity of that well (pp. 75–76) and in part has been trapped between the Cherry Hill fault on the southwest or coastal side of Signal Hill and the Northeast Flank and Reservoir Hill faults on the northeast or inland side. Any such body of brine poses the threat of extensive future contamination in the Silverado water-bearing zone to the north, which there has been pumped heavily at the Alamitos and Citizens well fields of the city of Long Beach. However, no trace of contamination has reached those wells as of 1944–45.

RESIDUAL PROBLEMS AND CONTINUING INVESTIGATION

This discussion of saline contamination in the Long Beach-Santa Ana area has outlined the conditions existing as of 1944–45, as fully as available data permit. Only tentative conclusions are justified about certain critical conditions. This is true in particular of future movement of oil-field brines which are inferred to have accumulated beneath the land surface in certain parts of the area, and to the mobility of the contamination fronts in the Gaspur water-bearing zone of the Dominguez Gap and the Talbert water-bearing zone of the Santa Ana Gap. The term of field investigation by the Geological Survey has been too short to afford dependable estimates of the current rates of salt-water movement, and such rates undoubtedly will accelerate during protracted droughts if withdrawals are maintained in their current amounts or, as is very likely, are increased. To forewarn of conditions before they become too serious for correction or alleviation, investigative studies must be continuously made. An outline of these follows.

DOMINGUEZ GAP

Presumably an increasing number of wells tapping the Gaspur water-bearing zone will be abandoned and pumps will be removed. It would be advisable to keep such wells open for sampling at least twice a year (or more frequently as is pertinent) to trace changes in the extent and intensity of the saline contamination; for most of the wells so sampled, determination of chloride should be adequate. However, samples bailed from or just below the static water level will not suffice, because commonly the saline water is most concentrated at the bottom of the water-bearing zone. Accordingly, samples should be taken at successive depths through the full span of perforations in the casing, or conductivity measurements should be made from top to bottom of the well. (See fig. 15.) Also, it would be advisable to obtain periodic comprehensive analyses for saline waters from selected wells near the several foci of contamination, and these analyses should include determination of borate and iodide in addition to the usual constituents.

Wells tapping the Silverado water-bearing zone also should be sampled periodically (with a uniform lapse of time after starting the pump), especially where pumping is heavy and where the Silverado zone is overlain by the contaminated reach of the Gaspur zone, as at the well field of the Dominguez Water Corporation. One or two outpost wells near Anaheim Street would give early indication of ocean water moving northward in the zone.

SIGNAL HILL UPLIFT

For many years the city of Long Beach has withdrawn large quantities of water from its Development, Citizens, and Alamitos well fields, which are respectively 1.2 miles, 0.8 mile, and 0.7 mile inland from the fault system of the Newport-Inglewood structural zone. Within that fault system a body or bodies of oil-field brine presumably have accumulated in beds which in whole or in part prolong the water-bearing zones of the well fields. Across the entire fault system, salt water is native along the coast. In recent years and continuously for several months at a time, pumping levels have been as much as 50 ft below sea level in the Development field, 60 ft below in the Citizens field, and 85 ft below in the Alamitos field. Under pumping levels so low, the ground-water head may be drawn down a considerable distance below sea level along the inland flank of the fault system, and native salt water or accumulated oil-field brine may have moved and may be moving continually inland. However, between the three well fields and the fault, only one existing well can show whether saline encroachment is likely to occur (water-level altitude) or already has occurred (water quality).

If withdrawal of water from these three well fields is to continue at the current rate or at a greater rate, it would seem advisable to sink one or two outpost wells to the bottom of the Silverado zone between each well field and the fault system, and to continue periodic observation of water level and water quality. Such wells could be sampled by the use of a portable pump or by transversing the full span of the Silverado zone with a cylinder-and-valve sampler or an electrical probe. If only one such outpost well were drilled near each field, that well would be located advantageously about one-third the distance from the master faults toward the particular field.

By periodically measuring water level and sampling such outpost wells, the city of Long Beach could be forewarned of any incursion of saline water across the barrier features of the Signal Hill uplift and could modify its withdrawal regimen accordingly. It is possible that even now (1945) saline waters may have encroached beyond these barrier features and may be moving toward the well fields of most intensive draft. In any event, such wells would reveal present conditions and would furnish observation points for control of future programs of withdrawals.

ALAMITOS GAP

Saline encroachment already has passed at least several hundred feet beyond the Seal Beach fault and has appeared in active well 5/12–11G1 (see pp. 158–161). Fortunately, as is indicated by the logs of wells proximate to but inland from the fault, at least in part of the gap the permeable deposits of Pleistocene age probably extend only about 200 ft below land surface. Yet, electric logs from oil wells show that highly permeable deposits containing fresh water are present to depths as great as 600 ft, at least in the southeastern part of the gap. Also, in the northwestern part of the gap and less than a mile inland from the master fault, permeable beds of sand and gravel of Pleistocene age extend to a depth of about 600 ft (5/12–2B).

Although withdrawals are not heavy in the Alamitos Gap, the summer water level declines as much as 10 ft below sea level during droughts such as that which culminated in 1936. Therefore, and especially because saline encroachment already has appeared on the inland side of the Seal Beach fault, it would be advantageous to sample all active wells and selected unused wells for periodic chemical analysis. Certain wells, such as 5/12–11G1, have been so sampled for many years and only so could the history of encroachment have been known. Only by an expanded sampling control can the extent of saline encroachment be appraised adequately in the future. As in the Dominguez Gap, inactive wells should be sampled by electrical or by mechanical means through the full span of water-bearing zones tapped. Also, results of such sampling should be reviewed periodically so that, within the extent of any saline encroachment, all wells which tap more than one water-bearing zone can be adequately cased or plugged to prevent movement of saline water vertically from zone to zone.

LANDING HILL TO BOLSA CHICA MESA

In the reach from Landing Hill through Sunset Gap, and for as much as 2 miles inland from the master faults of the Newport-Inglewood zone, draft from wells has been substantially reduced in the past two years owing to construction of the Naval Supply Depot within this area. Thus, well 5/12–12P1 on Landing Hill, which was becoming increasingly contaminated in the early forties (see pp. 155–158) and which was pumped considerably during that period, now is unused. However, a few hundred feet to the north the wells of the city of Seal Beach yield about 300 acre-ft of water a year. Because it is likely that the saline water which has crossed the Seal Beach fault near well 5/12–12P1 ultimately will reach them, these public-supply wells of the city of Seal Beach should be sampled periodically.

Southeast from Landing Hill to Bolsa Chica Mesa, little or no water now is withdrawn within half a mile of the master fault. On Bolsa Chica Mesa, the heaviest withdrawal is from public-supply wells 5/11–29C1 and –29C2, about 50 acre-ft a year. Because these wells are only about 600 ft from the master fault and because water nearly as saline as the ocean exists immediately on the coastal side of this fault, their effluent should be analyzed periodically.

These particular well groups are those most heavily pumped close to the master fault and within the reach of coast here described; thus, they are the most likely to draw water through the fault barrier. All other active wells, however, in this same reach and within a mile of the fault also should be sampled at more or less frequent intervals, depending on pumping rates occurring within this reach.

BOLSA GAP

Within the strip of land extending inland half a mile from the master fault and across the Bolsa Gap only water well

5/11–33H1 is active. It produces from a water-bearing zone between 302 and 363 ft below land surface in the San Pedro formation. When drilled in 1940, it encountered saline water in the "80-foot gravel" and in an underlying zone; accordingly, both zones were cased off. In order to obtain information on the extent and intensity of saline encroachment inland from the master fault in Bolsa Gap, it would seem advantageous to drill from two to four observation wells into the "80-foot gravel" in the strip of land immediately inland from the master fault and now barren of water wells. These observation wells could be measured and sampled periodically as suggested for those inland from the Signal Hill uplift. Such sampling would be especially significant in periods when water levels are drawn down several feet below sea level.

HUNTINGTON BEACH MESA

It has been explained on pages 129–153 that on the Huntington Beach Mesa the upper two of three water-bearing zones now are contaminated, that the salines now in those upper zones inevitably will become dispersed ever more widely, that the third and deepest zone contains a relatively large reserve source of water now (1945) only incipiently contaminated, and that contamination of this third zone can come about only as salines move downward through deep wells not tightly cased through the upper two zones. Under such circumstances effective control of contamination is possible only if all wells are maintained adequately. (See page 154.) Prudence suggests that all available wells within and at least half a mile beyond the contaminated area should be sampled periodically and indefinitely, and any points of surface disposal of brines and waste fluids should be sampled sufficiently often to ascertain trends in disposal methods in the future. With these and past data as a basis for study, effective control measures can keep pace with the dispersal of contaminated ground water whether under conditions of continued or curtailed surface disposal of brines and oil-field wastes.

SANTA ANA GAP

The current front of contamination in Santa Ana Gap has been indicated on plate 11*B*. This front has advanced slightly during the time of this investigation, a period of greater-than-normal rainfall. In the course of a few years of subnormal rainfall, a substantial additional encroachment will develop if effective control measures are not practiced. As one part of such control, all available wells within about half a mile of that front should be sampled at least twice a year and preferably quarterly to trace any changes that develop. As for wells in Dominguez Gap, determination of chloride should be adequate testing for most wells, but it would be advisable to obtain periodic comprehensive analyses for a selected few wells, preferably wells which are heavily pumped. Also, from time to time, unused wells should be sampled at successive depths through the full span of perforations, or a conductivity probe should be run from top to bottom of such wells.

The authors have suggested to the Orange County Flood Control District the sampling of a net of some 24 wells in order to furnish control data on movement of the saline front and change in concentration in the contaminated area.

HUNTINGTON PARK AREA

Although Huntington Park is not in the area examined comprehensively in this report, a most critical situation in its vicinity seems worthy of special mention. There, in the far northwestern part of the Long Beach-Santa Ana area, the westerly arm of the Gaspur water-bearing zone (and possibly the shallower deposits of Pleistocene age) has become substantially contaminated during the past 15 yr. In certain wells, the hardness has more than doubled and is 500 to 600 ppm. As is shown in the report on hydrologic features of the Long Beach-Santa Ana area (Poland and others), this upper zone, of Recent age, locally is underlain by two highly productive and widely utilized water-bearing zones of Pleistocene age—a major zone in the upper part of the San Pedro formation, roughly from 500 to 1,000 ft below land surface and here referred to as the middle zone, and a major zone in the lower part of the San Pedro formation, about 1,230 to 1,300 ft below land surface, and here referred to as the lower zone.

Because the water level in the upper zone, the westerly arm of the Gaspur water-bearing zone, now is from 10 to 40 ft above the level in the middle zone and about 50 ft above the level in the lower zone, any well perforated jointly in the upper and either in the middle or lower zones will act as a recharging well and will conduct contaminated water from shallow depth into the zones beneath containing water of good quality. Hence, agencies concerned with protecting the two zones of Pleistocene age should trace the areal extent of the deteriorated water in the upper zone and repair any wells feeding such water into the two underlying major zones that now (1945) supply nearly all water for the domestic and industrial needs of the Huntington Park area. Then the source of the deterioration should be determined, and eliminated if feasible. Finally, the rate of coastward movement of the deteriorated water should be watched. Because it is moving southward through the westerly arm of the Gaspur zone and eventually will reach the junction with the main Gaspur zone near Compton, the deeper wells in its downstream path, should be reconstructed as necessary to prevent contamination of the Pleistocene water-bearing deposits beneath. Under the gradient now prevailing, the rate of coastward advance is estimated to be from 400 to 800 ft a year.

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[2] Open-file copies of this report may be seen at the Geological Survey's Ground Water offices at room 2209, General Services Administration Building, 19th and F Streets, Washington, D. C.; 2520 Marconi Street, Sacramento, Calif.; and 221 Rendondo Avenue, Long Beach, Calif.

TABLE 29—*Chemical analyses representing known or potential contaminants*

[[a] Calculated; [b] recomputed as bicarbonate (HCO_3); [c] includes small equivalent quantity of carbonate (CO_3). Minor constituents are listed in notes at end of table]

Location and source of sample	Date of collection	Temperature (°F.)	Parts per million													
			Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Borate (BO_3)	Nitrate (NO_3)	Total hardness as $CaCO_3$
Ocean water																
Standard analysis as of 1940	......	......	34,482	......	......	400	1,272	10,556	380	......	140	2,649	18,980	25	......	......
San Pedro, 1 mile offshore	May 18, 1941	65	34,100	0.8	0.04	393	1,228	[a]10,220	353	0	139	2,560	18,360	......	......	6,030
Ventura, west of, opposite highway underpass of Southern Pacific railroad.	January 1929 to June 1930.	......	[a]33,964	......	......	444	1,266	[a]10,319		......	155	2,659	19,174	24	......	6,300
		......	[a]33,159	......	......	425	1,027	[a]10,964		......	134	2,353	18,313	10	......	5,270
Connate waters from known stratigraphic zones in the Dominguez oil field [1]																
3/13-28N. General Petroleum Co., Gardena well 1.	......	......	[a]9,944	......	......	452	......	3,384		[b]122		85	5,963	......	......	......
3/13-28N. Union Oil Co., Callender well 4	......	......	[a]30,927	......	......	641	205	10,953		......	232	5.0	19,007	......	......	2,440
3/13-32A. Union Oil Co., Callender well 23	Jan. 13, 1932	......	[a]31,572	......	......	651	308	11,242		......	268	......	19,237	......	......	2,890
3/13-33B. Union Oil Co., Hellman well 17	Jan. 13, 1932	......	[a]29,079	......	......	624	247	[a]10,383		0	190	0	17,730	......	......	2,570
3/13-33D. Union Oil Co., Callender well 50	Sept. 28, 1937	......	[a]17,533	......	......	117	11	[a]6,894		0	4,607	51	8,156	......	......	339
3/13-34Q. Tidewater Associated Oil Co., De Francis well 3.	Oct. 9, 1925	......	[a]38,697	......	......	1,679	19	13,319		[b]264		74	23,386	......	......	4,280
4/13-3J. West American Oil Co., Del Amo well 1.	Sept. 16, 1928	......	[a]28,798	......	......	479	126	10,623		......	3,418	62	15,630	......	......	1,710

[1] Analyses after Jensen (1934) except as indicated in notes.

Connate waters from known stratigraphic zones in the Long Beach oil field

4/12-19H. Superior Oil Co., Britton lease, well 3.	Mar. 2, 1928	------	[a]13,497	-------	-------	146	27	[a]5,149		60	1,350	165	7,305	-------	-------	476
4/12 19H. V. R. G. Wilbur, Bergstrom lease, well 1.	May 15, 1928	------	[a]21,026	-------	-------	389	91	[a]7,800		0	3,045	33	11,191	-------	-------	1,350
4/12-29K. Shell Oil Co., Alamitos lease, well 3.	Jan. 20, 1922	------	38,827	-------	-------	623	387	[a]11,267		[b]165		0	19,469	-------	-------	3,140
4/12-30A. Hope Oil Co., well 1	Feb. 2, 1928	------	[a]23,166	-------	-------	253	119	[a]8,669		0	604	26	13,797	-------	-------	1,120
Miller lease, well 1	Mar. 22, 1928	------	[a]13,220	-------	-------	325	5	[a]4,880		238	1,330	156	6,951	-------	-------	833

Connate waters from stratigraphic zones in the Seal Beach oil field [1]

5/11-11G. Continental Oil Co., Bryant well 6.	May 14, 1927	------	[a]28,906	-------	-------	621	364	[a]10,045		------	363	49	17,552	-------	-------	3,040
5/11-11G. Continental Oil Co., Hellman well 10.	May 19, 1927	------	[a]29,867	-------	-------	479	177	[a]10,690		------	1,331	37	17,622	-------	-------	1,920
5/11-11G. Shell Oil Co., Bryant well 1	Mar. 31, 1923	------	34,227	-------	-------	715	286	[a]11,472		[b]815		25	19,226	-------	-------	2,960

[1] Analyses after Jensen (1934) except as indicated in notes.

Connate waters from known stratigraphic zones in the Huntington Beach oil field

5/11-28R4. The Texas Co., Buck well 4	Apr. 22, 1941	120	29,700	27	20	376	176	[a]10,700	123	0	759	1.4	17,350	-------	-------	1,780
5/11-34H. West American Oil Co., Ashton well 6.	June 3, 1923	------	26,908	-------	-------	217	63	[a]8,889		[b]3,136		.0	12,419	-------	-------	801
5/11-34L. Standard Oil Co., Huntington-A, well 18.	Feb. 18, 1928	------	[a]31,621	-------	-------	536	543	[a]10,808		------	2,117	37	18,368	-------	-------	3,570
5/11-11A2. The Texas Co., A. W. Brown, well 9.	Apr. 22, 1941	123+	25,100	90	.79	177	127	9,400	124	0	1,505	1.0	14,370	-------	-------	984
Pacific Petroleum Corp., well 5	May 29, 1923	------	[a]34,096	-------	-------	819	713	[a]11,699		[b]2,194		-------	20,326	-------	-------	4,970
Selby Root, and Hague, Clark well 2.	June 14, 1923	------	[a]23,919	-------	-------	318	126	[a]9,335		------	[a]2,383	35	14,105	-------	-------	1,310

TABLE 29.—*Chemical analyses representing known or potential contaminants*—Continued

Location and source of sample	Date of collection	°F.	Parts per million: Solids	SiO_2	Fe	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	BO_3	NO_3	Hardness
Oil-field wastes																
3/11-5N. George F. Getty Co.	Sept. 5, 1932	------	[a]5,170	------	------	55	26	1,893	------	------	369	32	2,929	51	0	244
6/11-11A. Texas Company, Brown Lease	Oct. 23, 1931	------	[a]30,333	------	------	368	410	10,043	------	------	1,613	0	17,484	38	0	2,600
4/10-2A. Waste Water Disposal Co.	June 1927	------	[a]8,736	------	------	130	84	[a]3,191		------	[c]836	72	4,841	------	------	669
	Oct. 15, 1928	------	[a]9,452	------	------	85	73	[a]3,536		------	[c]1,084	111	5,105	------	------	512
6/11-13Q1.	Apr. 21, 1942	66	8,320	------	5.6	240	28	2,790	56	16	------	2.3	4,870	------	.5	714
6/11-2G.	Apr. 22, 1942	72	15,100	------	0.33	176	132	5,190	34	0	348	5.7	8,630	------	------	982
4/13-14R. Oil Operators, Inc.	May 17, 1941	82	26,500	38	4.1	547	286	[a]9,140	77	0	970	28	15,310	------	------	2,580
5/11-35M.	Dec. 4, 1942	84	25,400	35	.69	300	140	8,840	142	0	1,575	0	13,700	50+	3.9	1,320
Industrial and miscellaneous wastes [2]																
2/13-11M. General Petroleum Corp.	June 15, 1932	------	[a]1,505	------	------	29	7	[a]600		------	1,522	3	105	------	------	101
------	Dec. 17, 1932	------	[a]1,057	------	------	8	3	[a]373		------	152	327	270	------	------	32
Musto-Keenman Co.	Dec. 17, 1932	------	[a]892	------	------	142	55	[a]112		------	339	105	308	------	------	580
2/13-11P. Stauffer Chemical Co.	June 15, 1932	------	[a]1,023	------	------	107	19	[a]223		------	356	438	58	------	------	345
2/13-11K. Stauffer Chemical Co.	June 15, 1932	------	[a]4,771	------	------	39	35	[a]1,630		------	976	1,729	850	------	------	241
2/13-11N. Fibreboard Products Co.	June 15, 1932	------	[a]557	------	------	74	15	[a]97		------	196	236	37	------	------	246
Pacific R. & H. Chemical Co.	June 27, 1932	------	[a]6,015	------	------	388	21	[a]1,534		------	556	3,704	90	------	------	1,060
5/10-32J. Orange County Cities Joint Outfall Sewer.	Dec. 28, 1932 (12 m.)	------	[a]2,073	------	------	77	32	635	------	------	570	49	976	19	0	324
	Dec. 28, 1932 (3:55 p.m.)	------	[a]1,357	------	------	70	30	381	------	------	586	56	517	10	0	298
	Dec. 30, 1932 (10 a.m.)	------	[a]3,109	------	------	90	44	1,035	------	------	583	55	1,562	31	0	405
4/13-8C. Union Oil Co.	Mar. 5, 1932	------	[a]16,023	------	------	296	147	[a]5,768		------	148	58	9,680	------	------	1,340

4/13-8C. Shell Oil Co.	Mar. 5, 1932	------	[a]1,962	------	------	26	12	[a]641		------	24	807	464	------	------	114
4/13-16G. Shell Oil Co.	Mar. 5, 1932	------	[a]14,155	------	------	285	139	[a]5,052		------	506	96	8,330	------	------	1,280
3/13-36A. Richfield Oil Corp.	Jan. 20, 1932	------	[a]1,134	------	------	51	10	[a]360		------	156	195	440	------	------	168
	Mar. 11, 1932	------	[a]541	------	------	40	6	[a]157		------	188	82	162	------	------	125
	Mar. 23, 1932	------	[a]821	------	------	27	3	[a]289		------	162	41	380	------	------	80

[2] Analyses by Long Beach Chemical and Physical Testing Laboratory (after California Div. Water Resources Bull. 40–A) except as indicated in notes.

Streams whose lower reaches are substantially contaminated by industrial or other wastes [3]

4/13-8G. Dominguez Channel (Nigger Slough).	Apr. 11, 1932	------	[a]4,854	------	------	83	40	1,120	644	------	312	1,112	1,576	23	0	372
1/13-27K. Los Angeles River. At Los Angeles, under Aliso Street bridge.	Jan. 20, 1933	------	[a]312	------	------	57	15	37	------	------	131	96	34	.7	7	204
3/12-6B. Los Angeles River. West of Downey.	Apr. 11, 1932	------	[a]411	------	------	36	13	98	------	------	183	163	6	3.5	0	143
	Jan. 19, 1933 10 a.m.	------	[a]163	------	------	31	2	[a]25		------	78	48	18	------	tr	86
	Jan. 29, 1933 7:30 p.m.	------	[a]116	------	------	24	1	[a]16		------	61	33	11	------	tr	64
2/11-6B. Rio Hondo. Southwest of El Monte in Whittier Narrows.	Dec. 10, 1932	------	[a]322	------	------	43	16	53	------	------	235	27	57	1.6	7	173
3/12-5D. Rio Hondo. West of Downey	Jan. 19, 1933 (10:20 a.m.)	------	[a]85	------	------	15	1	[a]16		------	55	11	14	------	0	42
	Jan. 29, 1933 (8:05 p.m.)	------	[a]88	------	------	17	1	[a]15		------	56	13	14	------	tr	47
3/13-25A. Los Angeles River. East of Compton.	Apr. 11, 1932	------	[a]621	------	------	75	22	124	------	------	[d]332	127	105	2.3	0	278
4/13-14A or 13D. Los Angeles River. Southeast of Compton.	Jan. 25, 1933 3 p.m.	------	[a]475	------	------	67	3	[a]99		------	177	153	64	------	0	180
3/13-35C. Compton Creek (tributary to Los Angeles River).	Jan. 25, 1933 3:30 p.m.	------	[a]117	------	------	22	0	[a]21		------	50	28	21	------	tr	55
4/13-14R. Los Angeles River	Mar. 24, 1932	------	[a]23,768	------	------	504	265	8,163	------	------	723	16	14,289	169	0	2,350
2/11-5P. San Gabriel River	Dec. 14, 1931	------	[a]275	------	------	69	16	15	------	------	247	38	11	.3	2	------
3/11-33N. Coyote Creek	Mar. 2, 1932	------	[a]1,657	------	------	79	50	487	------	------	357	82	744	13	23	402
5/12-2A. San Gabriel River	Mar. 2, 1932	------	[a]1,692	------	------	81	52	497	------		[a]355	288	586	10	0	416

[3] Analyses by California Division of Water Resources (after California Div. Water Resources Bull. 40–A).

Notes to table 29

Ocean water, standard. Referred to a standard "chlorinity" of 19,000 ppm (after Sverdrup, Johnson, and Fleming, 1942, The oceans: their physics, chemistry, and general biology, p. 166). Strontium 13 ppm, bromide 65 ppm, fluoride 1 ppm.

Ocean water, San Pedro. From seaward side of breakwater. Iodine less than 0.5 ppm, bromide 49 ppm, iron 0.03 ppm when analyzed. Analysis by G. J. Petretic, Geological Survey.

Ocean water, Ventura. Table gives maximum and minimum quantities of each constituent among eight analyses by Department of Agriculture, Rubidoux Laboratory, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

3/13-28N. Reported depth 3,773 ft; water shut-off reported at 3,761 ft. Sample from streak of oil sand above first Callender zone, probably in upper part of Repetto formation.

3/13-28N. Reported depth 4,723 ft; water shut-off reported at 4,654 ft. Sample from second Callender zone in Repetto formation of Pliocene age.

3/13-32A. Reported depth 5,122 ft; water shut-off reported at 5,040 ft. Sample from fourth Callender zone in Repetto formation of Pliocene age. Analysis by Union Oil Co.

3/13-33B. Casing perforated between 4,590 and 4,823 ft below land surface in third Callender zone in Repetto formation of Pliocene age. Analysis by Union Oil Co.

3/13-33D. Reported depth 10,345 ft. Sample probably from interval between 6,871 and 7,561 ft below land surface in eighth Callender zone (?), of Miocene age. Analysis by Union Oil Co.

3/13-34Q. Reported depth 4,277 ft; water shut-off reported at 3,877 ft. Sample from first Callender zone in Repetto formation of Pliocene age. Ammonium 90 ppm.

4/13-3J. Reported depth 7,662 ft; water shut-off reported at 7,350 ft. Stratigraphic zone sampled is not known.

4/12-19H (Britton). Reported depth 5,925 ft. Casing probably perforated 5,418-5,925 ft below land surface. Sampled after swabbing well 24 hr. Analysis by Union Oil Co.

4/12-19H (Bergstrom). Reported depth 6,484 ft. Casing perforated 5,950– [illegible] land surface. Analysis by Union Oil Co.

[illegible] 512 ft. Casing perforated 3,169-3,564 ft [illegible] Los Angeles.

[illegible] 5,003–

Miller. Reported depth 5,930 ft. Casing perforated 5,014-5,610 ft below land surface. Analysis by Union Oil Co.

5/11-11G (Bryant well 6). Sample from Bixby zone in Repetto formation of lower Pliocene age. Ammonium 93 ppm.

5/11-11G (Hellman well 10). Sample from Selover zone in Repetto formation of lower Pliocene age. Ammonium 196 ppm.

5/11-11G (Bryant well 1). Reported depth 4,271 ft. Sample probably from between 4,173 and 4,271 ft below land surface. Analysis by Smith-Emery Co., Los Angeles.

5/11-28R4. Reported depth 4,484 ft. Taps oil sand 4,256-4,484 ft below land surface in upper Ashton zone of Repetto formation of lower Pliocene age. Barium 142 ppm, strontium 8.2 ppm, iodide 49 ppm, bromide 147 ppm, iron 0.16 ppm in solution when analyzed. Analysis by G. J. Petretic, Geological Survey.

5/11-34H. Reported depth 5,211 ft. Casing perforated near bottom. Top of Bolsa zone reported at 3,133 ft and top of Ashton zone at 3,967 ft. Sampled during swabbing. Analysis by Smith-Emery Co., Los Angeles.

5/11-34L. Reported depth 4,256 ft. Casing perforated through range of 889 ft, near bottom of well. Ammonium 218 ppm. Analysis by Tidewater Associated Oil Co.

6/11-11A2 (Brown well 9). Reported depth 3,833 ft. Taps oil sand 3,751-3,832 feet below land surface in lower Ashton zone of upper Miocene age. Sampled from separator tank at well. Barium 24 ppm, strontium 2,6 ppm, iodide 35 ppm, bromide 99 ppm, iron reported is that in solution when analyzed. Analysis by G. J. Petretic, Geological Survey.

Pacific well 5. Reported depth 2,799 ft. Sampled from tank. Analysis by Shell Oil Co.

Clark well 2. Reported depth 4,905 ft. Casing perforated 3,776-4,268 ft below land surface. Ammonium 100 ppm. Analysis by Amalgamated Oil Co.

3/11-5N. Sump at intersection of Lakeland Road and Atchison, Topeka, and Santa Fe Railway. Collects waste water from Santa Fe Springs oil field. Analysis by California Division of Water Resources.

6/11-11A. Composite sample of brine from several wells in Huntington Beach oil field. Analysis by California Division of Water Resources. (Compare with analysis for 6/11-11A2.)

4/10-2A. Sump east of Fullerton. Collects waste water from Richfield, Olinda, Brea Canyon, and East Coyote fields and discharges into Orange Cities Joint Outfall Sewer. Sump waters treated periodically by a [illegible] Discharge averaged 280,000 gal a day in 1928.

Analysis of June 1927 is weighted average for all districts contributing water to the sump. Analyses by Union Oil Co.

6/11-13Q1. Abandoned oil well. Brine leaking past concrete plug. Hydroxyl 1 ppm, iodide 0.5 ppm, bromide 0 ppm, fluoride 0.6 ppm. Analysis by E. W. Lohr, Geological Survey.

6/11-2G. Pond about 300 ft south of Clay Street and 200 ft east of Huntington Avenue. Receives waste fluids from oil-well operations. Iodide 80 ppm, bromide 25 ppm; electrical conductivity 24,440 micromhos. Analysis by E. W. Lohr, Geological Survey.

4/13-14R. Waste fluids from Long Beach oil field, discharged into Los Angeles River. Sampled from outfall flume of southernmost sump. Barium 41 ppm, strontium 5.5 ppm, iodide 39 ppm, bromide 173 ppm, iron 0.36 ppm in solution when analyzed. Analysis by G. J. Petretic, Geological Survey.

5/11-35M. Waste fluid. Sampled in gully at south side of Ellis Street, 1,000 ft east of Golden West Avenue. Barium 68 ppm, strontium 12 ppm, iodide 30 ppm, bromide 200 ppm, iron reported is that in solution when analyzed; electrical conductivity 37,000 micromhos. Analysis by W. F. White, Geological Survey.

2/13-11M. Waste-water outfall to Los Angeles River from refinery. In Vernon, West of Soto Street bridge.

Owner unknown. Waste-water outfall to Los Angeles River. In Los Angeles, 100 ft north of Union Pacific Railroad and 350 ft north of Washington Street.

Musto-Keenman Co. Waste-water outfall to Los Angeles River. In Los Angeles, one block south of Washington Street.

2/13-11P. Waste-water outfall to Los Angeles River. In Vernon, 0.25 mile east of Soto Street.

2/13-11K. Waste-water sump discharging to Los Angeles River. In Vernon, 0.4 mile west of Downey Road and 600 ft north of the river.

2/13-11N. Waste-water outfall to Los Angeles River. In Vernon, 600 ft east of Soto Street.

Pacific R. & H. Chemical Co. Waste-water sump discharging to Rio Hondo. In El Monte, 600 ft south of Pacific Electric Railway on south bank of river.

5/10-32J. Sampled at head of outfall to ocean, 100 ft south of screening plant. Analyses by California Division of Water Resources.

...2C (Union Oil Co.). Waste-water outfall to Domingues Channel from ...ier, 1.02 miles north of Carson Street and 0.21 ... from refinery. North of Wilmington, 1.0 mile north of Carson Street, and 0.20 mile west of Avalon Boulevard.

4/13-16G. Waste-water outfall flume to Dominguez Channel from refinery. North of Wilmington, 250 ft north of Willow Street and 250 ft west of Alameda Street.

3/13-36A. Waste-water outfall to Los Angeles River from refinery. South-east of Compton, 60 ft south of Artesia Street.

4/13-8G. Sampled southeast of Gardena, at Avalon Boulevard. Nearly all industrial waste.

1/13-27K. Los Angeles River. At Los Angeles, under Aliso Street bridge.

3/12-6B. At gaging station 34 of Los Angeles County Flood Control District, at Stewart and Gray Road. Analyses in 1933 by Los Angeles County Health Department. Discharges by Los Angeles County Flood Control District: 1.4 cfs on April 11, 1932; 2,000 cfs on Jan. 19, 1933, 1,100 cfs on Jan. 29, 1933.

2/11-6B. At gaging station 64 of Los Angeles County Flood Control District, 1,000 ft upstream from Mission Bridge and 200 ft upstream from Sycamore Canyon Creek. Discharge 26.0 cfs, after Los Angeles County Flood Control District. Effluent ground water mingled with treated sewage.

3/12-5D. At gaging station 45 of Los Angeles County Flood Control District, at Stewart and Gray Road. Analyses by Los Angeles County Health Department. Discharges by Los Angeles County Flood Control District: 400 cfs on Jan. 19, 1933, 600 cfs on Jan. 29, 1933.

3/13-25A. At Olive Street (Atlantic Boulevard). Discharge estimated 0.3 cfs by Los Angeles County Flood Control District.

4/13-14A or 13 D. At Del Amo Street. Analysis by Los Angeles County Health Department. Discharge 150 cfs, by Los Angeles County Flood Control District.

3/13-35C. South of Compton, at Alameda Street. Analysis by Los Angeles County Health Department. Discharge 40 cfs, by Los Angeles County Flood Control District.

4/13-14R. Just downstream from 223d Street, opposite sumps of Oil Operator's, Inc. Water probably substantially all from sump outfall.

2/11-5P. Southwest of El Monte in Whittier Narrows, in Cate Ditch at end of Syphon Road, 0.7 mile southeast of Durfee Road. Discharge 25 cfs, by Los Angeles County Flood Control District.

3/11-33N. East of Artesia, at Orangethorpe Avenue, 0.18 mile east of Carmenita Avenue. Discharge small.

5/12-2A. East of Long Beach and below Coyote Creek, at East Seventh Street.

TABLE 30.—*Chemical analysis of representative native and contaminated waters from the deposits penetrated by water wells, 1918–43*

[[a] Calculated; [b] analysis taken as essentially typical of the water native to a single stratigraphic zone in the locality of the source well (see table 4 for character in percentage equivalents); [c] calculated as calcium from total hardness; [d] iron and aluminum oxides ($Fe_2O_3 + Al_2O_3$); [e] includes small equivalent quantity of carbonate (CO_3). Minor constituents are listed in notes at end of table. Depths of most wells are reported depths.]

Well number and source of sample	See notes page	Depth in feet	Date of collection	Temperature (°F.)	Parts per million													
					Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Borate (BO_3)	Nitrate (NO_3)	Total hardness as $CaCO_3$
2/11-7J1. City of Whittier, well 7.	238	1,000	July 14, 1931	------	[a]272	------	------	63	13	23	------	------	210	67	7	1.4	1	211
2/11-18F2. Pico County Water District, well 1.	238	435	July 14, 1931	------	[a]237	------	------	55	12	22	------	------	214	34	6	1.4	1	187
2/11-18P1. Mrs. Mary Phelan.	238	509	June 17, 1931	------	[a]284	------	------	62	15	29	------	------	250	38	13	.3	2	217
2/11-30N6. Joseph Blacker	238	100	[b] Dec. 30, 1932	------	[a]425	------	------	88	24	37	------	------	314	88	27	.7	3	318
2/11-31M. ———	238	200	Apr. 15, 1925	------	442	20	8.0	79	16	13	36	------	299	64	25	------	25	263
2/12-9E2. Goodrich Tire & Rubber Co., well 1.	238	788	Oct. 3, 1931	------	[a]230	------	------	33	12	42	------	------	192	20	23	.4	4	132
			Sept. 13, 1939	73	[a]248	------	------	37	13	43	------	------	195	23	30	------	4	146
2/12-13R1. Z. Brown	238	50	[b] Jan. 10, 1933	------	[a]272	------	------	63	14	23	------	------	232	38	13	.4	5	215
2/12-19C. City of Maywood, well 4.	238	680	[b] Dec. 28, 1925	------	367	------	------	59	14	46	1.7	------	222	73	34	------	2.0	205
2/12-19M1. Maywood Mutual Water Co., well 1.	238	301	Sept. 19, 1939	------	[a]345	------	------	67	16	43	------	------	233	76	25	------	1	233
2/12-26R5. Walnut Irrigation District, well 5.	238	455	[b] July 14, 1931	------	[a]257	------	------	53	13	32	------	------	217	35	13	------	2	186
2/12-28N1. George Peterson	238	402	July 15, 1931	------	[a]272	------	------	55	13	38	------	------	250	18	18	1.4	4	191
2/12-31H1. Rio Grande Oil Co., well 1.	238	575	[b] July 15, 1931	------	[a]283	------	------	48	12	45	------	------	229	30	25	1.6	7	169
			Sept. 21, 1939	72	[a]288	------	------	55	13	38	------	------	247	25	29	------	4.0	191
2/12-31M1. City of South Gate, well 7 (formerly Guy Neville).	238	650	[b] Dec. 17, 1925	------	352	------	------	31	13	40	2.5	------	216	79	24	------	1	[illegible]
			Sept. 19, 1939	68	[a]433	------	------	61	22	53	------	------	235	100	77	------	2	243
2/12-33L1. Rio Hondo Country Club.	238	449	Dec. 15, 1925	------	279	------	------	64	11	19	4.2	------	255	24	10	------	3.0	205
			[b] July 15, 1931	------	[a]263	------	------	60	14	25	------	------	253	22	13	.5	2	207
2/12-34P1. Downey County Water District, well 2.	238	574	July 15, 1931	------	[a]279	------	------	63	14	25	------	------	250	28	13	1.6	9	215

2/12-36Q3.	A. O. Houghton	238	48	[b] Dec. 28, 1932	------	[a]296	------	------	63	16	28	------	------	244	54	12	.4	1	223
2/13-14L1.	Winger	238	180	[b] Mar. 23, 1932	------	[a]778	------	------	141	38	73	------	------	278	184	69	1.3	133	508
2/13-15N4.	Pioneer Paper Co.	238	531	[b] Aug. 6, 1931	------	[a]364	------	------	65	18	43	------	------	235	90	27	1.6	2	236
				Sept. 19, 1939	65	[a]362	------	------	66	17	42	------	------	232	93	27	------	1	235
2/13-25A2.	City of Bell, Turner well 1.	238	583	[b] Dec. 17, 1925	------	348	------	------	56	13	42	2.5	------	211	73	24	------	1.0	193
2/13-25H2.	Cudahy Ranch, tract 180, well 1.	238	599	[b] Dec. 17, 1925	------	348	------	------	59	11	39	2.5	------	208	72	24	------	------	193
2/13-27B11.	Walnut Park Mutual Water Co., well 4.	239	1,600	[b] Aug. 6, 1931	------	[a]334	------	------	60	17	40	------	------	226	80	23	1.4	0	220
2/13-27B14.	Walnut Park Mutual Water Co., well 2.	239	666	Aug. 6, 1931	------	[a]420	------	------	75	21	46	------	------	250	96	34	1.6	21	274
2/13-28G2.	Southern California Water Co., Miramonte well 1.	239	1,585	(1) May-June 1936	------	[a]738	16	.6	145	39	[a]57		------	348	193	114	------	------	521
				(2) May-June 1936	------	[a]470	12	tr	84	21	[a]51		------	247	126	52	------	------	296
				(3) May-June 1936	------	[a]408	15	tr	72	16	[a]48		------	238	100	38	------	------	247
				(4) May-June 1936	------	[a]376	8.9	.3	67	16	[a]43		------	204	101	38	------	------	234
				(5) May-June 1936	------	[a]350	20	.1	64	16	[a]35		------	220	81	26	------	------	224
				(6) May-June 1936	------	[a]380	17	.3	64	14	[a]48		------	226	90	33	------	------	219
				(7) May-June 1936	------	[a]366	26	.05	64	13	[a]42		------	223	84	25	------	------	215
2/13-28H2.	Southern California Water Co.	239	195	Aug. 6, 1931	------	[a]606	------	------	114	32	63	------	------	305	156	66	1.4	21	416
				Sept. 20, 1937	64	[a]723	------	------	131	35	67	------	------	329	182	81	2.4	60	471
				Sept. 21, 1939	65	[a]668	------	------	125	33	64	------	------	326	168	77	------	38	448
3/9-20M1.	H. H. Hale	239	311	[b] Sept. 11, 1939	------	[a]881	------	------	98	51	143	------	------	336	273	113	------	35	454
3/9-32J1.	——	239	264	[b] Mar. 1, 1926	------	482	------	------	83	14	71	3.3	------	291	66	76	------	12	265
3/9-33E2.	——	239	300	Mar. 1, 1926	------	473	------	------	74	13	82	4.2	------	316	40	82	------	8.0	238
3/10-28D1.	Bastanchury Ranch Co., Valencia Mesa well 1.	239	1,174	June 9, 1931	------	[a]496	------	------	56	20	[a]102		------	270	90	92	1.4	------	222
				June 22, 1931	------	[a]590	------	------	64	23	[a]121		------	287	127	99	.8	12	254
3/10-28G1.	Bastanchury Ranch Co., Fullerton Heights well 1.	239	3,100	June 9, 1931	------	[a]526	------	------	59	22	[a]104		------	261	124	85	1.0	------	238
				June 22, 1931	------	[a]487	------	------	53	21	[a]99		------	256	113	73	.4	------	219
				July 31, 1931	------	[a]482	------	------	50	22	[a]101		------	271	103	69	1.0	------	215
3/10-29C1.	Bastanchury Ranch Co., Lemon Mesa well 1.	239	352	July 10, 1925	------	395	------	------	37	11	79	5.8	------	225	70	41	------	3.0	138
3/10-30B1.	Bastanchury Ranch Co., Coyote well 2.	239	700	June 9, 1931	------	[a]428	------	------	22	7	[a]132		------	235	68	80	1.6	------	84
				June 22, 1931	------	[a]433	------	------	22	6	[a]135		------	235	67	84	1.3	------	80

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Parts per million: Solids	SiO_2	Fe	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	BO_3	NO_3	Hardness
3/10-32C2. Bastanchury Ranch Co., Santa Fe well 1.	239	197	Sept. 5, 1939	80	[a]418			17	5	139			226	82	62		0	63
			[b]July 10, 1925		677			116	22	59	4.2		288	151	68		30	380
3/10-32N1. H. J. Schulte	239	500	June 26, 1925		368			65	13	36	4.2		238	67	22		5.0	216
3/11-5E. ———	239	400	Apr. 22, 1925		302	29	0.0	26	10	65	3.0		258	2.0	35		.0	65
3/11-5Q. ———	239	144	[b]Apr. 21, 1925		287	6.0	10	29	8	50	6.0		189	53	25		.0	105
3/11-6D. ———	239	135	[b]Apr. 8, 1925		385	9.0	15	72	14	14	27		280	50	23		5.0	237
3/11-6P2. The Norwalk Co., absorption plant 1.	239	740	[b]Aug. 7, 1939	81	[a]461			24	11	155			357	13	79		.0	105
3/11-16E1. Wilshire Oil Co., well 3.	240	1,258	Apr. 24, 1942		430			[a]44		[a]144		24	242	86	67			110
3/11-17B. ———	240	964	[b]May 11, 1925		235	5.0	18	21	1.0	53	0.0		133	24	35		.0	57
3/11-18G1. Pendleton, west well.	240	270	[b]Mar. 12, 1932		[a]290			66	12	[a]27			249	37	23			214
3/11-20D. ———	240	775	[b]May 29, 1925		227	13	5	46	8.4	11	14		195	23	6.0		1.0	149
3/11-26B1. Charles L. McComber, well 2.	240	740	[b]Feb. 26, 1926		385			16	1.2	124	1.7	5.5	216	70	40		1.0	45
3/11-26D1. Charles L. McComber, well 4.	240	275	June 5, 1931		[a]348			40	16	69			238	75	27	1.6		166
			[b]Oct. 18, 1939		[a]369			42	18	74			249	85	25		.0	179
3/11-27G1. Standard Oil Co., Northam well 4.	240	1,023	Jan. 5, 1931		[a]295			16	4	97			195	57	21	2.2	.0	56
3/11-28D2. John Clanton	240	1,248	June 1, 1925		225	19	.0	37	6.6	42	4.2		201	35	10		1.0	117
3/11-28P2. D. E. Viega	240	98	[b]Mar. 24, 1932		[a]277			42	12	48			217	38	28	.5	.0	154
3/11-29A. ———	240	1,[illegible]	[b]June 6, 1925		214	8.0	.0	18	6.6	49	4.2		161	6.0	32		1.0	72
3/11-30D1. Ralph Nottingham.	240	298	[b]June 4, 1931		[a]356			77	19	36			275	61	25	.4		270
3/11-31A1. Ludwick	240	191	[b]June 4, 1931		[a]306			65	16	35			262	38	21	.4		228
3/11-32R2. Durrand Brothers.	240	1,103	May 14, 1925		295	12	2.0	47	8.0	39	3.0		189	64	20		1.0	150
3/11-32R3. A. D. Durrand	240	271	[b]Mar. 2, 1932		[a]264			45	14	38			226	37	16	.7		170

3/11-34J3.	R. W. Bingham, Jr.	240	427	June 15, 1925		312	15	.0	55	13	24	9.1		209	56	15		2.0	191
3/11-34P.		240	1,200	[b]June 23, 1925		283	24	.0	51	10	29	5.8		215	37	18		1.0	169
3/11-35J2.	Orange County Water District 2 (Buena Park Water District), well 2.	240	396	[b]June 17, 1931		[a]298			52	19	44			232	49	18	1.1		208
				May 2, 1938	66	[a]476			65	21	80			249	145	39	.8	1	249
				May 31, 1938	68	[a]494			65	27	77			256	152	43	1.2	1	273
				July 5, 1938	70	[a]489			65	23	77			253	147	45	1.4	4	257
				Aug. 1, 1938	70	[a]498			66	17	86			263	149	41	.8	2	235
				Aug. 30, 1938	68	[a]484			66	23	77			260	140	46	.8	1	259
				Oct. 3, 1938	71	[a]476			62	22	76			253	145	42	.7	2	245
				Oct. 31, 1938	68	[a]471			65	19	75			247	146	41	.4	1	240
				Nov. 28, 1938	68	[a]479			66	22	76			249	149	39	.8	2	255
				Jan. 3, 1939	63	[a]481			73	22	69			237	149	46	.9	3	273
				Feb. 6, 1939	66	[a]495			68	21	82			248	156	42	.4	2	256
				Mar. 7, 1939	66	[a]509			68	21	86			258	153	49	1.1	2	256
				Apr. 3, 1939	66	[a]499			67	24	80			266	150	41	1.0	3	266
				May 1, 1939	68	[a]499			67	23	71			256	168	39	.5	2	262
3/12-3M1.	Downey County Water District, well 1.	240	608	[b]July 15, 1931		[a]268			61	13	28			247	25	13	1.1	3	206
3/12-5G.		241	200	[b]Dec. 15, 1925		281			62	10	22	3.3		255	20	12		3.0	196
3/12-6N.		241	300	[b]Feb. 9, 1926		360			64	13	41	2.5		255	64	21		1.0	213
3/12-8F1.	Los Angeles County Farm.	241	1,755	[b](1) May 1931		339			51	7.5	[a]52			205	55	33			158
				[b](2) May 1931		298			60	11	[a]22			240	27	19			195
				May 2, 1938	68	[a]265			60	11	26			244	30	16	tr		195
				May 31, 1938	68	[a]264			52	16	29			265	11	20	.8	3	196
				July 5, 1938	68	[a]276			61	22	26			249	19	18	.4	5	243
				Aug. 1, 1938	68	[a]278			61	12	28			258	30	16	.5	1	202
				Aug. 30, 1938	68	[a]279			61	13	28			257	30	18	.8		206
				Oct. 3, 1938	68	[a]275			60	11	30			252	30	16	.5	1	195
				Oct. 31, 1938	68	[a]279			61	12	29			247	29	21	.3	3	202
				Nov. 28, 1938	68	[a]275			60	11	30			246	31	14	.4	6	195
				Jan. 3, 1939	68	[a]272			64	11	27			232	34	20	.3		205
				Feb. 6, 1939	64	[a]279			65	11	27			246	30	20	.4	3	208
				Mar. 7, 1939	66	[a]286			62	12	30			252	31	21	.8	3	204
				Apr. 3, 1939	68	[a]286			63	13	26			261	30	17	.8	6	211
				May 1, 1939	68	[a]265			58	11	26			245	32	13	.8	2	190
3/12-9L1.	J. A. Quill	241	501	[b]Dec. 10, 1925		275			61	10	22	2.5		236	31	9.0		5.0	194
				July 15, 1931		[a]275			62	13	25			253	29	14	1.1	4	208
3/12-10E1.	C. Reiman	241	163	[b]Dec. 10, 1925		328			68	13	28	4.2		272	36	19		2.0	223
3/12-12G2.	W. L. Houghton	241	200	[b]May 1, 1925		377	20	.0	73	13	36	3.0		305	59	17		.0	236
3/12-17A.		241	[illegible]	Feb. 15, 1926		[illegible]			64	10	22	2.5		258	20	14			[illegible]
3/12-19L1.	George Faulkner, well 2.	241	150	[b]Sept. 21, 1939	36	[a]255			53	11	31			235	29	13		0	178
3/12-23E1.	Jim Blythe, well 1.	241	147	[b]June 18, 1931		[a]376			81	22	38			299	51	34		0	293
3/12-24G.		241	250	[b]May 29, 1925		333	25	.0	66	.6	32	17		247	53	14		2.0	167
3/12-26D1.	Somerset Mutual Water Co.	241	875	June 8, 1925		244	21	2.0	55	12	8.9	4.2		204	35	6.0			187

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Parts per million													
					Solids	SiO_2	Fe	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	BO_3	NO_3	Hardness
3/12-29B.	241	158	[b]Nov. 30, 1925		248			54	8.4	13	5.8		216	18	7.0		1.0	169
3/12-29K.	241	650	[b]Nov. 28, 1925		236			40	7.8	31	2.5		208	17	10		1.0	132
3/12-30C1.	241	10	[b]Feb. 11, 1932		[a]612			130	41	52			613	61	21	0.9		493
3/12-31E.	241	348	[b]Dec. 6, 1925		338			61	8.4	44			219	67	24		1.0	184
3/12-31E3. Burrows Mortgage Co.	241	1,107	[b]Aug. 16, 1934		328	8.5	[d]0.40	46	4.0	[a]42			204	23	23			131
3/12-31G1.[1] City of Long Beach, North Long Beach well 1.	241	1,000	(1) Dec. 1, 1933		278	6.5	[d].20	27	2.0	[a]54			166	23	24			76
			(2) July 2, 1937		426	22	[d]1.0	53	7.0	[a]56			214	62	32			161
			(3) Jan. 3, 1934		426	15	[d].50	54	7.0	[a]52			232	53	23			164
			(4) Dec. 1, 1932		285	8.8	[d].40	36	4.0	[a]44			180	18	25			106
3/12-32B3. City of Long Beach, Funderburk well.	242	200	June 19, 1931		[a]221			53	11	25			232	6	9	1.1		178
			July 5, 1932		295	6.0	[d]1.0	55	8.0	[a]26			236	15	12			170
			Aug. 3, 1932		296	9.4	[d].70	53	7.0	[a]23			225	16	9.0			161
			Sept. 13, 1932		317	11	[d].60	49	6.0	[a]31			212	21	13			147
			Oct. 17, 1932		310	8.3	[d]1.0	44	6.0	[a]41			200	31	19			135
			Nov. 1, 1932		329	8.3	[d]1.0	40	5.0	[a]50			100	35	24			121
			Dec. 1, 1932		297	5.0	[d].50	40	5.4	[a]43			195	19	25			122
			Jan. 4, 1933		317	11	[d].40	37	4.7	[a]52			184	37	25			112
3/12-33H1. Montana Land Co., well 8.	242	982	[b]Nov. 25, 1925		240			46	7.8	28	1.7		213	19	10		1.0	147
			June 18, 1931		[a]242			51	17	28			232	15	13	1.6		197
			July 25, 1939	64	[a]225			55	8	21			233	16	7		1	170
3/12-33N2.	242	17	[b]Feb. 15, 1932		[a]329			58	14	54			277	41	23	.9		202
3/12-33R.	242	250	[b]Nov. 24, 1925		260			53	6.0	18	3.3		216	13	6.0		1.0	157
3/12-36B.	242	945	[b]May 14, 1925		240	19	3.0	52	9.0	14	5.0		200	29	10		1.0	167
3/12-36G1. J. W. Smith	242	239	[b]June 4, 1931		[a]236			54	10	26			232	22	7	.5	0	176
3/13-2B1. Home Gardens Water Co.	242	732	[b]Feb. 9, 1926		454			79	16	43	5.0		252	103	34			263
			Aug. 6, 1931		[a]428			79	21	50			271	102	39	1.6	0	284
			Sept. 19, 1939	64	[a]437			80	20	50			267	112	41		0	282
3/13-12Q.	242	395	Feb. 9, 1926		272			39	9.6	37	2.5		222	20	11		1.0	137
3/13-14H.	242	500	Feb. 9, 1926		295			52	9.1	38	2.5		222	44	17		1.0	167
3/13-15M1. City of Compton, well 3.	242	350	July 22, 1931		[a]337			60	16	45			220	81	23	1.6	1	216

3/13-20H1.	Southern California Water Co., Wadsworth plant.	242	250	[b] Sept. 21, 1939	69	[a]342			64	14	42			225	87	22		0	217
3/13-22H3.	City of Compton, Magnolia plant 4.	242	714	[b] July 22, 1931		[a]297			52	13	44			220	56	20	1.6		183
3/13-23A.		242	350	[b] Feb. 9, 1926		334			59	10	42	2.5		225	66	21		1.0	189
3/13-24B.		242	300	Feb. 9, 1926		278			48	9.1	39	2.5		225	38	13		2.0	157
3/13-26H1.	City of Compton, Shinner tract well 5.	242	199	July 22, 1931		[a]411			76	18	50			250	106	34	1.6	0	264
3/13-29G3.	John Myers	242	235	July 23, 1931		[a]332			59	15	46			223	76	23	1.6	0	209
3/13-31H4.	Joe Claro	242	50	Apr. 10, 1942		924	20	0.16	146	38	105	3.1	.0	244	160	255	.2	16	521
3/13-34D2.	G. D. Hufford and Morrell, well 2.	242	374	[b] Aug. 19, 1931		[a]301			50	11	49			204	65	23	1.4	0	170
				Sept. 20, 1937	73	[a]310			53	12	46			203	68	25	1.2	3	182
3/13-36D1.	City of Long Beach, North Long Beach well 2.	243	200	[b] 1932-37		404	17	[d].49	61	9.6	[a]45			242	54	24			192
4/9-7P1.	Santa Ana Valley Irrigation Co., well 8.	243	506	Sept. 19, 1931		[a]357			62	16	50			232	62	46	.5	4	221
				[b] Sept. 10, 1937	61	[a]372			66	13	52			228	71	48	2.0	6	218
4/9-15R1.	Villa Park Well Co.	243	240	[b] Oct. 1918		[a]693			76	39	[a]113			•328	226	67		8	350
4/9-17H.		243	200	[b] Jan. 29, 1926		455			66	20	48	17		200	94	78		1.0	247
4/9-18N1.	John Stinson	243	222	Feb. 2, 1926		369			69	12	35	5.0		227	56	38		9.0	222
4/9-21J1.	Citrus Well Association.	243	550	[b] Oct. 1918		[a]504			92	21	[a]49			•231	154	62		11	316
4/9-22K1.	Villa Park Mutual Water Co., well 5.	243	543	Oct. 1918		[a]522			86	29	[a]52			•262	177	39		8	334
				July 1919		[a]371			72	16	[a]43			229	68	50		7	246
				June 1928		[a]522			90	44	[a]30			253	200	31			405
4/9-22R1.	John T. Carpenter Water Co., well 1.	243	473	Oct. 1918		[a]495			81	15	[a]74			•262	173	13		8	264
4/9-27E1.	Santa Ana Valley Irrigation Co., well 9.	243	1,[illegible]	[b] Aug. 27, 1931		[a]368			62	19	[a]48			•217	98	27	1.9	4	233
				Sept. 10, 1937	64	[a]396			63	21	[a]53			230	105	33	1.0	5	244
4/9-30N.		243	206	[b] Feb. 4, 1926		412			78	14	39	3.3		225	55	56		24	252
4/9-32B2.	City of Orange, well 5.	243	750	July 5, 1939	68	[a]431			88	18	44			232	91	61		13	294
				Sept. 26, 1939	68	[a]429			85	17	44			227	93	57		19	282

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Solids	SiO₂	Fe	Ca	Mg	Na	K	CO₃	HCO₃	SO₄	Cl	BO₃	NO₃	Hardness
					Parts per million													
			Apr. 25, 1940		[a]391			57	14	[a]57			220	92	50		11	200
4/9-32K2. Santa Ana Valley Irrigation Co., well 12.	243	800	Aug. 27, 1931		[a]295			51	13	44			204	58	20	2.7	4	181
4/9-33H1. David Hewes Mutual Water Co.	243	430	[b] Nov. 1918		[a]479			84	27	[a]47			256	160	33		0	321
4/10-1D1. Anaheim Union Water Co., well 6.	243	504	[b] June 17, 1931		[a]430			77	18	62			278	65	59	1.1	9	266
4/10-1F. ———	243	331	July 6, 1925		435			78	14	35	5.0		222	71	45		18	252
4/10-2E. ———	243	500	June 30, 1925		529			96	16	35	4.2		248	91	51		20	306
4/10-2L. ———	243	248	July 7, 1925		417			79	13	33	2.5		230	72	39		5.0	251
4/10-4C1. R. and V. Porter	243	357	[b] July 2, 1925		688			131	23	39	5.0		264	178	67		20	422
4/10-4N. ———	243	257	July 2, 1925		557			103	20	44	3.3		291	84	67		20	340
4/10-6F. ———	243	790	[b] June 26, 1925		305			56	11	26	5.0		207	52	16		2.0	185
4/10-7F. ———	244	510	June 22, 1925		302	25	1.0	54	12	29	3.3		218	47	17		2.0	184
4/10-8J1. Montgomery Ranch	244	320	[b] June 11, 1925		475	24	.0	89	17	32	4.2		275	66	38		25	292
4/10-13C. ———	244	180	[b] July 6, 1925		340			55	11	40	3.3		205	50	35		9.0	183
4/10-14H1. Henry Wagner	244	416	[b] Feb. 4, 1926		353			63	9.1	46	3.3		222	53	42		3.0	195
4/10-17K. ———	244	410	July 8, 1925		395			74	13	39	3.3		247	62	40		6.0	238
4/10-19F1. Mrs. Anna B. Taylor.	244	170	June 17, 1931		[a]313			62	13	42			238	52	23	1.1	1	208
4/10-22R. ———	244	212	Aug. 18, 1925		389			69	13	34	4.2		212	67	39		10	226
4/10-23D1. Perry Mathis	244	406	[b] Aug. 27, 1931		[a]283			56	13	32			214	44	27	1.6	2	193
			Sept. 11, 1939	63	[a]286			59	11	33			209	50	27		1	193
4/10-28D1. ———	244	579	[b] Aug. 12, 1925		354			66	13	26	4.2		216	55	30		4.0	218
4/10-28J. ———	244	270	Aug. 5, 1925		390			68	14	42	5.0		230	59	40		20	227
4/10-28N1. W. E. Schnitger	244	128	[b] Nov. 1918		[a]329			68	12	45			222	40	44		9	219
			Sept. 17, 1931		[a]408			77	17	45			238	81	48	.4	21	262
			Sept. 21, 1937	64	[a]425			82	17	41			234	86	56	.5	25	275
4/10-30A1. H. D. Mevers	244	280	Aug. 5, 1925		403			77	13	29	4.2		238	64	33		7.0	246
4-10-31Q1. R. B. Woodside	244	167	[b] May 23, 1931		[a]353			66	15	42			235	62	33	.4	11	227
4/10-34N1. W. W. Dungan	244	216	Aug. 27, 1931		[a]341			66	15	40			253	30	52	2.2	9	227
4/10-35C1. Dawn Water Co.	244	205	Aug. 12, 1925		505			94	7.8	53	3.3		267	66	60		20	267
4/11-1P1. Harold Covey	244	544	[b] June 17, 1925		300	23	3	64	12	21	2.5		221	48	17		5.0	209
4/11-2K. ———	244	1,100	[b] June 19, 1925		319			53	14	37	2.5		229	59	16		2.0	190
4/11-3P1. Notre	244	261	[b] June 4, 1931		[a]270			52	13	34			220	40	20	1.1		183
4/11-6N1. ———	244	320	June 15, 1925		247			52	6.0	17	6.6		198	28	6.0		1.0	155
4/11-8D1. B. F. Draper	244	320	[b] June 4, 1931		[a]264			44	11	43			220	18	37	.8		155

4/11-8E2.	E. A. Reed	245	626	[b] July 14, 1925		315			43	6.6	53	3.3		213	54	17		1.0	135
4/11-9J.	———	245	300	July 14, 1925		278			47	8.4	38	3.3		222	37	13			152
4/11-10E1.	L. H. Magor	245	750	[b] May 22, 1931		•294			46	16	42			232	53	21	.4		181
				July 5, 1939	68	•271			41	14	43			222	47	15		0	160
				Oct. 2, 1939	68	•269			39	14	44			223	45	15		0	155
4/11-11G.	———	245	515	June 19, 1925		294			56	10	31		1.7	225	44	15		2.0	181
4/11-13L1.	Lee C. Demings	245	160-268	[b] June 17, 1931		•254			51	13	31			226	25	18	1.6	1	181
				Sept. 12, 1939	67	•255			53	11	33			217	36	13		0	178
4/11-14K.	———	245	575	[b] July 8, 1925		340			64	12	32	6.6		233	61	21		3.0	209
4/11-16E1.	Steve Luther	245	84	[b] May 22, 1931		•252			39	15	38			229	29	14	.3	2	159
4/11-19K2.	———	245	443	[b] July 20, 1925		258			35	4.8	46	2.5		197	34	10			107
4/11-19Q1.	Southern California Water Company, Los Alamitos plant, well 1.	245	285	[b] Oct. 3, 1939	67	•257			47	13	34			223	38	13		0	171
4/11-19R1.	———	245	5,542	[b] Dec. 2, 1922		•223			5.5		•85			191	22	15			14
4/11-22H1.	Charles W. Eckert.	245	198	[b] June 5, 1931		•285			56	12	45			223	40	20	.8		189
				Sept. 12, 1939	67	•285			59	12	34			229	47	18		0	197
4/11-22M1.	———	245	7	[b] Mar. 7, 1932		•12,391			444	455	3,180			1,113	5,438	2,308	9.6	0	2,976
4/11-24Q1.	W. H. Kennedy	245	617	[b] Aug. 1, 1925		361			69	13	35	4.2		241	59	30		3.0	226
4/11-26J.	———	245	690	July 29, 1925		533			104	17	30	2.5		294	79	54		4.0	330
4/11-27J1.	Bryant Ranch, well 1.	245	1,003	July 21, 1925		275			48	9.6	27	4.2		200	38	13		1.0	159
4/11-28J1.	Bryant Ranch, well 2.	245	1,001	[b] July 21, 1925		271			49	9.1	28	4.2		213	32	12			160
4/11-29L2.	United States Department of Navy.	245	710	[b] March 1942		378	15	•8.0	51	11	•28			218	35	12			173
4/11-31F1.	Fred H. Bixby Co.	245	965	July 28, 1925		231			10	1.2	63	5.0		141	35	10			30
				June 6, 1931		•224			10	2	77			164	36	14	2.7	0	33
				Sept. 18, 1939	80	•223			10	2	76			•169	37	13		0	33
4/11-34G1.	Fred H. Bixby Co.	245	900	July 28, 1925		315			61	10	23	5.0		215	47	17		1.0	194
4/11-35Q.	———	245	550	July 22, 1925		294			56	7.8	28	4.2		211	41	15		2.0	172
4/11-36R1.	C. [illegible] Jones	245	94	Sept. 17, 1931		•322			65	13	41			247	56	23	.3	0	213
				[b] July 3, 1939		•275			57	12	30			231	42	18		0	192
				Oct. 3, 1939		•270			55	12	32			223	43	16		0	187
4/12-1D.	A. Decker, well 1	246	1,023	[b] June 1, 1925		237			54	6.6	13	3.3		208	16	5.0		1.0	162
4/12-3R1.	Montana Land Co., well 1.	246	900	June 8, 1925		253			50	12	16	5.0		217	24	9.0		1.0	174
				June 18, 1931		•229			49	12	28			229	16	9			172

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Parts per million: Solids	SiO2	Fe	Ca	Mg	Na	K	CO3	HCO3	SO4	Cl	BO3	NO3	Hardness
4/12-4J. ——	246	300	[b] Nov. 24, 1925	------	253	------	------	57	9.1	19	2.5	------	236	16	9.0	------	1.0	180
4/12-6K1. City of Long Beach, North Long Beach well 4.	246	1,160	[b] (1) 1934–40	------	271	7.4	[d]0.29	11	.6	[a]81		------	198	1.1	30	------	------	30
			(2) Nov. 1, 1940	89	253	20	.13	11	1.0	80	2.2	0.0	205	.9	29	------	.80	32
4/12-8L. ——	246	1,200–1,500	[b] Nov. 13, 1925	------	244	------	------	7.1	1.8	79	1.7	------	191	------	28	------	1.0	25
4/12-9B. ——	246	300	Nov. 10, 1925	------	241	------	------	49	4.8	29	2.5	------	222	13	8.0	------	1.0	142
4/12-13D1. City of Long Beach, Commission well 4.	246	920	1933–42	------	290	12	[d].70	50	6.0	[a]26		------	211	16	9.9	------	------	149
4/12-13F1. City of Long Beach, Commission well 6.	246	986	(1) 1933–35	------	289	10	[d].54	50	5.3	[a]27		------	212	16	11	------	------	147
			(2) 1936–40	------	293	12	[d].66	50	5.5	[a]26		------	211	16	9.4	------	------	148
			(3) 1942–43	------	300	12	[d].51	51	5.9	[a]25		------	215	17	8.2	------	------	152
4/12-13G1. Bixby Land Co., well 1.	246	875	[b] Nov. 5, 1925	------	235	------	------	51	4.8	24	2.5	------	225	13	5.0	------	------	147
4/12-14B1. City of Long Beach, Commission well 2.	246	1,080	(1) 1932–34	------	276	11	[d].57	45	5.3	[a]29		------	200	17	10	------	------	134
			(2) 1934–37	------	274	10	[d].44	44	5.1	[a]30		------	197	17	11	------	------	131
			(3) 1937–39	------	271	11	[d].47	43	5.0	[a]28		------	193	17	9.0	------	------	128
			(4) 1941–43	------	285	9.8	[d].57	44	5.9	[a]26		------	198	17	8.5	------	------	134
4/12-14C1. City of Long Beach, Commission well 5.	246	324	[b] (1) 1933–40	------	283	12	[d].59	47	5.5	[a]27		------	203	16	10	------	------	140
			(2) 1941–43	------	288	13	[d].53	47	5.4	[a]26		------	204	16	9.4	------	------	140
			(3) Nov. 4, 1940	68	228	21	.06	48	7.4	23	3.3	0	206	17	7.9	------	.0	150
4/12-14D1. City of Long Beach, Commission well 1.	246	1,668	(1) July 2, 1940	------	262	6.1	[d].20	4.4	.4	[a]85		------	202	1.2	21	------	------	13
			(2) Sept. 1, 1933	------	299	7.0	[d].50	5.4	.3	[a]102		------	221	.2	39	------	------	15
			[b] (3) 1933–36	------	302	9.3	[d].26	5.4	.4	[a]101		------	218	.9	40	------	------	15
			(4) 1936–37	------	275	7.0	[d].30	4.9	.4	[a]95		------	205	.7	36	------	------	14
			(5) 1938–40	------	272	7.3	[d].27	4.6	.4	[a]90		------	199	1.2	31	------	------	13
			(6) Nov. 1, 1940	95	256	19	.04	4.5	.5	87	1.7	0	200	1.4	29	------	1.4	13

				(7) 1941–43	------	280	6.4	[d].31	4.4	.4	[a]85		------	196	1.2	29	------	------	13
4/12-14D2.	City of Long Beach.	247	717	Nov. 9, 1925	------	231	------	------	46	6.0	24	3.3	------	213	14	6.0	------	------	140
4/12-14P1.	City of Long Beach, Wilson Ranch well.	247	1,700	(1) July 1, 1936	------	289	9.0	[d].40	3.6	.3	[a]97		------	205	14	28	------	------	10
				[b](2) 1933–40	------	275	7.8	[d].30	3.8	.4	[a]93		------	217	5.1	21	------	------	11
				(3) 1941–43	------	261	6.9	[d].30	3.4	.5	[a]80		------	189	4.6	18	------	------	11
4/12-15B1.	City of Long Beach, Commission well 3.	247	1,570	[b](1) 1935–37	------	243	7.8	[d].28	5.8	.4	[a]78		------	174	1.6	30	------	------	16
				(2) 1937–38	------	234	7.1	[d].31	5.4	.4	[a]75		------	171	1.6	26	------	------	15
				(3) 1938–40	------	240	6.9	[d].26	5.3	.4	[a]76		------	173	1.7	26	------	------	15
				(4) 1941–43	------	255	6.3	[d].34	5.4	.4	[a]76		------	175	1.7	26	------	------	15
4/12-15D1.	City of Long Beach.	247	270	[b] Nov. 10, 1925	------	215	------	------	34	3.0	40	1.7	------	194	13	9.0	------	3.0	98
				June 18, 1931	------	[a]211	------	------	33	8	49	------	------	183	16	13	------	------	115
4/12-17N1.	City of Long Beach, Development well 7.	247	650	(1) 1931–34	------	244	7.2	[d].29	9.1	.8	[a]75		------	186	1.0	25	------	------	26
				(2) 1935–37	------	247	8.0	[d].26	9.1	.8	[a]75		------	184	.8	27	------	------	26
				(3) 1938–40	------	247	6.3	[d].27	8.7	.8	[a]73		------	183	.8	24	------	------	25
				(4) 1941–43	------	257	5.0	[d].30	8.4	.8	[a]74		------	183	1.5	24	------	------	24
				[b](5) Jan. 4, 1933	------	270	12.7	[d].60	9.4	1.0	[a]79		------	177	16	27	------	------	28
				(6) Nov. 1, 1932	------	244	7.6	[d].30	9.2	1.0	[a]71		------	195	1.2	14	------	------	227
4/12-17N2.	City of Long Beach, Development well 8.	247	662	(1) 1932–34	------	231	6.2	[d].36	9.4	.9	[a]70		------	171	.9	27	------	------	27
				(2) 1934–37	------	233	7.1	[d].30	9.5	.8	[a]69		------	167	1.5	27	------	------	27
				(3) 1937–40	------	233	5.9	[d].33	10	.9	[a]67		------	168	1.6	25	------	------	29
				(4) 1941–43	------	239	5.5	[d].34	9.7	1.1	[a]67		------	170	1.1	25	------	------	29
4/12-17Q1.	City of Long Beach, Development well 4.	247	1,004	(1) 1932–34	------	233	6.9	[d].34	6.3	.4	[a]84		------	203	.7	23	------	------	17
				(2) 1932–41	------	232	6.4	[d].20	12.5	1.0	[a]61		------	158	1.3	27	------	------	35
4/12-18R1.	City of Long Beach, Development well 6.	247	962	(1) 1931–34	------	256	6.2	[d].31	9.8	.9	[a]78		------	196	.6	25	------	------	28
				(2) 1937–40	------	267	5.3	[d].26	10	1.0	[a]80		------	208	.6	23	------	------	29
				(3) 1941–43	------	278	5.5	[d].36	9.9	1.0	[a]78		------	200	1.0	24	------	------	29
4/12-20C1.	City of Long Beach, Development well 3.	247	752	(1) 1931–43	------	225	5.6	[d].34	12	1.1	[a]62		------	160	1.2	25	------	------	35
				(2) 1931–40	------	232	5.8	[d].39	27	2.1	[a]42		------	164	13	13	------	------	76
				(3) Sept. 13, 1932	------	235	5.7	[d].50	27	2.0	[a]37		------	168	.8	13	------	------	76
				(4) Dec. 6, 1934	------	256	8.8	[d].20	28	2.0	[a]49		------	167	14	23	------	------	78
4/12-20D1.	City of Long Beach, Development well 1.	248	1,017	(1) Oct. 19, 1921	------	203	21	.07	12	1.8	55	4.4	------	151	5.5	17	------	tr	37
				(2) Sept. 8, 1925	------	[a]196	------	------	14	.0	[a]67		------	170	.0	30	------	------	35
4/12-20G1.	City of Long Beach, Development well 5.	248	1,016	(1) July 1, 1933	------	271	8.3	[d].20	6.4	.4	[a]91		------	225	.5	22	------	------	18
				(2) Jan. 4, 1933	------	253	15	[d].70	22	2.0	[a]56		------	185	11	17	------	------	63
				(3) July 2, 1935	------	211	8.0	[d].60	12	.7	[a]59		------	146	.4	28	------	------	33
4/12-21L1.[2]	City of Long Beach, Citizens well 4.	248	1,155	Oct. 19, 1921	------	246	19	.04	6.0	1.7	78	3.9	13	181	2.1	17	------	tr	22

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Parts per million: Solids	SiO$_2$	Fe	Ca	Mg	Na	K	CO$_3$	HCO$_3$	SO$_4$	Cl	BO$_3$	NO$_3$	Hardness
4/12-21M2. City of Long Beach, Citizens well 7.	248	1,105	[b](1) 1931–36	......	248	8.2	[d]0.44	6.5	0.9	[a]84		......	207	1.1	22	......	......	20
			(2) 1933–43	......	211	5.0	[d].33	12	1.0	[a]55		......	144	2.8	24	......	......	34
			(3) Nov. 2, 1934	......	286	9.8	[d].50	28	3.3	[a]53		......	158	11	41	......	......	84
			(4) Aug. 1, 1935	......	239	7.8	[d].40	30	2.8	[a]39		......	162	14	16	......	......	86
4/12-21M3. City of Long Beach, Citizens well 1.	248	420	[b]Oct. 19, 1921	......	209	26	.06	22	2.7	43	3.6	......	164	13	12	......	0.6	66
			June 19, 1931	......	[a]190	......	......	25	7	47	......	......	168	16	11	......	......	91
4/12-21M4. City of Long Beach, Citizens well 6.	248	1,422	(1) 1932–35	......	216	6.5	[d].31	11	.9	[a]60		......	147	3.4	26	......	......	31
			(2) 1935–38	......	214	4.8	[d].34	11	.9	[a]58		......	146	3.0	25	......	......	31
			(3) 1938–40	......	211	5.7	[d].27	10	.9	[a]58		......	144	3.3	24	......	......	29
			(4) 1941–43	......	223	5.3	[d].31	10	1.0	[a]58		......	144	3.9	24	......	......	29
			(5) 1932–35	......	238	6.6	[d].39	28	2.7	[a]43		......	165	14	18	......	......	81
			(6) 1935–38	......	246	7.2	[d].50	29	2.7	[a]40		......	163	14	16	......	......	84
			(7) 1938–40	......	247	6.5	[d].54	28	2.9	[a]42		......	165	12	18	......	......	82
			(8) 1941–43	......	251	6.2	[d].49	29	2.5	[a]41		......	167	14	15	......	......	83
			(9) June 1, 1940	......	209	7.6	[d].20	10	.9	[a]57		......	144	1.9	24	......	......	29
			(10) May 1, 1934	......	213	6.0	[d].4	10	.9	[a]60		......	145	2.5	28	......	......	29
			(11) Sept. 2, 1942	......	254	4.8	[d].70	31	3.1	[a]37		......	169	14	13	......	......	90
			(12) Nov. 2, 1935	......	202	7.2	[d].3	26	2.4	[a]30		......	125	13	17	......	......	75
4/12-21M5. City of Long Beach, Citizens well 5.	248	695	(1) 1932–43	......	222	5.7	[b].30	9.4	.9	[a]63		......	156	4.4	22	......	......	27
			(2) 1932–43	......	226	5.0	[d].37	20	1.5	[a]41		......	158	12	16	......	......	56
			(3) Nov. 2, 1940	82	203	18	.04	9.0	1.6	62	1.8	0	159	5.0	21	......	.67	29
4/12-22F1. ———	249	11	[b]Mar. 2, 1932	......	[a]298	......	......	40	12	57	......	......	235	30	41	0.9	0	149
4/12-24B1. Bixby Land Co.	249	780	Nov. 9, 1925	......	240	......	......	48	4.2	27	2.5	......	213	16	5.0	......	1.0	137
4/12-24M1. City of Long Beach.	249	318	[b]Nov. 3, 1925	......	228	......	......	46	7.8	24	2.5	......	211	14	10	......	1.0	147
4/12-24M2. City of Long Beach, Wise Ranch well 1.	249	1,086	(1) Mar. 3, 1943	......	245	7.0	[d].30	11	.8	[a]66		......	160	20	16	......	......	31
			(2) May 1, 1934	......	259	4.0	[d].50	27	3.0	[a]57		......	179	31	17	......	......	80
			(3) Oct. 2, 1936	......	284	13	[d].50	43	5.0	[a]34		......	182	29	15	......	......	128
			(4) June 1, 1940	......	288	7.8	[d].50	44	5.0	[a]28		......	176	14	12	......	......	131
4/12-24M4. City of Long Beach, Wise Ranch well 2.	249	1,014	(1) June 4, 1942	......	247	8.0	[d].30	8.8	.6	[a]66		......	151	22	15	......	......	24
			(2) Nov. 1, 1936	......	256	7.8	[d].40	14	1.0	[a]66		......	154	31	19	......	......	39
			(3) Dec. 1, 1932	......	300	15	[d].50	44	5.0	[a]33		......	202	15	13	......	......	131
4/12-25H1. Bryant Ranch	249	547	[b]Nov. 3, 1925	......	277	......	......	43	8.4	39	1.7	......	203	41	13	......	1.0	142

4/12-26M1.	Bryant Ranch, well 7.	249	849	Nov. 5, 1925		216			13	.6	65	2.5		183	14	10			35
				Aug. 7, 1939	76	[e]181			22	3	45			164	16	13		0	67
4/12-27K1.	Bryant Ranch	249	238	[b] 1939 (?)		[e]173			27	4.0	30			170	22	5		0	84
4/12-27K2.	Bryant Ranch, well 8.	249	835	Nov. 25, 1925		222			11	.6	68	1.7		158	31	12		2.0	30
4/12-27M1.	Bryant Ranch	249	283	Aug. 7, 1939	73	[e]187			16	4	52			168	22	9.0		0	56
4/12-28B1.	———	249	15	[b] Mar. 7, 1932		[e]1,433			24	15	535			1,165	128	144	4.2	0	122
4/12-28H1.[3]	City of Long Beach, Alamitos well 9.	249	1,184	[b] (1) 1932–43		260	5.8	[d].37	6.8	.8	[e]80			199	3.2	20			20
				(2) 1932–40		226	6.3	[d].34	5.8	.6	[e]70			162	7.3	20			17
				(3) Feb. 1, 1943		276	4.5	[d].30	4.8	.5	[e]82			200	1.9	19			14
				(4) May 3, 1938		227	4.0	[d].20	7.1	.7	[e]70			154	18	19			21
				(5) Nov. 2, 1939		211	7.5	[d].50	14	1.3	[e]50			122	18	20			40
				(6) Nov. 4, 1942		246	6.0	[d].60	26	2.5	[e]43			167	14	11			75
4/12-28H4.	City of Long Beach, Alamitos well 12.	249	505	(1) Dec. 1, 1932		262	5.7	[d].30	5.4	.4	[e]86			207	1.0	22			15
				(2) July 1, 1936		255	6.7	[d].50	12	1.0	[e]70			153	28	22			34
				(3) July 2, 1937		220	5.7	[d]1.43	28	3.0	[e]40			156	18	17			82
				(4) Oct. 1, 1935		286	10	[d].50	35	2.0	[e]45			158	18	32			96
4/12-28H5.	City of Long Beach, Alamitos well 6.	250	982	June 19, 1931		[e]222			8	4	85			195	11	14	1.6	1	36
4/12-28H6.	City of Long Beach, Alamitos well 8.	250	982	(1) Nov. 11, 1934		224	7.6	[d].10	4.8	.3	[e]78			195	.8	16			13
				(2) Jan. 4, 1933		275	5.8	[d].20	6.6	.5	[e]89			207	3.0	28			19
				(3) 1932–43		254	5.7	[d].37	5.2	.5	[e]82			200	1.2	20			15
4/12-28H7.	City of Long Beach, Alamitos well 11.	250	500	(1) 1932–40		217	5.7	[d].30	8.8	.8	[e]63			155	6.2	21			25
				(2) June 4, 1942		264	4.0	[d].30	8.4	.8	[e]73			178	1.2	23			24
				(3) Sept. 2, 1937		224	7.0	[d].30	8.0	.7	[e]69			152	17	21			23
				(4) Oct. 1, 1933		224	3.7	[d].80	15	1.1	[e]57			141	25	17			42
				(5) Apr. 3, 1940		258	7.0	[d].20	26	2.3	[e]46			167	21	12			74
				(6) Nov. 2, 1939		227	9.0	[d].40	25	2.4	[e]39			141	23	13			72
4/12-28H8.	City of Long Beach, Alamitos well 2.	250	273	Oct. 19, 1921		214	20	.07	13	1.7	58	3.5		158	22	12		.61	39
				June 19, 1931		[e]217			12	3	76			177	21	16	.5		42
4/12-28H9.	City of Long Beach, Alamitos well 1.	250	745	1933–38		226	5.4	[d].30	12	1.0	[e]63			157	15	19		.0	34
4/12-28H10.	City of Long Beach, Alamitos well 7.	250	1,114	Aug. 4, 1937		211	5.6	[d].40	11	.9	[e]56			141	3.1	24			31
4/12-32G1.	Long Beach Peoples Ice and	250	130	[b] Mar. 24, 1932		[e]1,015			116	50	205			305	53	437	1.3		495
				May 11, 1932		[e]1,021			117	50	201			308	54	444	.9		498

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Parts per million: Solids	SiO₂	Fe	Ca	Mg	Na	K	CO₃	HCO₃	SO₄	Cl	BO₃	NO₃	Hardness
Cold Storage Co.			Aug. 8, 1932	------	[a]861	------	------	58	37	225	------	------	146	3	464	0.8	------	297
			Nov. 2, 1932	------	[a]901	------	------	56	38	238	------	------	113	7	504	1.2	------	296
			Feb. 3, 1933	------	[a]1,017	------	------	75	50	248	------	------	210	26	511	1.9	------	393
4/12-34B1. Bryant Ranch	250	849	[b] Mar. 25, 1932	------	[a]189	------	------	8	3.0	68	------	------	162	12	16	.7	------	32
			July 25, 1939	------	[a]181	------	------	6	1.0	67	------	------	160	10	16	------	1.0	19
4/13-1F1. City of Long Beach	250	467	[b] 1932–35	------	316	7.3	0.24	28	2.4	[a]68		------	164	55	26	------	------	808
4/13-2P4. George Mindrup	250	161	[b] July 22, 1931	------	[a]338	------	------	65	9	52	------	------	223	72	27	1.9	0	199
4/13-6J1. Dominguez Estate Co.	250	95	Aug. 19, 1931	------	[a]318	------	------	55	16	44	------	------	[c]216	66	27	1.6	0	203
			[b] Mar. 31, 1932	------	[a]308	------	------	56	10	42	------	------	217	67	23	.7	0	181
4/13-8L1. Joseph Loria	250	32	Apr. 11, 1932	------	[a]3,454	------	------	331	190	580	------	------	250	1,356	870	1.5	0	1,607
			July 5, 1932	------	[a]4,014	------	------	408	223	638	------	------	253	1,596	1,021	1.6	0	1,934
4/13-10F1. Dominguez Estate Co.	250	18	Apr. 21, 1942	63	12,900	------	------	255	320	3,530	24	0	1,111	6,910	1,047	------	134	1,950
4/13-10G3. Ladislado Torres	251	80	Apr. 13, 1942	------	2,620	19	.29	398	107	255	5.8	0	240	947	595	------	.8	1,434
4/13-12C1. Virginia City	251	138	[b] Nov. 17, 1925	------	270	------	------	42	4.8	48	1.7	------	202	32	22	------	2.0	125
4/13-13M1. Alfred Encinas	251	450	Nov. 16, 1925	------	247	------	------	24	4.2	57	1.7	------	183	20	22	------	2	77
4/13-14D2. Dominguez Water Corp., well 11.	251	161	Apr. 13, 1942	66	600	------	------	106	14	75	3.8	0	249	147	95	------	.4	322
			July 20, 1943	------	1,129	17	.4	120	9.7	[a]206		------	293	360	123	tr	------	340
			Oct. 11, 1943	------	831	16	.4	120	10	[a]111		------	275	169	129	tr	------	341
			May 2, 1944	------	817	25	tr	130	19	[a]80		------	262	181	121	tr	------	403
4/13-14F1. Dominguez Estate Co.	251	130	Aug. 7, 1939	------	[a]1,421	------	------	213	56	216	------	------	493	367	321	------	1	762
4/13-14L1. Southern California Edison Co., Ltd.	251	120	Oct. 5, 1932	------	[a]1,637	------	------	317	73	233	------	------	293	104	760	3.8	0	1,092
			Jan. 4, 1933	------	[a]1,546	------	------	206	66	283	------	------	281	115	731	4.7	0	786
4/13-14M3. J. K. Raven	251	87	Apr. 13, 1942	------	1,530	19	13	253	71	149	7.2	0	440	449	310	------	1.2	936
4/13-14M8. S. D. Wilson	251	125	Aug. 7, 1939	------	[a]1,268	------	------	225	57	164	------	225	407	225	392	------	1	796
4/13-14P1. City of Long Beach.	251	30	Apr. 22, 1942	66	6,230	14	.12	944	252	804	19	0	1,045	1,130	2,231	------	.0	3,393
4/13-14Q2. Oil Operators, Inc., test well 1.	251	134	Oct. 5, 1931	------	[a]5,753	------	------	747	218	1,075	------	------	58	36	3,639	9.2	0	2,761
4/13-14Q4. Bell Ranch	251	900	July 22, 1931	------	[a]230	------	------	24	2	67	------	------	168	28	21	2.2	2	68
			Mar. 21, 1932	------	[a]236	------	------	24	6	62	------	------	168	36	23	.8	0	85
			May 11, 1932	------	[a]224	------	------	24	5	60	------	------	168	30	20	.8	0	81

				Aug. 8, 1932	------	[a]239	------	------	23	7	62	------	------	171	36	25	.8	0	86
				Nov. 2, 1932	------	[a]225	------	------	24	5	61	------	------	165	31	21	.8	------	81
				Jan. 4, 1933	------	[a]233	------	------	23	5	62	------	------	171	34	23	.7	------	78
				Aug. 7, 1939	75	[a]219	------	------	22	4	56	------	------	173	29	21	------	0	71
4/13-15A2.	Dominguez Water Corp., well 8.	251	998	[b] July 23, 1931	------	[a]208	------	------	20	7	59	------	------	174	9	23	1.6	1	79
				Sept. 2, 1937	77	[a]221	------	------	21	5	60	------	------	188	15	24	2.1	0	73
				Aug. 7, 1939	77	[a]205	------	------	19	6	52	------	------	176	16	24	------	0	72
				July 20, 1943	------	378	11	.2	32	2.3	[a]69		------	201	36	26	tr	------	89S
				Oct. 11, 1943	------	361	14	.2	36	4.9	[a]55		0	195	31	25	0	------	110S
				May 2, 1944	------	349	18	tr	28	6.1	[a]58		3.0	183	28	25	tr	------	95S
4/13-15A3.	Dominguez Water Corp., well 10.	251	158	[b] July 23, 1931	------	[a]449	------	------	83	17	62	------	------	253	108	52	.27	------	277
				July 20, 1943	------	693	15	.4	85	7.9	[a]105		0	268	128	84	tr	------	245
				Oct. 11, 1943	------	768	16	.4	84	8.9	[a]130		0	256	182	91	tr	------	246
				May 2, 1944	------	689	26	tr	105	16	[a]67		0	244	137	94	tr	------	329
4/13-15B3.	Dominguez Water Corp., well 3.	251	947	[b] 1923 (?)	------	[a]229	------	------	31	8.7	[a]44		18	165	19	25	------	------	113
				July 20, 1943	------	378	10	.4	26	3.9	[a]73		0	214	24	28	tr	------	81
				Oct. 11, 1943	------	383	15	.2	38	6.1	[a]56		0	207	33	27	tr	------	120
				May 2, 1944	------	324	15	[d].1	26	9.1	[a]48		tr	183	19	25	tr	------	102
4/13-15D1.	J. P. Hoeptner	251	461	Aug. 7, 1939	72	[a]384	------	------	59	16	57	------	------	244	94	36	------	0	213
4/13-19H1.	F. L. Forrester	251	90	Apr. 22, 1942	69	518	22	.41	76	17	68	3.9	0	196	58	132	------	2.1	260
4/13-19J2.	Theodore E. Kleinmeyer.	251	325	[b] Apr. 11, 1932	------	[a]224	------	------	23	10	55	------	------	217	2	25	.8	------	99
4/13-19J4.	Mrs. Addie V. Stewart.	251	100	[b] Apr. 11, 1932	------	[a]787	------	------	100	34	156	------	------	265	37	325	.7	2	389
				Aug. 7, 1939	------	[a]849	------	------	113	37	152	------	------	287	39	358	------	6	434
4/13-20L1.	Mrs. Ana-May Kreyssler.	252	554	July 22, 1931	------	[a]384	------	------	53	17	76	------	------	223	0	126	.54	------	202
4/13-21H3.	Richfield Oil Corp., well 3.	252	800	Jan. 13, 1931	------	[a]247	------	------	20	5	[a]73		------	211	13	30	------	------	71
				July 22, 1931	------	[a]222	------	------	21	7	64	------	------	198	4	25	1.9	------	81
				Apr. 1932	------	[a]238	------	------	24	3	[a]69		------	213	6	29	------	------	72
4/13-21Q1.	Shell Oil Co., Inc., Wilmington well 1.	252	750	Feb. 7, 1938	------	[a]218	31	.0	13	2.5	[a]74		------	204	0	26	------	------	45
4/13-21R1.	Shell Oil Co., Inc., Wilmington well 2.	252	846	Feb. 7, 1938	------	[a]360	37	[d]35	33	12	[a]90		0	201	36	88	------	------	132
4/13-22E1.	Richfield Oil Corp., well 5.	252	650	[b] Apr. 10, 1942	------	221	24	.01	20	5.1	53	1.9	0	185	2.8	22	------	------	71
4/13-22L2.	Tide Water Associated Oil Co.	252	728	May 13, 1941	------	[a]302	------	------	46	11	57	------	------	252	28	34	------	------	160
4/13-23C1.	C. H. Barnes	252	74	May 17, 1941	67	1,479	27	1.33	167	42	293	15	0	569	242	380	------	1.8	590

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Parts per million: Solids	SiO_2	Fe	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	BO_3	NO_3	Hardness
4/13-23G2. City of Long Beach, Silverado well 1.	252	1,074[b]	(1) Aug. 4, 1931	------	[a]207	------	------	13	0.0	[a]73		------	188	0	27	------	------	33
			(2) Apr. 10, 1933	------	344	15	[d]0.70	25	4.9	[a]73		------	165	42	42	------	------	83
			(3) May 1, 1933	------	329	14	[d].40	24	5.2	[a]70		------	170	42	36	------	------	81
			(4) Nov. 8, 1933	------	358	13	[d].70	35	7.1	[a]60		------	192	50	27	------	------	117
4/13-23L3. Irwin Stewart	252	115	Jan. 4, 1933	------	[a]1,534	------	------	217	51	265	------	------	567	436	280	1.6	0	752
4/13-26A1. Oil Operators, Inc., test well 4.	252	131	Oct. 5, 1931	------	[a]1,181	------	------	188	49	175	------	------	601	249	219	.7	0	671
4/13-26B1. Dora E. Kahler	252	60	Apr. 21, 1942	------	1,287	25	2.0	220	42	124	6.0	0	346	214	350	------	.4	722
4/13-29M1. Robert Tracy	252	110	Jan. 13, 1933	------	[a]388	------	------	54	16	78	------	------	250	0	114	.5	------	201
4/13-30G1. City of Los Angeles, Lomita plant, well 6.	252	682	Sept. 4, 1935	------	[a]231	------	.15	19	9	[a]66		------	184	0	45	------	------	84
4/13-30K1. City of Los Angeles, Lomita plant, well 7.	252	675	Dec. 11, 1941	------	[a]272	------	------	24	13	66		9	224	6	42	------	------	113
			Jan. 14, 1942	------	[a]239	------	------	15	10	[a]61		22	211	1	24	------	------	79
4/13-31E2. City of Los Angeles, Lomita plant, well 2.	253	509	Aug. 1928	------	[a]743	------	0	52	28	[a]204		------	366	0	276	------	tr	245
4/13-31E3. City of Los Angeles, Lomita plant, well 3.	253	671	Mar. 25, 1932	------	[a]377	------	------	18	9	123		------	311	0	69	2.0	------	82
4/13-31E4. City of Los Angeles, Lomita plant, well 4.	253	680	July 26, 1932	------	[a]388	------	------	16	7	[a]131		------	258	36	69	------	------	69
4/13-33D1. City of Los Angeles, Wilmington plant, well 14.	253	888	Feb. 14, 1933	------	[a]236	------	------	15	11	[a]64		tr	143	2	72	------	------	83
			[b]Nov. 2, 1939	------	[a]344	------	------	19	1	[a]114		tr	222	56	43	------	------	52
4/13-33D2. City of Los Angeles, Wilmington plant, well 7.	253	502	Feb. 14, 1933	------	[a]252	------	------	9	6	[a]86		tr	209	3	43	------	------	47
4/13-33E2. City of Los Angeles, Wilmington plant, well 1.	253	600	July 23, 1931	------	[a]405	------	------	14	9	145	------	------	271	tr	101	.3	------	72
			Feb. 14, 1933	------	[a]357	------	------	13	10	[a]118		tr	245	3	90	------	------	

4/13-33E8.	City of Los Angeles, Wilmington plant, well 13.	253	566	Mar. 8, 1927		[a]382			22	11	[a]118			293	0	84			100
				Feb. 14, 1933		[a]369			10	13	[a]122			264	3	89			78
4/13-33K1.	Consolidated Lumber Co.	253	320	Sept. 29, 1931		[a]2, 817			42	146	846			[a]107	5	1, 722	2.2	0	704
4/13-34K1.	Frank Martinez	253	101	Jan. 4, 1933		[a]1, 814			137	159	331			214	0	1, 079	.7	0	994
				Aug. 7, 1939	69	[a]3, 517			256	167	645			218	74	2, 265		1	1, 325
4/13-35M1.	City of Long Beach.	253	137	Feb. 15, 1933		[a]801			61	45	186			253	16	364	1.0	1	337
4/13-35M3.	Southern California Edison Co., Ltd., west Gaspur well.	253	201	[b] (1) Jan. 8, 1923		[a]318			27	11	[a]82			[a]235	40	40			113
				(2) Jan. 6, 1930		[a]577			66	25	[a]122			[a]226	17	234			268
				(3) Jan. 23, 1930		[a]631	16	[d]1.0	91	30	[a]139			253	20	224			351
				(4) Mar. 17, 1930		[a]606			66	32	[a]121			[a]226	30	244			296
				(5) Apr. 28, 1930		[a]655			68	22	[a]155			[a]238	26	265			260
				(6) June 5, 1930		[a]589			69	16	[a]137			230	20	232			238
				(7) Oct. 28, 1930		[a]637			64	0	[a]185			223	26	250			160
				(8) Nov. 14, 1930		[a]582			54	18	[a]147			[a]223	23	228			209
				(9) Feb. 11, 1931		[a]591			48	16	[a]159			[a]236	38	212			186
				(10) Mar. 20, 1931		[a]773			58	30	[a]201			[a]270	22	327			268
				(11) July 23, 1931		[a]644			53	40	136			250	19	270	.8		297
				(12) Aug. 7, 1939	71	[a]6, 784			357	303	1, 717			219	475	3, 820		2	2, 135
				(13) Apr. 28, 1942	69	8, 200	20	.97	438	418	1, 865	56	0	193	565	4, 410		1.8	3, 809
4/13-35Q3.	California Sea Food Co., Inc., well 3.	253	125	June 5, 1930		[a]13, 357			619	275	[a]4, 063			255	972	7, 300			2, 675
4/13-35Q4.	California Sea Food Co., Inc., well 4.	253	124	Jan. 4, 1933		[a]20, 491			485	816	6, 035			482	1, 277	11, 626	11	0	4, 558
5/9-4A1.	A. M. Robinson	253	350	Nov. 1918		[a]366			58	17	[a]54			223	79	45		1	215
5/9-8B.	———	253	600	[b] Jan. 26, 1926		719			127	40	45	4.2		335	133	104		28	482
5/9-8J1.	V. V. Tubbs	254	220	[b] Jan. 26, 1926		427			71	16	41	4.2		219	108	26		10	244
5/9-9C1.	F. G. Fuller Ranch	254	220	Jan. 26, 1926		607			84	31	44	4.2		280	68	80		30	337
5/9-10D1.	Red Hill Water Co.	254	450	[b] Jan. 11, 1926		470			79	21	46	3.3		216	102	59		24	284
5/9-19A1.	F. H. Stewart	254	44	[b] Sept. 17, 1931		[a]989			189	60	62			320	362	137	.5	18	719
5/9-19R1.	Fitzpatrick Bros. and E. Cubbons.	254	715	[b] June 1925		[a]429			74	23	[a]48			252	122	36			279
				Sept. 17, 1931		[a]467			83	23	48			232	156	34	.4	6	302
				May 4, 1932		[a]464			85	25	48			229	148	39	.7	4	315
				Sept. 11, 1939	70	[a]545			100	28	53			223	186	60		6	365
5/10-2B1.	———	254	210	Aug. 13, 1925		459			87	15	30	4.2		263	56	46		15	279

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Parts per million													
					Solids	SiO_2	Fe	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	BO_3	NO_3	Hardness
5/10-7J. ———	254	200	[b] Aug. 18, 1925		344			66	7.2	36	5.0		213	55	27		9.0	195
5/10-9A1. W. M. Paquette	254	310	[b] Sept. 17, 1931		[a]701			124	34	74			339	187	94	0.9	18	449
5/10-9G1. S. D. Teal	254	214	May 23, 1931		[a]341			69	15	40			259	53	32	.3	2	234
5/10-9P2. State of California	254	20	[b] Sept. 4, 1939		[a]301			63	12	[a]35			228	50	26		1	207
			[b] Feb. 25, 1931		[a]483			98	29	[a]34			268	124	64			364
5/10-13B3. City of Santa Ana, well 7.	254	960	Jan. 11, 1932		[a]510			81	27	76			317	98	57	1.1	11	313
			[b] Jan. 29, 1926		373			67	13	36	6.6		213	82	29		10	221
			July 5, 1938	73	[a]380			76	17	37			257	67	42	.8	12	260
			Aug. 30, 1938	70	[a]264			47	11	38			211	41	20	.3	1	163
5/10-13B4. City of Santa Ana, well 8.	254	151	[b] Sept. 17, 1931		[a]366			72	17	40			235	74	36	.5	9	250
5/10-13C1. City of Santa Ana, well 15.	254	1,140	Sept. 17, 1931		[a]480			100	24	45			265	101	69	.7	8	348
5/10-15E1. M. C. Heacock	254	163	[b] May 23, 1931		[a]350			69	15	43			268	57	28	.4	4	234
5/10-16J. ———	254	900	[b] Oct. 2, 1925		248			42	6.6	33	2.5		183	37	12		1.0	132
5/10-17H. ———	254	175	Oct. 5, 1925		362			69	12	38	3.3		244	59	28		10	222
5/10-18B. ———	254	475	[b] Sept. 29, 1925		269			52	9.6	22	9.1		208	38	13		1.0	169
5/10-19B. ———	254	250	Aug. 24, 1925		323			65	10	25	4.2		211	58	21		2.0	204
5/10-21P1. G. M. Henson	254	110	[b] Jan. 28, 1932		[a]261			50	12	34			217	38	18	.4		174
			Sept. 5, 1939		[a]262			37	12	35			226	45	19		1	142
5/10-23L1. La Bolsa Tile Co.	254	1,350	[b] Feb. 3, 1932		[a]213			6	2	82			167	26	13	.6	0	23
5/10-24F1. ———	255	200	[b] Jan. 25, 1926		540			93	22	42	1.7		238	126	52		15	323
5/10-24A4. ———	255	957	[b] Jan. 22, 1926		224			15	2.4	59	1.7		133	44	14		4.0	47
5/10-25A5. ———	255	600	Jan. 22, 1926		367			56	5.4	53	2.5		202	80	20		4.0	162
5/10-26D2. S. H. Manderscheid and W. R. McClintock	255	800	[b] Feb. 3, 1932		[a]266			45	13	41			207	48	14	.9	1	166
5/10-27H. ———	255	180	[b] Jan. 22, 1926		315			59	4.2	47	1.7		225	52	20		5.0	165
5/10-30Q1. Edward Muller	255	140	[b] Apr. 9, 1942		339	21	.12	67	13	35	2.1	0	241	59	25	.3	1.3	221
5/10-32C1. Mrs. H. E. Chan	255	105	[b] Sept. 4, 1939		[a]326			69	13	37			243	54	29		2	226
5/10-32J2. Orange County Joint Outfall Sewer District.	255	163	[b] Aug. 20, 1931		[a]275			49	13	42			210	48	16	.5	1	176
5/10-34E1. City of Newport Beach.	255	411	Mar. 15, 1935		[a]478			50	10	[a]109			217	152	48			166
5/10-35B. ———	255	336	[b] Jan. 22, 1926		352			59	14	38	2.5		208	88	17		5.0	205
5/10-36J. ———	255	1,000	Jan. 22, 1926		242			16	3.0	66	1.7	5.5	147	48	14		1.0	52
5/11-1C. ———	255	1,400	Aug. 5, 1925		291			55	9.1	30	4.2		216	42	16		1.0	175

5/11-4A1.	I. W. Hellman Ranch, well 9.	255	921	[b] July 21, 1925		275			51	9.1	31	4.2		216	38	13		1.0	165
5/11-6A1.	I. W. Hellman Ranch.	255	1,030	[b] July 23, 1925		200			6.4	1.2	59	2.5	6.8	135	18	9.0			21
5/11-8C1.	I. W. Hellman Ranch.	255	915	Oct. 28, 1925		210			8.6	1.8	67	.8	5.5	144	32	10		1.0	29
				June 6, 1931		[a]215			14	4	69			[a]155	35	14	1.6	0	51
				Sept. 12, 1939	72	[a]218			11	1	74			167	36	12		0	32
5/11-9G1.	Anaheim Sugar Co.	255	900	[b] July 28, 1925		304			56	8.4	33	5.8		222	47	16		1.0	174
5/11-10H1.	R. W. Edwards Ranch.	255	80	[b] Sept. 18, 1931		[a]268			54	12	32			238	34	16	1.0	0	183
				Sept. 5, 1939		[a]270			62	11	33			223	35	17			200
5/11-12A2.	N. M. Clinton	255	153	Sept. 17, 1931		[a]316			62	13	37			223	53	30	.4	9	208
				Sept. 21, 1937	64	[a]308			63	13	36			231	47	29	.5	4	211
5/11-13D1.	R. F. Hazard	255	80	[b] May 23, 1931		[a]280			53	12	32			220	55	18	.3		182
5/11-13L1.	Ben Justice	255	392	[b] Sept. 28, 1925		280			54	9.1	22	10		202	42	15		2.0	172
5/11-14C2.	R. W. Edwards	255	850	[b] July 23, 1925		251			49	6.6	24	2.5	4.1	191	25	10		1.0	150
5/11-15M.	———	255	700	Oct. 22, 1925		230			29	1.8	51	1.7		175	34	10		1.0	80
5/11-17E2.	Casa Tores Gun Club.	255	153	[b] Mar. 3, 1932		[a]263			53	14	29			226	37	16	.5	0	190
				Sept. 12, 1939		[a]250			53	10	31			207	37	15		0	174
5/11-18P4.	Los Alamitos Land Co.	256	8	[b] Apr. 17, 1942	67	57,300		.01	898	2,004	16,900	437	0	600	3,850	30,900			9,211
5/11-18R1.	Lomita Land and Water Co.	256	895	[b] Apr. 25, 1942	80	218	17	.01	6.7	.7	73	.9	6.9	170	14	12		.4	20
5/11-21P2.	William A. Schonle.	256	102	[b] Feb. 15, 1932		[a]389			74	17	45			183	75	85	.4	1	255
5/11-21Q1.	Meadow Lark Country Club.	256	537	[b] June 5, 1931		[a]210			7	2	79			192	9	14	2.7		26
5/11-21Q3.	Meadow Lark Country Club.	256	180	[b] June 5, 1931		[a]239			42	11	37			201	31	16	1.1	0	150
5/11-23A1.	Boulevard Gardens Water Co.	256	263	[b] May 23, 1931		[a]256			50	12	30			210	40	18	.3	1	174
				Sept. 4, 1939	66	[a]259			53	10	30			209	42	18		1	174
5/11-23P.	———	256	2,900	[b] Oct. 9, 1925		316			4.3	.6	111	.8	4.1	274	2.4	14		1.0	13
5/11-26H1.	Preston Estate	256	400	[b] Sept. 17, 1925		239			46	4.8	34	2.5	2.7	191	36	8.0			135
5/11-26M1.	Southern California Water Co., Golden West plant, well 2.	256	201	Apr. 27, 1939		[a]277	10	[d]2.0	58	10	[a]32			207	44	29			186
				Jan. 20, 1943		695	18	.02	112	20	91	5.0	0	229	73	208	1.0	1.3	362
5/11-26M2.	Southern California Water Co., Golden West plant, well 1.	256	282	Sept. 18, 1931		[a]256			46	11	34			210	42	16	.6	1	160
				Nov. 9, 1931		[a]271	7.7	[d]5.0	51	2	51			218	37	21			136
				May 2, 1938	67	[a]407			63	12	71			208	107	46	.4	4	207
				May 31, 1938		[a]322			59	13	39			217	46	55	.5	1	201
				July 5, 1938		[a]324			63	10	44			216	53	45	1.4		199
				Aug. 1, 1938		[a]289			55	10	39			205	43	35	.3	4	179
				Aug. 30, 1938		[a]332			63	11	46			221	50	48	.5	3	203
				Oct. 3, 1938		[a]333			66	11	41			206	54	55	.5	2	210
				Oct. 31, 1938		[a]361			68	17	42			211	64	62	.4	2	240
				Nov. 28, 1938		[a]377			80	10	46			233	55	64	.4	5	241
				Jan. 3, 1939		[a]233			40	6	42			176	34	20	.7	2	125
				Feb. 6, 1939		[a]242			44	7	39			188	37	20	.7		139

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Parts per million: Solids	SiO₂	Fe	Ca	Mg	Na	K	CO₃	HCO₃	SO₄	Cl	BO₃	NO₃	Hardness
			Mar. 7, 1939		[a]305			62	11	37			206	51	38	0.7	2	200
			Apr. 3, 1939		[a]249			43	7	40			198	38	20	.7	1	136
			Apr. 27, 1939		392	12	[d]2.0	57	11	[a]30			214	42	24			188
			May 1, 1939		[a]294			59	10	37			205	45	39	.8	0	189
			June 12, 1939		[a]298			58	11	37			209	51	34	.5	1	190
			Sept. 5, 1939		[a]277			56	11	33			209	49	22		1	185
			Dec. 5, 1939		[a]313			63	11	37			218	56	36		1	203
			Dec. 4, 1942	67	512	22	.04	88	16	65	4.8	6.9	211	56	129	1.2	1.3	286
5/11-26P1. Harry T. Groves	256	510	[b] Oct. 15, 1925		254			7.2	.6	89	1.7	4.1	230		13		1.0	21
5/11-28K1. Bolsa Land Co.	256	917	[b] June 19, 1931		[a]352			8	6	132			375	0	18		0	45
5/11-29C1. Sunset Land and Water Co.	256	450	[b] Oct. 27, 1925		198			8.6	1.2	63	5.0		172	8.4	13		2.0	26
			June 5, 1931		[a]171			7	3	63			[a]146	9	14	2.2		30
			Sept. 5, 1939		[a]180			8	1	66			165	10	12		0	24
5/11-29P1. United States Department of Army.	256	539	Oct. 27, 1925		3,611			147	42	1,102	18		460	1.2	1,820		1.0	538
5/11-34F. ———	256	200	Oct. 15, 1925		489			90	13	48	1.7		200	37	129		3.0	278
5/11-34H. ———	256		Oct. 15, 1925		499			99	16	42	2.5	4.1	227	42	120		3.0	313
5/11-35L1. Frank Dispalatro	257	350	Apr. 9, 1942		964	22	.16	154	27	135	5.0	0	340	52	325	2.0	1.2	496
5/11-35P1. Holly Sugar Co., well 6.	257	391	Oct. 21, 1931		[a]247			16	2	84			232	12	16	.7	0	48
			Sept. 3, 1937	72	[a]334			26	3	103			220	tr	91	1.2	0	77
			Sept. 11, 1939	72	[a]342			25	4	110			214	11	85		0	79
5/12-1D. ———	257	440	[b] Nov. 2, 1925		261			34	5.4	52	2.5	2.7	197	37	11		1.0	107
5/12-2J2. City of Los Angeles Department of Water and Power, well 5.	257	404	Nov. 2, 1925		212			5.7	.6	73	1.7	5.5	175	7.2	12		1.0	17
5/12-12P1. I. W. Hellman Ranch.	257	185	Apr. 9, 1942	66	441	17	.88	50	9.2	99	2.0	0	184	48	127	.3	.2	163
5/12-12Q. ———	257	600	[b] Oct. 30, 1925		214			6.4	.6	74	1.7	5.5	186	4.8	10		1.0	19
5/12-13D1. I. W. Hellman Ranch.	257	210	[b] Apr. 27, 1942	65	17,9[illegible]		2.4	[illegible]	5[illegible]8	5,3[illegible]0	31	0	24	1,146	9,7[illegible]0			3,035
5/13-3D1. Long Beach Salt Co.	257	116	Jan. 27, 1933		[a]3,129			88	143	860			296	66	1,822	1.9	0	806
			Sept. 2, 1937	70	[a]5,537			150	244	1,599			314	123	3,250	1.6	12	1,293
			July 24, 1939	79	[a]6,357			171	298	1,820			305	299	3,613		3	1,649
5/13-3H. ———	257		[b] Mar. 11, 1942(?)		750			18	5	[a]240			[a]487	5	130			66
5/13-6D1. Union Oil Co.	257	1,016	Oct. 15, 1929		[a]1,198			25	14	[a]437			510	17	450			120
			[b] Nov. 15, 1929		[a]1,115			36	7	[a]393			466	1	445			119

				Jan. 6, 1930	------	[a]1,125	------	------	25	10	[a]414		------	460	1	445	------	------	104
				Feb. 28, 1930	------	[a]1,158	------	------	30	4	[a]430		------	453	7	460	------	------	91
				Apr. 28, 1930	------	[a]1,207	------	------	31	11	[a]438		------	453	5	495	------	------	123
				Oct. 30, 1930	------	[a]1,088	------	------	28	7	[a]399		------	435	10	426	------	------	99
				Mar. 22, 1932	------	[a]1,234	------	------	27	19	431	------	------	528	1	483	9.0	0	145
				May 11, 1932	------	[a]1,284	------	------	26	19	433	------	------	528	8.0	524	9.5	0	143
				Aug. 8, 1932	------	[a]1,227	------	------	27	15	434	------	------	528	tr	478	9.4	0	129
				Nov. 2, 1932	------	[a]1,253	------	------	25	17	467	------	------	528	0	471	9.3	0	132
				Jan. 4, 1933	------	[a]1,208	------	------	28	19	432	------	------	494	0	472	10	0	148
6/10-1E2.	Santa Ana Heights Water Co.	257	945	Oct. 16, 1941	------	236	12	.2	1	1	[a]72		14	156	12	44	------	------	6.6
				Apr. 16, 1942	------	231	16	.02	2.6	.5	82	.6	21	147	13	16	------	.2	9.0
				July 31, 1942	------	235	11	.0	3	1	[a]87		12	165	22	16	------	.3	12
				Aug. 14, 1944	------	237	11	------	1	1	[a]91		7	179	14	22	------	.3	6.6
6/10-2H1.	Nate Hughes	257	200	[b] Apr. 9, 1942	------	2,730	23	.12	394	107	298	4.4	0	311	1,239	380	.4	13	1,424
6/10-2H3.	E. E. Jamieson	257	680	Jan. 21, 1926	------	228	------	------	5.0	.6	77	1.7	5.5	150	32	14	------	------	15
6/10-3H2.	W. S. Babb	257	637	[b] Jan. 21, 1926	------	250	------	------	6.4	.6	85	3.3	5.5	211	2.4	16	------	------	19
6/10-6B1.	H. J. Lamb	257	140	[b] Aug. 13, 1925	------	274	------	------	52	9.1	27	2.5	------	205	41	13	------	2.0	167
6/10-7K5.	The Irvine Co.	257	202	Dec. 7, 1939	67	[a]243	------	------	37	9	44	------	------	212	34	13	------	------	129
				July 31, 1942	------	276	18	.05	42	8	[a]45		0	207	46	13	------	.2	138
6/10-8D2.	City of Newport Beach, well 9.	257	176	[b] Apr. 23, 1937	------	[a]260	------	------	45	6	[a]46		------	205	43	17	------	------	137
				June 6, 1938	------	[a]267	------	------	47	13	[a]37		------	222	39	20	------	------	171
				Feb. 15, 1939	------	[a]276	------	------	45	8	[a]50		------	222	43	19	------	------	145
				Sept. 24, 1939	------	[a]240	------	------	40	8	[a]41		------	197	34	18	------	------	133
				Dec. 6, 1939	70	[a]244	------	------	38	9	[a]44		------	208	36	13	------	0	132
				Mar. 15, 1940	------	[a]278	------	------	46	7	[a]51		------	224	44	18	------	------	154
				Dec. 20, 1940	68	263	20	.08	42	8.3	40	3.0	0	204	36	16	------	.1	139
				Feb. 10, 1941	------	[a]240	------	------	40	8	[a]35		------	206	37	17	------	------	133
				Sept. 9, 1942	------	[a]275	11	.35	44	8	[a]51		------	223	40	20	------	------	143
6/10-8D4.	City of Newport Beach, well 8.	258	288	(A) Dec. 19, 1934	------	[a]294	------	------	43	8.0	[a]58		------	213	50	28	------	------	140
				(B) Dec. 19, 1934	------	[a]355	------	------	17	3.0	[a]118		------	227	53	50	------	------	55
				[b](C) Dec. 28, 1934	------	[a]3,253	------	------	113	85	[a]873		------	290	1,567	470	------	------	631
				(D) Jan. 12, 1935	------	[a]280	------	------	19	3	[a]93		------	268	5	26	------	------	60
				(E) Jan. 16, 1935	------	[a]281	------	------	26	6	[a]78		------	231	22	33	------	------	90

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Solids	SiO_2	Fe	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	BO_3	NO_3	Hardness
					Parts per million													
			(F) Jan. 23, 1935		[a]229			40	11	[a]32			192	34	16			145
			(G) Mar. 21, 1935		[a]238			35	7	[a]47			192	37	16			116
			(H) Sept. 4, 1935		[a]251			41	7	[a]46			210	37	15			131
			(I) June 30, 1936		[a]242			37	8	[a]46			205	30	18			125
			(J) Apr. 24, 1937		[a]249			39	6	[a]49			205	35	17			122
			(K) June 6, 1938		[a]243			40	11	[a]40			222	23	18			145
			(L) Feb. 15, 1939		[a]236			40	8	[a]41			209	25	17			133
			(M) Sept. 24, 1939		[a]210			32	6	[a]45			217	3	15			105
			(N) Mar. 9, 1940		[a]234			41	5	[a]45			217	17	17			123
			(O) Sept. 9, 1942		[a]239	11	0.45	39	7	[a]46			223	17	18			126
6/10-8D5. City of Newport Beach, well 7.	258	279	Mar. 3, 1930		[a]228			41	6	[a]38			180	33	20			127
			Sept. 4, 1935		[a]251			40	7	[a]47			210	37	15			129
			June 30, 1936		[a]264			36	7	[a]57			217	35	20			119
6/10-8G1. Sasoku	258	303	Jan. 7, 1932		[a]269			8.0	4	95			222	30	21			36
			[b] Jan. 26, 1932		[a]304			5.0	4	116			[a]249	20	30	2.2	2	29
			Sept. 3, 1937	73	[a]408			3.0	4	162			272	tr	100	2.7	0	24
			Aug. 29, 1939	72	[a]452			9.0	4	170			293	2	119		1	39
			Dec. 6, 1939	72	[a]401			7.0	3	156			276	2	94		1	30
6/10-10D3. The Irvine Co.	258	844	Sept. 14, 1938		[a]364			11	2	[a]145			235	17	71			36
			Sept. 14, 1938		[a]364			10	0	[a]145			248	10	75			25
			Mar. 24, 1939		[a]586			20	9	[a]202		0	278	14	202			87
6/10-10E. ———	258	500	[b] Jan. 21, 1926		891			12	1.2	329	2.5	8.2	258		375			35
6/10-11B1. United States Department of Army, well 1.	258	380	(1) Sept. 29, 1941		230	2.4	.2	17	1.2	[a]74		9.5	190	24	25	.5	.3	47
			(2) Sept. 30, 1941		262	2.0	.3	13	.7	[a]81		7.2	214	14	25	.5	.3	35
			(3) Oct. 5, 1941		228	13	.2	5.6	.8	[a]92		18	180	.8	24	.5	.9	17
6/10-11B2. United States Department of Army, well 2.	258	586	(1) Oct. 13, 1941		220	12	.0	6.9	.9	[a]69		16	137	24	14	1.6	.4	21
			(2) Sept. 19, 1942		220	14	.1	5.0	2.4	[a]77		11	161	19	12	.5	.4	22
			(3) Dec. 1, 1942	83	270	7.6	.05	8.8	1.2	[a]70		5.0	180	17	12	.5	.2	27
			(4) Feb. 1, 1943	85	238	8.0	.05	8.0	.7	[a]73		7.0	185	17	12		.3	23
			(5) Mar. 31, 1943	77	244	14	.2	21	3.4	[a]64		3.0	160	40	20	.0	.1	67
			(6) June 1, 1943	79	298	14	.15	7.3	2.1	[a]77		13	178	22	12	.5	.1	27
			(7) July 31, 1943	79	210	17	.05	5.6	1.9	[a]74		4.0	175	24	14	.5	.1	22
			(8) Oct. 7, 1943	79	230	9.6	.1	14	2.1	[a]63		6.0	154	32	16	.0	.1	44
			(9) Nov. 30, 1943		190	14	.1	4.8	.9	[a]72		5.0	162	26	12	.5	.1	16

				(10) Feb. 29, 1944	83	222	14	.05	6.0	1.4	[a]76		6.9	149	28	16		.2	21
				(11) Aug. 31, 1944		240	19	.07	5.2	1.0	[a]72		.0	162	28	12	.1	.2	17
6/10-17C1.	I. D. Meyer	258	600	Jan. 26, 1932		[a]610			10	3	229			[a]314	0	201	6.1	4	37
6/10-18C1.	Laguna Beach County Water District, well 3.	259	196	Sept. 18, 1939		[a]306		[d]6.7	48	12	[a]54			234	40	35	tr		169
				Oct. 16, 1941		265	22	.1	41	9	[a]40		0	218	23	17			139
				July 31, 1942		277	18	.0	45	9	[a]42		0	216	37	18		.2	149
6/10-18C2.	Laguna Beach County Water District, well 2.	259	190	[b] June 3, 1931		[a]238			39	10	47			[a]204	24	16	.3	0	139
				Sept. 3, 1937	67	[a]305			56	11	44			208	21	68	1.3	0	185
				July 3, 1939	67	[a]279			52	9	43			213	19	49		0	167
				Sept. 22, 1939	67	[a]290			54	10	45			214	17	57		0	176
				Dec. 20, 1940		566	20	.08	102	19	54	3.6	0	203	6.7	199		.0	333
				Oct. 16, 1941		603	19	.01	117	22	[a]72		9	204	6	260			383
				July 31, 1942		676	18	.0	138	24	[a]76		0	201	19	300		.2	443
6/10-18C4.	Laguna Beach County Water District, well 1.	259	410	June 13, 1931		[a]238			40	9	45			201	27	16	.3	0	137
				Nov. 1, 1934		[a]262			48	11	[a]38			217	24	32			165
				Aug. 22, 1939		[a]476			102	18	54			201	7.0	194		0	329
6/10-18J1.	Newport Mesa Irrigation District, well 4.	259	270	Mar. 23, 1931		578	15	1.8	44	14	[a]162			266	0	209			167
				June 13, 1931		[a]583			48	20	157			256	1	229	2.7	0	202
				Nov. 7, 1935		1,056	17	.7	58	18	[a]274			281	2.4	411	2.1		219
				Aug. 22, 1939	68	[a]1,141			104	33	289			267	1	580		0	395
				Mar. 25, 1941		[a]1,046	13	1.3	119	32	[a]241			250		525	3.3		429
				Oct. 16, 1941		1,363	19	.10	115	38	[a]351		0	266	1	700			443
				July 31, 1942		1,419	17	.05	129	40	[a]357		0	268	12	730		.2	487
				May 11, 1944		1,781	14	.3	144	46	[a]420			286	1.9	869	tr		549
				Aug. 14, 1944		1,717	15		152	48	[a]438		0	265	5	925	1.0	1.0	577
6/10-18J2.	Fairview Farms Water Co., well 4.	259	270	June 13, 1931		[a]563			41	12	165			268	0	209	2.2	0	152
				Sept. 18, 1931		[a]613			44	12	183			265	3	234	4.4	0	159
				Sept. 3, 1937	68	[a]1,154			35	43	345			279	tr	585	5.0	1	264

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Solids	SiO_2	Fe	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	BO_3	NO_3	Hardness
					Parts per million													
			Oct. 28, 1937		[a]776			65	25	202			254	4	345	4.4	4	265
			May 1, 1939	68	[a]938			60	20	265			279	23	429	1.1	0	232
			July 3, 1939	68	[a]1,141			69	23	337			281	4	566		1	267
			Oct. 3, 1939	68	[a]705			61	17	193			232	2	315		1	222
			Oct. 16, 1941		1,342	20	tr	79	28	[a]298		0	284	0	670			312
			Apr. 9, 1942	68	1,097	19	0.16	83	25	280	3.4	0	273	2.3	495	3.2	.2	310
			Apr. 12, 1945	66	4,520	12	.41	117	137	1,350	11	0	564	0	2,450	15	1.9	878
6/10-18J3. Fairview Farms Water Co., well 2.	259	290	June 13, 1931		[a]454			27	10	146			250	2	142	2.2	0	109
			Oct. 22, 1936		[a]664			30	13	[a]217			262		273			128
			Oct. 28, 1937	69	[a]821			47	13	255			273	12	349	5.1	3	171
			Aug. 29, 1939		[a]598			27	7	208			247	2	228		2	96
			Dec. 6, 1939	68	[a]883			46	15	282			270	1	403		1	177
			May 16, 1941		[a]974			33	14	[a]343			228		470			140
6/10-18J6. Newport Mesa Irrigation District, well 1.	259	332	Feb. 28, 1921		[a]679			25	7.2	[a]231			321		255			92
6/10-18J9. Fairview Farms Water Co., well 1.	259	302	Oct. 5, 1925		436			29	6.6	124	2.5	5.5	233	1.2	121			100
6/10-18K1. City of Newport Beach, well 4.	259	234	Sept. 11, 1929		[a]273			53	6	[a]45			249	28	16			157
			June 6, 1931		[a]260			40	10	52			207	21	32	1.6		141
			Sept. 18, 1931		[a]287			46	12	50			204	21	55	.7	0	164
			Nov. 9, 1933		[a]240			49	14	[a]24			196	15	40			180
			June 1934		[a]403			84	14	[a]51			207	10	140			267
			Aug. 30, 1934		[a]715			145	27	[a]87			207	10	342			473
			Sept. 11, 1934		[a]877			157	28	[a]136			207	11	441			507
			Sept. 4, 1935		[a]1,178			273	45	[a]102			166	0	675			867
			June 30, 1936		[a]2,227			466	77	[a]255			166	0	1,346			1,481

6/10-18K2.	City of Newport Beach, well 6.	259	330	Oct. 7, 1929		[a]276			32	9	[a]62			205	42	28			117
				Oct. 23, 1933		[a]417			72	15	[a]68			210	14	143			242
				Aug. 30, 1934		[a]1,038			193	38	[a]146			220	7	544			638
6/10-18K3.	City of Newport Beach, well 5.	259	336	Aug. 1, 1927		[a]244	14	[d]2.7	31	.4	[a]65			225	12	23			79
				Mar. 8, 1928		[a]417			40	7.2	[a]175			246	22	50			129
				Sept. 11, 1929		[a]397			36	5	[a]175			237	18	44			111
				Oct. 23, 1933		[a]564			67	15	[a]188			210	14	175			229
				June 1934		[a]665			109	25	[a]110			220	13	298			375
				Aug. 10, 1934		[a]756			128	25	[a]125			207	11	364			423
6/10-18K4.	City of Newport Beach, well 3.	259	270	Oct. 9, 1934		[a]4,305			725	120	[a]724			168	0	2,652			2,305
6/10-18K7.	City of Newport Beach, well 1.	260	340	Oct. 5, 1925		248			29	7.2	45	4.2	2.7	197	19	13		1.0	102
6/10-18L1.	Orange County	260	14	[b] Apr. 22, 1942	66	3,280	20	1.6	336	160	519	21	.0	714	591	1,020		11	1,496
6/11-1C1.	Associated Oil Co.	260	182	[b] June 16, 1931		[a]250			49	13	39			201	30	16	1.4	1	176
				Sept. 5, 1939		[a]255			51	9	34			204	41	18		0	164
6/11-1J2.	U. H. Plaven	260	125	Oct. 9, 1925		259			49	8.4	25	3.3		200	36	10			157
6/11-1N1.	Mrs. W. T. Newland.	260	600	Oct. 14, 1925		329			11	2.4	109	1.7		310	1.2	15		1.0	37
				[b] Oct. 21, 1931		[a]297			13	4	107			311	0	16	1.7	0	49
6/11-2D1.	Turley	260	202	Oct. 21, 1931		[a]2,907			474	110	432			198	14	1,757	18	0	1,636
6/11-2G1.	Southern California Water Co., Clay plant, well 2.	260	252	Oct. 14, 1925		325			59	9.6	40	2.5		213	42	41		2.0	187
				Oct. 18, 1930		[a]402	17	[d]2.6	66	15	[a]67			228	37	103			227
				May 5, 1931		[a]1,321	11	[d]5.1	154	28	[a]316			342	35	617			500
6/11-2G2.	Southern California Water Co., Clay plant, well 4.	260	123	Aug. 11, 1930		1,081	18	[d]1.5	171	30	[a]191			276	39	495			551
6/11-2G4.	Southern California Water Co., Clay plant, well 1.	260	263	Oct. 21, 1930		[a]361	15	[d]2.6	68	12	[a]53			228	41	73			219
				Apr. 5, 1931		[a]869	13	[d]4.1	141	24	[a]156			261	40	377			451
				July 18, 1933		1,066	17	[d]3.0	144	16	[a]184			256	38	408			426
				May 20, 1941	69	3,570	19	.65	452	87	633	22	0	336	37	1,845		.25	1,487
6/11-2J1.	Henry Lacabonne	260	113	Oct. 21, 1931		[a]231			42	10	32			189	32	20	.4		146
6/11-11E1.	Southern California Water Co.	260	447	Oct. 14, 1925		842			81	21	183	4.2		286	24	308			289
6/11-11J2.	L. W. Cady	260	130	Oct. 19, 1931		[a]322			37	12	75			223	24	62	.8	0	142
6/11-11J3.	Mrs. David Stewart.	260	144	Oct. 19, 1931		[a]1,069			216	46	112			192	56	542	.7	0	729
6/11-11K1.	Vernon V. Brown	260	110	Oct. 19, 1931		[a]294			55	9	45			210	34	46	.4	0	174
6/11-11K2.	Jack Long	260	90	Oct. 19, 1931		[a]251			35	10	46			192	2	60	1.5	0	129
6/11-12C2.	Thompson	260	161	[b] Oct. 12, 1925		265			46	5.4	44	2.5	6.8	211	35	10			137
6/11-12E1.	F. E. Farnsworth	260	95	Sept. 5, 1939	70	[a]220			38	8	39			203	20	12		1	128
6/11-12N1.	Standard Oil Co.	260	333	Sept. 18, 1931		[a]504			105	23	53			195	35	190	.5	0	357
6/11-13G2.	Surf Land and Water Co.	261	154	(1) Sept. 3, 1931		[a]212			14	8	56			107	21	59	.2	1	68
				(2) Oct. 19, 1931		[a]232			29	11	49			177	7	46	1.4	0	118
				(3) Oct. 19, 1931		[a]211			14	7	60			107	14	60	2.9	0	64

TABLE 30.—*Chemical analyses of representative native and contaminated waters, 1918–43*—Continued

Well number and source of sample	Notes page	Depth	Date of collection	°F.	Parts per million													
					Solids	SiO_2	Fe	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	BO_3	NO_3	Hardness
6/11-13J1. Deeble-Chapman Corp.	261	150	Nov. 1, 1934	------	[a]924	------	------	162	30	133	------	------	97	104	446	------	------	528
			Sept. 3, 1937	------	[a]2,983	------	------	398	96	595	------	------	279	5	1,730	2.8	17	1,389
			Sept. 22, 1939	------	[a]2,011	------	------	255	52	442	------	------	278	5	1,118	------	0	851
			Apr. 15, 1942	------	423	19	4.3	60	12	78	2.5	0	225	11	122	0	.5	199
6/11-13K2. City of Huntington Beach, treatment plant	261	135	Apr. 15, 1942	67	2,210	18	.50	264	50	426	6.4	0	265	3.8	1,125	------	.2	865
			Sept. 29, 1944	------	32,500	------	.00	376	1,190	[a]10,000		0	156	2,430	17,700	------	------	5,819
6/11-13Q1. A. C. Thorpe, et al.	261	4,980	Apr. 21, 1942	66	8,320	------	5.6	240	28	2,790	56	16	------	2.3	4,870	------	.5	714
I-6G1. The Irvine Co.	261	952	[b] 1920	------	[a]422	------	------	5.0	5.0	[a]165		------	[a]405	22	23	------	------	33
I-8B1. The Irvine Co., plant 51, well 1185.	261	775	1923	------	[a]224	------	------	30	11	[a]40		------	160	42	21	------	------	120
			July 1926	------	[a]259	------	------	25	15	[a]50		------	203	50	17	------	------	124
I-8H1. W. Pollard, well 2	261	592	Apr. 26, 1932	------	[a]2,063	------	------	140	65	[a]500		------	366	715	460	------	------	617
I-9A2. The Irvine Co., plant 81, well 1251.	261	1,186	Feb. 1931	------	[a]314	------	------	62	22	[a]24		------	[a]222	60	35	------	------	245
I-11B1. P. H. Ebel	261	200	[b] Oct. 1918	------	[a]454	------	------	81	23	[a]46		------	243	140	34	------	8	297
I-43F1. The Irvine Co., plant 46, well 1149.	261	271	June 17, 1920	------	[a]595	------	------	52	30	[a]124		------	262	141	110	------	7	253
			May 20, 1925	------	[a]999	------	------	92	28	[a]275		------	348	200	230	------	------	345
			Sept. 25, 1928	------	[a]1,056	------	------	172		[a]214		------	342	240	259	------	------	430
			[b] May 15, 1929	------	[a]954	------	------	96	40	[a]195		------	355	237	208	------	------	404
			June 8, 1929	------	[a]981	------	------	95	41	[a]206		------	346	232	234	------	------	406
			July 3, 1929	------	[a]897	------	------	98	49	[a]161		------	296	191	250	------	------	446
I-45E1. The Irvine Co., plant 19, well 691, pit 2.	261	86	[b] 1920	------	[a]680	------	------	120	34	[a]63		------	256	261	60	------	14	439
I-45G2. Frances Mutual Water Co., well 2.	261	100-368	[b] Aug. 1918	------	[a]345	------	------	53	17	[a]65		------	275	46	24	------	2	202
I-45N1. The Irvine Co., plant 29, well 744, pit 4.	261	31	[b] 1922	------	[a]1,106	------	------	83	46	[a]250		------	300	402	75	------	0	396
I-48B1. The Irvine Co., well 985 (Sprig Gun Club).	262	1,100	Jan. 5, 1926	------	304	------	------	1.4	1.8	112	1.7	18	172	13	51	------	1.0	11

I-62Q1.	The Irvine Co., plant 82, well 1246.	262	1,145	July 3, 1930	------	a435	------	------	70	30	a35		------	225	82	105	------	------	298
I-63A1.	The Irvine Co., plant 80, well 1245.	262	1,553	May 20, 1930	------	a574	------	------	124	25	a40		------	305	172	60	------	------	413
I-63G1.	The Irvine Co., Penman well 1 (well 1271).	262	236	b June 6, 1932	------	a3,059	------	------	128	54	a875		------	560	1,222	500	------	------	541
				June 27, 1932	------	a2,804	------	------	105	60	a850		------	587	1,080	415	------	------	509
I-84G1.	Frances Mutual Water Co., well 9.	232	1,397	b Mar. 30, 1920	------	a618	------	------	41	27	a152		------	334	150	81	------	0	213
				Nov. 1930	------	a565	------	------	102	26	a71		------	330	105	96	------	------	362
I-85A4.	W. L. West, E. T. McFadden, and W. H. Walker.	262	402	Sept. 1929	------	a837	------	------	100	30	a169		------	332	140	232	------	------	373
I-86N1.	The Irvine Co., well 1238.	262	951	b Oct. 2, 1929	------	a456	------	------	64	35	a50		------	244	123	62	------	------	304
I-86R1.	The Irvine Co., plant 48, well 1177.	262	540	Sept. 1929	------	a1,667	------	------	158	94	a275		------	336	722	250	------	------	780
I-88C1.	The Irvine Co., well 297.	262	312	Jan. 4, 1926	------	543	------	------	7.9	.6	198	1.7	------	233	3.6	185	------	------	22
I-102J1.	The Irvine Co., plant 9, well 707.	262	301	b Jan. 1919	------	a540	------	------	49	12	a142		------	223	66	159	------	0	172
				1921	------	a534	------	------	56	17	a136		------	214	66	152	------	0	210
I-106B.	———————	262	980	Jan. 12, 1926	------	1,629	------	------	81	74	331	3.3	------	360	558	248	------	6.0	506
I-121C1.	The Irvine Co., plant 62, well 1223	262	967	July 1928	------	a1,129	------	------	124	70	a175		------	335	375	217	------	------	597
I-123K1.	The Irvine Co., plant 47, well 1193	262	1,525	Mar. 18, 1925	------	a720	------	------	80	24	a150		------	244	188	156	------	------	298
				May 20, 1925	------	a831	------	------	100	30	a160		------	300	203	188	------	------	373
				Jan. 8, 1926	------	787	------	------	86	19	139	4.2	------	219	176	160	------	14	293
				Sept. 25, 1928	------	a722	------	------	113		a151		------	244	173	163	------	------	283
I-140G1.	The Irvine Co., plant 55, well 1210	262	746	May 1927	------	a565	------	------	77	40	a75		------	295	158	67	------	------	357
				b Sept. 1927	------	a562	------	------	80	32	a76		------	283	165	67	------	------	331
				Sept. 25, 1928	------	a545	------	------	88		a115		------	299	125	67	------	------	220
I-142K1.	The Irvine Co., well 298.	262	232	Feb. 1920	------	a1,192	------	------	109	66	a207		------	317	512	135	------	4	543
				b Jan. 24, 1922	------	a1,173	------	------	115	68	a190		------	323	500	138	------	0	566
I-156C1.	The Irvine Co., plant 59, well 1217	262	918	Jan. 3, 1928	------	a901	------	------	90	20	a200		------	244	295	174	------	------	307
				July 1928	------	a870	------	------	90	26	a184		------	244	280	168	------	------	332

Notes to table 30

2/11-7J1. Drilled public-supply well; diam 18 in; casing perforated 55-100 ft below land surface in Gaspur zone of alluvial deposits of Recent age, and 136-160, 256-265, 687-694, and 716-722 ft in undifferentiated Pleistocene deposits and possibly in upper Pliocene deposits. Native calcium bicarbonate water, probably blended from several zones but in substantial part from the Gaspur. Analysis by California Division of Water Resources.

2/11-18F2. Drilled public-supply well; diam 12 in; casing perforated 40-76 ft below land surface in Gaspur zone of alluvial deposits of Recent age, and 221-226, 243-248, 339-347, 354-360, and 405-413 ft in undifferentiated deposits. Native calcium bicarbonate water, probably blended from the several zones. Analysis by California Division of Water Resources.

2/11-18P1. Drilled irrigation well; diam 18 in; casing perforated 161-168, 196-252, 354-363, and 480-490 ft below land surface in undifferentiated Pleistocene deposits. Native calcium bicarbonate water, probably blended. Analysis by California Division of Water Resources.

2/11-30N6. Domestic well; diam 5 in. Native calcium bicarbonate water from alluvial deposits of Recent age or undifferentiated Pleistocene deposits. Analysis by California Division of Water Resources.

2/11-31M. Domestic well. Probably native water from undifferentiated Pleistocene deposits.

2/12-9E2. Drilled industrial well; diam 16 in. Taps undifferentiated Pleistocene deposits. Calcium bicarbonate water, probably native to deeper part of the range penetrated. Analyses by California Division of Water Resources.

2/12-13R1. Domestic well; diam 5 in. Calcium bicarbonate water, native to unconfined body at shallow depth. Analysis by California Division of Water Resources.

2/12-19C. Drilled public-supply well. Penetrates undifferentiated Pleistocene deposits. Calcium sodium bicarbonate water, probably native to deeper part of range penetrated, which may reach a correlative of some part of the San Pedro formation.

2/12-19M1. Drilled public-supply well; diam 12 in; casing perforated 130-134, 150-170, 270-280, and 284-285 ft below land surface in undifferentiated Pleistocene deposits. Native waters from the several zones probably blended. Analysis by California Division of Water Resources.

2/12-26R5. Drilled irrigation well; diam 18 in; casing perforated 233-278, 337-365, and 383-430 ft below land surface in undifferentiated Pleistocene deposits. Native calcium bicarbonate water, probably blended. Analysis by California Division of Water Resources.

2/12-28N1. Drilled irrigation well; diam 12 in. Penetrates undifferentiated Pleistocene deposits. Possibly a blend of native waters from several zones. Analysis by California Division of Water Resources.

2/12-31H1. Drilled industrial and domestic well; diam 12 in; casing perforated 431-465 and 482-499 ft below land surface, probably in unnamed upper Pleistocene deposits. Water native to the zone perforated. Analyses by California Division of Water Resources.

2/12-31M1. Drilled public-supply well; diam 12 in. Penetrates undifferentiated Pleistocene deposits. Analysis in 1925 of calcium bicarbonate water, probably native to deeper part of range penetrated; hydrogen sulfide 0.5 ppm. Analysis in 1939 by California Division of Water Resources indicates incipient deterioration.

2/12-33L1. Drilled domestic and irrigation well; diam 14 in; casing perforated 356-390 ft below land surface in undifferentiated Pleistocene deposits. Calcium bicarbonate water, native to the zone perforated. Analysis in 1925, hydrogen sulfide 0.5 ppm; that in 1931 by California Division of Water Resources.

2/12-34P1. Drilled public-supply well; diam 16 in. Penetrates Gaspur zone in alluvial deposits of Recent age, and undifferentiated Pleistocene deposits below. Native water, possibly a blend from several zones. Analysis by California Division of Water Resources.

2/12-36Q3. Drilled domestic well; diam 10 in. Calcium bicarbonate water, native to unconfined body at shallow depth. Analysis by California Division of Water Resources.

2/13-14L1. Drilled domestic well; diam 8 in. Penetrates undifferentiated Pleistocene deposits. Calcium bicarbonate sulfate water, locally native (?) to zone penetrated. Analysis by California Division of Water Resources.

2/13-15N4. Drilled industrial well; diam 16 in. Passes through Gaspur zone in alluvial deposits of Recent age, into underlying Pleistocene deposits. Calcium bicarbonate water, largely native to deeper part of range penetrated (?). Analyses by California Division of Water Resources.

2/13-25A2. Diam 12 in; casing perforated 220-228 ft below land surface in undifferentiated Pleistocene deposits. Native calcium sodium bicarbonate water. Hydrogen sulfide 0.9 ppm.

2/13-25H2. Drilled domestic and irrigation well; diam 12 in; casing perforated 518–538 and 541–563 ft below land surface in undifferentiated Pleistocene deposits (uppermost San Pedro formation?). Calcium bicarbonate water, native to zone perforated. Hydrogen sulfide 0.6 ppm.

2/13–27B11. Drilled public-supply well; diam 20 in; casing perforated 928–1,600 ft below land surface, probably in San Pedro formation but possibly in upper Pliocene deposits in part. Probably a blend of several waters from range perforated, but substantially native to lower part of San Pedro formation. Analysis by California Division of Water Resources.

2/13–27B14. Drilled public-supply well; diam 12 in. Passes through arm of Gaspur zone in alluvial deposits of Recent age into undifferentiated Pleistocene deposits below. Water largely native to Gaspur zone. Analysis by California Division of Water Resources.

2/13–28G2. Drilled public-supply well; diam 16 in; casing perforated 1,332–1,365, 1,430–1,444, 1,458–1,504, and 1,560–1,567 ft below land surface, probably in lower part of San Pedro formation. (1) Calcium bicarbonate sulfate water, in arm of Gaspur zone in alluvial deposits of Recent age; probably deteriorated. (2), (3), and (4) Formation samples while drilling, respectively at 550, 590, and 990 ft below land surface; calcium bicarbonate waters, native in upper part of so-called San Pedro formation. (5) and (6) Formation samples while drilling, respectively at 1,320 and 1,580 ft below land surface; calcium bicarbonate waters, native in lower part of so-called San Pedro formation. (7) Sample taken after casing perforated and well developed. Manganese 0.02 ppm in analysis (1), 0.18 ppm in (2), 0.2 ppm in (3), 0.11 ppm in (4), 0.06 ppm in (5), 0.15 ppm in (6), 0.03 ppm in (7). Analyses by Smith-Emery Co., Los Angeles.

2/13–28H2. Drilled public-supply well; diam 14 in; casing perforated 93–116 and 123–167 ft below land surface in arm of Gaspur zone in alluvial deposits of Recent age. Calcium bicarbonate sulfate water; some progressive deterioration in quality from 1931 to 1939. Analyses by California Division of Water Resources.

3/9–20M1. Domestic well. Sodium calcium sulfate bicarbonate water; possibly a blend of dissimilar native waters from two or more zones in undifferentiated Pleistocene deposits in flank of Coyote Hills uplift. Analysis by California Division of Water Resources.

3/9–32J1. Drilled industrial well. Native calcium sodium bicarbonate water, from undifferentiated Pleistocene deposits.

3/9–33E2. Drilled industrial well. Probably a blend of native waters from Talbert zone in alluvial deposits of Recent age and from undifferentiated Pleistocene deposits.

3/10–28D1. Drilled irrigation well (former oil well); diam 16 in; casing perforated 210-840 ft below land surface in undifferentiated Pleistocene deposits. Sodium bicarbonate chloride water; locally native, possibly blended from several zones on flank of Coyote Hills uplift. Analysis of June 9, 1931 from H. M. Bergen, Brea, Calif.; that of June 22, 1931 by U. S. Department of Agriculture, Rubidoux Laboratory, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

3/10–28G1. Drilled irrigation well (former oil well); diam 12½ in; casing perforated 180–750 ft below land surface. Sodium bicarbonate water; probably a blend of native waters from several zones, largely in undifferentiated Pleistocene deposits. Analysis of June 9, 1931 from H. M. Bergen, Brea, Calif.; other analyses by U. S. Department of Agriculture, Rubidoux Laboratory, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

3/10–29C1. Drilled irrigation well; casing perforated 144–335 ft below land surface in undifferentiated Pleistocene deposits. Sodium bicarbonate water, probably native locally. Hydrogen sulfide 0.4 ppm.

3/10–30B1. Drilled irrigation well; diam 16 in; casing perforated 275–676 ft below land surface in undifferentiated Pleistocene deposits. Sodium bicarbonate water, possibly a blend of native waters from several local zones. Analysis of June 9, 1931 by Los Angeles Testing Laboratory; that of June 22, 1931 by Orange County Flood Control District (after California Div. Water Resources Bull. 40–A).

3/10–32C2. Drilled irrigation well. Calcium bicarbonate sulfate water, locally native at relatively shallow depth in undifferentiated Pleistocene deposits; in zone of transition between native waters of the Coyote Hills uplift and those of the Downey Plain. Hydrogen sulfide 0.3 ppm.

3/10–32N1. Drilled irrigation well. Local native water in undifferentiated Pleistocene deposits, possibly a blend from several zones. Hydrogen sulfide 3.2 ppm.

3/11–5E. Drilled industrial well. Taps undifferentiated Pleistocene deposits. Sodium bicarbonate water, probably native to deeper part of range penetrated. Hydrogen sulfide 0.2 ppm.

3/11–5Q. Domestic well. Sodium bicarbonate water, essentially native to Pleistocene deposits locally along flank of Coyote Hills, within range penetrated by well. Iodide 0.1 ppm.

3/11–6D. Drilled domestic and industrial well. Taps undifferentiated Pleistocene deposits. Calcium bicarbonate water, essentially native to the range penetrated.

3/11–6P2. Drilled industrial well; diam 12 in; casing perforated 653–670

Notes to table 30—*Continued*

ft below land surface in undifferentiated Pleistocene deposits. Sodium bicarbonate water, essentially native to deeper part of range penetrated and to a zone probably correlative with some part of San Pedro formation. Analysis by California Division of Water Resources.

3/11-16E1. Drilled industrial well; diam 16 in; casing perforated 1,112-1,158 and 1,182-1,238 ft below land surface in undifferentiated Pleistocene deposits (probably equivalent to San Pedro formation). Sodium bicarbonate water; analysis approximate but substantially characteristic of water native to the zone perforated. Analysis by Wilshire Oil Co.

3/11-17B. Drilled irrigation well. Taps undifferentiated Pleistocene deposits. Sodium bicarbonate water, probably native to deeper part of range penetrated and to a zone equivalent to that of well 16E1.

3/11-18G1. Drilled irrigation well, diam 12 in. Calcium bicarbonate water, essentially native in undifferentiated Pleistocene deposits. Analysis by Los Angeles Testing Laboratory (after California Div. Water Resources Bull. 40-A).

3/11-20D. Drilled irrigation well. Taps undifferentiated Pleistocene deposits. Calcium bicarbonate water, probably blended and not all from the deeper zones penetrated.

3/11-26B1. Drilled irrigation well; diam 12 in; casing perforated 695-715 ft below land surface in undifferentiated Pleistocene deposits probably correlative with part of San Pedro formation. Sodium bicarbonate water, locally native to the zone perforated. Hydrogen sulfide 1.4 ppm.

3/11-26D1. Drilled irrigation well; diam 11-5/8 in. Sodium calcium bicarbonate water, essentially native in undifferentiated Pleistocene deposits locally. Analyses by California Division of Water Resources.

3/11-27G1. Drilled domestic and industrial well; diam 12 in. Penetrates undifferentiated Pleistocene deposits and probably reaches a zone correlative with some part of San Pedro formation. Sodium bicarbonate water, essentially native to deeper part of range penetrated (?). Analysis by California Division of Water Resources.

3/11-28D2. Drilled domestic and irrigation well; diam 12 in; casing perforated 551-567, 1,137-1,140, 1,147-1,150, and 1,189-1,193 ft below land surface in undifferentiated Pleistocene deposits. Probably a blend of native waters from the several zones perforated.

3/11-28P2. Drilled domestic and irrigation well; diam 11 in. Sodium calcium bicarbonate water, native to alluvial deposits of Recent age or to uppermost Pleistocene deposits. Analysis by California Division of Water Resources.

3/11-29A. Drilled irrigation well. Taps undifferentiated Pleistocene deposits. Sodium bicarbonate water, presumably native to deepest range of penetration, which is approximately correlative with some part of San Pedro formation. Iodide 0.04 ppm.

3/11-30D1. Drilled domestic and irrigation well; diam 12 in; casing perforated 99-131 (?) ft below land surface, probably in uppermost Pleistocene deposits. Calcium bicarbonate water, essentially native. Analysis by California Division of Water Resources.

3/11-31A1. Drilled irrigation and domestic well; diam 12 in; casing perforated 123-137, 155-165, and 172-176 ft below land surface, probably in unnamed upper Pleistocene deposits. Calcium bicarbonate water, native to the zone perforated. Analysis by California Division of Water Resources.

3/11-32R2. Drilled domestic and irrigation well; diam 12 in; casing perforated 649-659, 679-688, 747-755, 923-926, and 977-1,076 ft below land surface in undifferentiated Pleistocene deposits. Probably a blend of waters native to the several zones perforated.

3/11-32R3. Domestic well; diam 4 in. Taps upper part of undifferentiated Pleistocene deposits. Calcium sodium bicarbonate water, essentially native. Analysis by California Division of Water Resources.

3/11-34J3. Drilled domestic and irrigation well. Native calcuim bicarbonate water from unnamed upper Pleistocene deposits (or an equivalent of uppermost San Pedro formation ?). Hydrogen sulfide 1.0 ppm and trace of iodide.

3/11-34P. Drilled irrigation well. Penetrates undifferentiated Pleistocene deposits and taps a zone probably correlative with upper part of San Pedro formation. Calcium bicarbonate water.

3/11-35J2. Drilled public-supply well; diam 12 in; casing perforated 360-380 ft below land surface in unnamed upper Pleistocene deposits. Analysis of June 1931 shows substantially native calcium bicarbonate water; those of August 1938 and May 1939 show extremes of quality in monthly samples from May 1938 until May 1939, and suggest slight deterioration. Analyses by California Division of Water Resources.

3/12-3M1. Drilled public-supply well; diam 16 in. Passes through Gaspur zone in alluvial deposits of Recent age into underlying Pleistocene deposits, and probably reaches a zone roughly correlative with uppermost part of

San Pedro formation. Calcium bicarbonate water, essentially native to deeper part of range penetrated (?). Analysis by California Division of Water Resources.

3/12-5G. Domestic and irrigation well. Probably taps Gaspur zone in alluvial deposits of Recent age. Native calcium bicarbonate water. Hydrogen sulfide 1.6 ppm.

3/12-6N. Domestic well. Penetrates undifferentiated Pleistocene deposits. Calcium bicarbonate water, native to range penetrated. Hydrogen sulfide 0.2 ppm.

3/12-8F1. Drilled well; diam 16 and 14 in; casing perforated 578-628 ft below land surface in probable correlative of upper part of Silverado zone of San Pedro formation, and 920-926, 990-998, 1,416-1,421, and 1,478-1,492 ft in San Pedro formation. (1) Sampled after perforating below 920 ft; calcium bicarbonate water, essentially native to the zones then perforated. (2) Sampled after perforating 578-628 ft; water substantially identical in character to that of well 9L1 and essentially native to upper zone. Analyses (1) and (2) by Los Angeles County Flood Control District; others by California Division of Water Resources (after Bull. 40-A).

3/12-9L1. Drilled domestic and irrigation well; diam 12 in; casing perforated 409-423, 440-471, and 480-491 ft below land surface, probably in correlative of unnamed upper Pleistocene deposits. Calcium bicarbonate water, native to zone perforated. Analysis in 1925, hydrogen sulfide 0.9 ppm. Analysis in 1931 by California Division of Water Resources.

3/12-10E1. Drilled domestic and irrigation well; diam 12 in; casing perforated 79-98 and 100-141 ft below land surface in Gaspur zone of alluvial deposits of Recent age. Native calcium bicarbonate water. Hydrogen sulfide 0.5 ppm.

3/12-12G2. Drilled irrigation well; diam 12 in; casing perforated 40-112 ft below land surface in alluvial deposits of Recent age or underlying Pleistocene deposits. Calcium bicarbonate water, native to the zone perforated.

3/12-17A. Domestic well. Passes through Gaspur zone in alluvial deposits of Recent age into undifferentiated Pleistocene deposits. Water essentially native to Gaspur zone.

3/12-19L1. Drilled domestic and irrigation well; diam 10 in; casing perforated 106-140 ft below land surface in Gaspur zone of alluvial deposits of Recent age. Calcium bicarbonate water, native to the Gaspur zone. [illegible] of Water Resources.

[illegible] perforated 94-109 ft below land surface in alluvial deposits of Recent age (probably) and 132-140 ft in unnamed upper Pleistocene deposits. Native calcium bicarbonate water, probably blended from the two zones perforated. Analysis by California Division of Water Resources.

3/12-24G. Drilled irrigation well. Passes through alluvial deposits of Recent age into unnamed upper Pleistocene deposits. Native calcium bicarbonate water, possibly blended from several zones.

3/12-26D1. Drilled domestic and irrigation well; diam 18 in; casing perforated 80-83 ft below land surface in alluvial deposits of Recent age, and 632-840 (?) ft in San Pedro formation (probably). Calcium bicarbonate water, probably in large part from the shallower zone perforated.

3/12-29B. Domestic well. Probably draws from unnamed upper Pleistocene deposits. Calcium bicarbonate water, essentially native to range penetrated.

3/12-29K. Irrigation and domestic well. Native calcium sodium bicarbonate water, substantially from deeper part of range penetrated, which reaches approximate correlative of uppermost part San Pedro formation. Hydrogen sulfide 1.1 ppm.

3/12-30C1. Test hole. Calcium bicarbonate water, native to unconfined body at shallow depth; probably concentrated by evaporation from capillary fringe. Analysis by California Division of Water Resources.

3/12-31E. Drilled domestic and irrigation well. Calcium bicarbonate water, essentially native to unnamed upper Pleistocene deposits or to uppermost part San Pedro formation. Hydrogen sulfide 1.5 ppm.

3/12-31E3. Drilled public-supply well; diam 12 and 10 in; casing perforated 705-907 ft below land surface in Silverado zone of San Pedro formation. Calcium bicarbonate water, essentially native to the zone perforated (but largely its upper part ?). Analysis by city of Long Beach.

3/12-31G1. Drilled public-supply well; diam 16 in; casing perforated 316-324, 368-398, 790-820, and 993-990 ft below land surface, probably all in San Pedro formation. Periodic analyses over 6-yr term indicate water drawn from the several zones in variable proportions, so that character of water pumped has ranged substantially and has tended to increase in hardness. Selected analyses show extremes of ordinary range, as follows: (1) Least relative concentration of calcium; probably substantially native to lowest perforated zone. (2) Least relative concentration of bicarbonate and nearly greatest of calcium; probably substantially native to upper perforated zones. (3) Greatest relative concentration of calcium. (4) Greatest

Notes to table 30—*Continued*

relative concentration of bicarbonate; probably essentially native to upper
zone in San Pedro formation.
3/12-32B3. Drilled public-supply well. Taps unnamed upper Pleistocene
deposits of alluvial deposits of Recent age, or both. Analysis in June 1931
is calcium bicarbonate water, probably native to deeper part of range
penetrated. Periodic analyses in 1932-33 indicate progressive change to
sodium bicarbonate water, with substantial increases in sodium, sulfate, and
chloride; probably owing to indraft of shallow water. Analysis in 1931
by California Division of Water Resources.
3/12-33H1. Drilled irrigation well; diam 26 and 12 in; casing per-
forated 778-790 and 852-874 ft below land surface, probably in upper
part of San Pedro formation. Native calcium bicarbonate water, probably
blended from the two zones perforated. Analysis in 1925, hydrogen sulfide
0.9 ppm; those in 1931 and 1939 by California Division of Water Resources.
3/12-33N2. Test hole. Calcium sodium bicarbonate water, native to un-
confined body at shallow depth. Analysis by California Division of Water
Resources.
3/12-33R. Domestic well. Penetrates unnamed upper Pleistocene deposits.
Calcium bicarbonate water, essentially native to the range penetrated. Hydro-
gen sulfide 0.3 ppm.
3/12-36B. Drilled domestic and irrigation well. Probably reaches San
Pedro formation. Calcium bicarbonate water, largely native to deeper part
of range penetrated (?).
3/12-36G1. Drilled domestic and irrigation well; diam 12 in; casing
perforated 167-171 and 197-224 ft below land surface, probably in un-
named upper Pleistocene deposits. Calcium bicarbonate water, native to
zones perforated. Analysis by California Division of Water Resources.
3/13-2B1. Drilled public-supply well; diam 12 in. Probably passes through
arm of Gaspur zone in alluvial deposits of Recent age, into Pleistocene
deposits. Native calcium bicarbonate water, probably blended from several
zones but substantially from deeper part of range penetrated. Analyses in
1931 and 1939 by California Division of Water Resources.
3/13-12Q. Drilled domestic and irrigation well. Penetrates undifferentiated
Pleistocene deposits. Native water, possibly blended from two or more zones.
3/13-14H. Drilled domestic and irrigation well. Penetrates undifferentiated
... deposits. Native water, possibly blended from several zones.

3/13-15M1. Drilled public-supply well; diam 12 in. Probably draws from
unnamed upper Pleistocene deposits. Essentially native water. Analysis by
California Division of Water Resources.
3/13-20H1. Drilled public-supply well; diam 12 in; casing perforated
178-195 ft below land surface in unnamed upper Pleistocene deposits.
Calcium bicarbonate water, essentially native to zone perforated but incipient
deterioration suggested. Analysis by California Division of Water Resources.
3/13-22H3. Drilled public-supply well; diam 16 in; casing perforated
669-688 ft below land surface, probably in San Pedro formation (Silverado
zone ?). Calcium sodium bicarbonate water, native to zone perforated.
Analysis by California Division of Water Resources.
3/13-23A. Drilled domestic and irrigation well. Passes through Gaspur
zone in alluvial deposits of Recent age, into undifferentiated Pleistocene
deposits. Calcium bicarbonate water, probably a blend of waters native to
the Gaspur and underlying zones.
3/13-24B. Drilled domestic and irrigation well. Passes through Gaspur
zone in alluvial deposits of Recent age, into undifferentiated Pleistocene
deposits. Calcium bicarbonate water, probably a blend of waters native to
the Gaspur and underlying zones.
3/13-26H1. Drilled public-supply well; diam 18 in; casing perforated
92-132 ft below land surface in Gaspur zone of alluvial deposits of Recent
age. Calcium bicarbonate water with inordinately large content of sulfate;
probably deteriorated somewhat by water from arm of the Gaspur zone to
the northwest (see analyses for well 2/13-28H2). Analyses by California
Division of Water Resources.
3/13-29G3. Drilled domestic and irrigation well; diam 8 in. Draws from
unnamed upper Pleistocene deposits. Calcium bicarbonate water, substantially
native to the range penetrated but incipient deterioration suggested. Analysis
by California Division of Water Resources.
3/13-31H4. Domestic well; diam 3 in. Taps unnamed upper Pleistocene
deposits. Calcium sodium chloride bicarbonate water, concentrated by evapora-
tion and possibly by the addition of saline waters. Fluoride 0.2 ppm, iodide
0.0 ppm, electrical conductivity 1,470 micromhos. Analysis by E. W. Lohr,
U. S. Geological Survey.
3/13-34D2. Drilled irrigation well; diam 16 in. Probably passes through
unnamed upper Pleistocene deposits into upper part San Pedro formation.
Calcium sodium bicarbonate water, essentially native but possibly blended from

several zones. Analyses by California Division of Water Resources. See table 31, p. 265.

3/13-36D1. Drilled public-supply well; diam 10 in. Taps Gaspur zone in alluvial deposits of Recent age. Calcium bicarbonate water, native to the Gaspur. Periodic analyses indicate virtually no range in chemical character over 5-yr term beginning 1932. Average of 24 analyses between July 5, 1932 and March 3, 1937; 4 analyses excluded.

4/9-7P1. Drilled irrigation well; diam 24 in; casing perforated 200-230, 277-287, 368-372, 380-382, 391-415, 437-464, and 467-492 ft below land surface in undifferentiated Pleistocene deposits. Native waters from several zones probably blended. Analyses by California Division of Water Resources.

4/9-15R1. Drilled irrigation well; diam 20 in. Sodium calcium bicarbonate sulfate water, probably native to undifferentiated Pleistocene deposits locally near flank of Santa Ana Mountains. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

4/9-17H. Drilled domestic and irrigation well. Calcium sodium bicarbonate chloride water, probably native to upper Pleistocene deposits. Hydrogen sulfide 3.2 ppm.

4/9-18N1. Drilled domestic and irrigation well. Essentially native water, probably from upper Pleistocene deposits. Hydrogen sulfide 0.8 ppm.

4/9-21J1. Drilled domestic well. Calcium bicarbonate sulfate water, essentially native locally in undifferentiated Pleistocene deposits. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

4/9-22K1. Drilled domestic and irrigation well; diam 18 in. Calcium bicarbonate sulfate water, essentially native to undifferentiated Pleistocene deposits. Analyses show moderate range over a 10-yr term, probably owing to unequal withdrawal from several zones of somewhat unlike quality. Analyses by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

4/9-22R1. Former irrigation well. Water native to undifferentiated Pleistocene deposits, but character probably influenced by adjacent rocks of Tertiary age. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

4/9-27E1. Drilled irrigation well; diam 27 and 18 in; casing perforated discontinuously 416-792 ft below land surface in undifferentiated Pleistocene ... Calcium sodium bicarbonate water, probably blended from several ... Division of Water Resources.

4/9-30N. Domestic well. Calcium bicarbonate water, native to upper Pleistocene deposits.

4/9-32B2. Drilled public-supply well. Taps upper Pleistocene deposits. Native waters from several zones probably blended. Analyses by California Division of Water Resources.

4/9-32K2. Drilled irrigation well; diam 26 and 16 in; casing perforated 272-283, 367-392, 453-459, 495-528, 615-660, and 760-765 ft below land surface, probably in upper Pleistocene deposits. Probably blends native waters from the several zones perforated. Analysis by California Division of Water Resources.

4/9-33H1. Drilled irrigation well; diam 18 in; casing perforated discontinuously 132-290 and 380-430 ft below land surface in undifferentiated Pleistocene deposits. Calcium magnesium bicarbonate sulfate water, possibly a blend of native waters from the several zones perforated. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

4/10-1D1. Drilled irrigation well; casing perforated 280-385 and 420-455 ft below land surface in undifferentiated Pleistocene deposits. Calcium sodium bicarbonate water, probably a blend of native waters from the two zones perforated. Analysis by California Division of Water Resources.

4/10-1F. Drilled irrigation well. Native water from undifferentiated Pleistocene deposits. Hydrogen sulfide 1.1 ppm.

4/10-2E. Drilled domestic and irrigation well. Probably a blend of native waters from several zones in undifferentiated Pleistocene deposits, and possibly from alluvial deposits of Recent age. Hydrogen sulfide 1.0 ppm.

4/10-2L. Drilled domestic and irrigation well. Native water from undifferentiated Pleistocene deposits. Hydrogen sulfide 0.6 ppm.

4/10-4C1. Drilled irrigation well; diam 12 in; casing perforated 230-254, 257-269, 295-300, and 336-350 ft below land surface in unnamed upper Pleistocene deposits. Calcium bicarbonate sulfate water, probably native in upper part of perforated range. Hydrogen sulfide 0.8 ppm.

4/10-4N. Domestic well. Native water from unnamed upper Pleistocene deposits and possibly from alluvial deposits of Recent age, within but near south margin of transition zone between native waters of Coyote Hills uplift and those of the Downey Plain. Hydrogen sulfide 0.6 ppm.

4/10-6F. Drilled domestic and irrigation well. Taps undifferentiated Pleistocene deposits. Calcium bicarbonate water, probably native to margin of transition zone from waters of the Downey Plain to those of the Coyote Hills uplift. Hydrogen sulfide 2.2 ppm.

Notes to table 30—*Continued*

4/10-7F. Drilled irrigation well. Penetrates Talbert zone in alluvial deposits of Recent age and taps unnamed upper Pleistocene deposits. Essentially native water from the Pleistocene, possibly blended from several zones. Hydrogen sulfide 0.2 ppm and trace of iodide.

4/10-8J1. Drilled irrigation well; diam 14 in; casing perforated 200–208, 282–292, and 295–312 ft below land surface in unnamed upper Pleistocene deposits. Calcium bicarbonate water, probably a blend of native waters from the several zones perforated. Hydrogen sulfide 1.1 ppm.

4/10-13C. Drilled domestic and irrigation well. Calcium bicarbonate water, native to Talbert zone in alluvial deposits of Recent age. Hydrogen sulfide 1.2 ppm.

4/10-14H1. Drilled domestic and irrigation well; casing perforated 326–342 and 392–408 ft below land surface in unnamed upper Pleistocene deposits. Calcium bicarbonate water, native to the zone perforated.

4/10-17K. Drilled domestic and irrigation well. Probably taps Talbert zone in alluvial deposits of Recent age and unnamed upper Pleistocene deposits. Probably a blend of somewhat similar native waters from at least two zones. Hydrogen sulfide 0.8 ppm.

4/10-19F1. Drilled domestic and irrigation well; diam 10 in. Native water of Talbert zone in deposits of Recent age. Analysis by California Division of Water Resources.

4/10-22R. Drilled irrigation well. Probably a blend of waters native to Talbert zone in alluvial deposits of Recent age and to unnamed upper Pleistocene deposits.

4/10-23D1. Drilled irrigation well; diam 16 in; casing perforated 271–305 and 317–401 ft below land surface in unnamed upper Pleistocene deposits. Essentially a native calcium bicarbonate water from beneath the alluvial deposits of Recent age. Analyses by California Division of Water Resources.

4/10-28D1. Drilled irrigation well. Probably a blend of calcium bicarbonate waters native to the Talbert zone in deposits of Recent age and to unnamed upper Pleistocene deposits.

4/10-28J. Drilled irrigation well. Taps Talbert zone in deposits of Recent age and possibly unnamed upper Pleistocene deposits. Native water of the Talbert zone, probably blended with some from lower zones. Hydrogen [illegible] ppm.

[illegible] well; diam 7 in. Earliest analysis essentially [illegible] of Recent age; later analyses show progressive slight change in chemical character over a 19-yr term. Analysis in November 1918 by Association Laboratory, Anaheim, Calif. (after California Div. Water Resources Bull. 40-A); later analyses by California Division of Water Resources.

4/10-30A1. Drilled domestic and irrigation well. Taps Talbert zone in deposits of Recent age and possibly unnamed upper Pleistocene deposits. Native water of the Talbert zone, probably blended with some from lower zones. Hydrogen sulfide 0.2 ppm.

4/10-31Q1. Drilled domestic and irrigation well; diam 12 in. Native water of the Talbert zone in deposits of Recent age. Analysis by California Division of Water Resources.

4/10-34N1. Drilled irrigation well; diam 16 in. Probably a blend of waters native to Talbert zone in alluvial deposits of Recent age and to unnamed upper Pleistocene deposits. Analysis by California Division of Water Resources.

4/10-35C1. Drilled irrigation well; casing perforated 168–178 ft below land surface in Talbert zone of alluvial deposits of Recent age, and 192–198 ft, probably in unnamed upper Pleistocene deposits. Probably a blend of waters native to the two zones.

4/11-1P1. Drilled irrigation well; diam 12 in. Calcium bicarbonate water from Pleistocene deposits which possibly are equivalent to uppermost part of San Pedro formation. Hydrogen sulfide 0.6 ppm and trace of iodide.

4/11-2K. Drilled irrigation well. Taps San Pedro formation or unnamed upper Pleistocene deposits. Calcium sodium bicarbonate water, possibly native to correlative of upper part San Pedro formation. Hydrogen sulfide 0.4 ppm and trace of iodide.

4/11-3P1. Drilled irrigation well; diam 12 in; casing perforated 195–210 and 235–246 ft below land surface, probably in unnamed upper Pleistocene deposits. Essentially a native calcium bicarbonate water. Analysis by California Division of Water Resources.

4/11-6N1. Drilled domestic and irrigation well. Probably taps unnamed upper Pleistocene deposits. Essentially native water for the locality and depth. Hydrogen sulfide 0.5 ppm and trace of iodide.

4/11-8D1. Drilled domestic and irrigation well; diam 12 in; casing perforated 218–233, 298–305, and 313–320 ft below land surface in unnamed upper Pleistocene deposits. Calcium sodium bicarbonate water, essentially native in the range perforated (compare with that of well 8E2 which has greater penetration). Analysis by California Division of Water Resources.

4/11-8E2. Drilled domestic and irrigation well; casing perforated 223–237, 540–548, and 583–618 ft below land surface in unnamed upper Pleistocene deposits, and in San Pedro formation (?). Sodium calcium bicarbonate water, probably a blend of waters native to range perforated, but largely from lower part of that range. Hydrogen sulfide 0.6 ppm.

4/11-9J. Drilled irrigation well. Probably taps unnamed upper Pleistocene deposits. Essentially native water for the locality and depth. Hydrogen sulfide 0.6 ppm.

4/11-10E1. Drilled irrigation well; diam 12 in; casing perforated 553–567, 641–650, 691–700, and 712–731 ft below land surface in Pleistocene deposits possibly equivalent to an upper part of San Pedro formation. Calcium sodium bicarbonate water. Analyses by California Division of Water Resources.

4/11-11G. Drilled irrigation well. Calcium bicarbonate water from Pleistocene deposits which possibly are equivalent to uppermost part of San Pedro formation. Hydrogen sulfide 0.8 ppm.

4/11-13L1. Drilled irrigation well; diam 12 in. Taps unnamed upper Pleistocene deposits or alluvial deposits of Recent age, or both. Essentially native calcium bicarbonate water. Analyses by California Division of Water Resources.

4/11-14K. Drilled irrigation well. Calcium bicarbonate water from Pleistocene deposits which possibly are equivalent to uppermost part of San Pedro formation. Hydrogen sulfide 0.4 ppm.

4/11-16E1. Drilled irrigation well; diam 6 in. Calcium sodium bicarbonate water, essentially native to alluvial deposits of Recent age or latest Pleistocene deposits. Analysis by California Division of Water Resources.

4/11-19K2. Drilled domestic well; casing perforated 417–432 ft below land surface in upper part of Silverado zone of San Pedro formation. Sodium calcium bicarbonate water, essentially native to the perforated zone locally. Hydrogen sulfide 1.0 ppm. See table 31, p. 265.

4/11-19Q1. Drilled public-supply well. Probably draws from unnamed upper Pleistocene deposits. Native calcium sodium bicarbonate water. Analysis by California Division of Water Resources.

4/11-19R1. Casing shot at 3,275–3,295 ft and plugged with cement 3,286–3,294 ft below land surface, probably in upper division Pico formation. Analysis on sample bailed just above plug; sodium bicarbonate water substantially identical in composition with water from that stratigraphic zone higher on flank of Newport-Inglewood structural zone. Analysis by Smith-Emery Co., Los Angeles.

4/11-22H1. Drilled domestic and irrigation well; diam 7 in. Calcium sodium bicarbonate water, essentially native in unnamed upper Pleistocene deposits or possibly in alluvial deposits of Recent age. Analyses by California Division of Water Resources.

4/11-22M1. Test hole. Sodium sulfate water, presumably native to unconfined body at shallow depth. Analysis by California Division of Water Resources.

4/11-24Q1. Drilled irrigation well; diam 12 in; casing perforated 545–599 ft below land surface in unnamed upper Pleistocene deposits or possibly uppermost part of San Pedro formation. Calcium bicarbonate water, native to the zone perforated. Hydrogen sulfide 0.8 ppm.

4/11-26J. Drilled domestic and irrigation well. Probably taps unnamed upper Pleistocene deposits. Probably a blend of native waters from several zones. Hydrogen sulfide 0.6 ppm.

4/11-27J1. Drilled irrigation well; diam 12 and 10 in; casing perforated 527–557 and 939–978 ft below land surface in San Pedro formation. Chemical character suggests water derived largely from upper perforated zone.

4/11-28J1. Drilled domestic and irrigation well; casing perforated 435–460 and 500–530 ft below land surface in uppermost San Pedro formation (?). Native calcium bicarbonate water. Hydrogen sulfide 1.2 ppm. See table 31, p. 266.

4/11-29L2. Drilled well; diam 16 in; casing perforated 382–398 ft below land surface in uppermost part San Pedro formation (?). Native calcium bicarbonate water.

4/11-31F1. Drilled domestic and irrigation well; diam 12 in. Penetrates San Pedro formation (middle part ?). Sodium bicarbonate water native to the stratigraphic zone reached. Analysis in 1925, hydrogen sulfide 0.6 ppm. Analyses in 1931 and 1939 by California Division of Water Resources. See table 31, p. 266.

4/11-34G1. Drilled domestic and irrigation well. Taps San Pedro formation or unnamed upper Pleistocene deposits, or both. Probably a blend of native waters from several zones.

4/11-35Q. Drilled irrigation well. Calcium bicarbonate water, native to Pleistocene deposits and from a zone roughly equivalent to uppermost part San Pedro formation.

4/11-36R1. Drilled domestic and irrigation well; diam 8 in. Calcium

Notes to table 30—*Continued*

bicarbonate water, probably native to the Talbert zone in deposits of Recent age. Analyses by California Division of Water Resources.

4/12-1D. Drilled domestic and irrigation well. Taps undifferentiated Pleistocene deposits. Calcium bicarbonate water, probably blended from several zones.

4/12-3R1. Drilled domestic and irrigation well. Probably passes through unnamed upper Pleistocene deposits into uppermost part San Pedro formation. Calcium bicarbonate water, probably blended from several native waters. Analysis in 1925, hydrogen sulfide 0.4 ppm.

4/12-4J. Domestic well. Native calcium bicarbonate water from unnamed upper Pleistocene deposits or possibly from uppermost part San Pedro formation. Hydrogen sulfide 0.7 ppm.

4/12-6K1. Drilled public-supply well; diam 26 and 16 in; casing perforated 972-1,142 ft below land surface in basal division of San Pedro formation. Under continual withdrawal, yields sodium bicarbonate water approximately of the composition native to the zone perforated; immediately following pump shut-down character of water ranges widely, chiefly in the ratio of sodium to calcium. (1) Average of 55 analyses between August 1934 and December 1940, water substantially native to basal division of San Pedro formation; 8 analyses excluded from average. (2) Analysis by G. J. Petretic, Geological Survey. Fluoride 0.5 ppm.

4/12-8L. Drilled irrigation well. Sodium bicarbonate water native to lower part of Silverado zone in San Pedro formation. Hydrogen sulfide 5.2 ppm.

4/12-9B. Domestic well. May pass through unnamed upper Pleistocene deposits into San Pedro formation. Calcium bicarbonate water, probably a blend of waters native to several zones. Hydrogen sulfide 2.4 ppm.

4/12-13D1. Drilled public-supply well; diam 26 and 16 in; casing perforated 470-484, 530-550, 720-742, and 820-890 ft below land surface, all in San Pedro formation. Native calcium bicarbonate water. Periodic analyses show no substantial range in chemical quality over 9-yr term beginning 1933. Average of 48 analyses between January 1933 and May 1942; 1 analysis excluded.

4/12-13F1. Drilled public-supply well; diam 26 and 16 in; casing perforated [illegible]-914 ft below land surface in San Pedro formation. [illegible] analyses show no substantial [illegible] Average of

35 analyses between January 1933 and November 1935. (2) Average of 34 analyses between April 1936 and September 1940; 4 analyses excluded. (3) Average of 5 analyses between July 1942 and June 1943; 2 analyses excluded.

4/12-13G1. Drilled irrigation well; diam 12 in; casing perforated 140-165 ft below land surface in unnamed upper Pleistocene deposits, and 512-540 ft probably in San Pedro formation. Calcium bicarbonate water, native to the two zones perforated. Hydrogen sulfide 0.9 ppm.

4/12-14B1. Drilled public-supply well; diam 26 and 16 in; casing perforated 300-316, 364-394, and 618-628 ft below land surface, probably in San Pedro formation. Yields calcium bicarbonate water under continual draft, probably in large part from upper two perforated zones. However, first withdrawal after pump shut-down is, at times, a sodium bicarbonate water. Periodic analyses beginning 1932. See table 31, p. 267. (1) Average of 22 analyses between July 1932 and October 1934; 6 analyses excluded. (2) Average of 15 analyses between November 1934 and June 1937; 4 analyses excluded. (3) Average of 20 analyses between July 1937 and October 1939; 7 analyses excluded. (4) Average of 15 analyses between April 1941 and June 1943; 2 analyses excluded.

4/12-14C1. Drilled public-supply well; diam 16 in; casing perforated 240-260 and 294-300 ft below land surface in unnamed upper Pleistocene deposits or in San Pedro formation. Calcium bicarbonate water, native to the zone perforated. Periodic analyses beginning 1933. (1) Average of 87 analyses from January 1933 to December 1940; 4 analyses excluded. (2) Average of 30 analyses from January 1941 to July 1943. (3) Sample after pumping 28 hr; fluoride 0.3 ppm, iron 0.02 ppm in solution when analyzed; analysis by G. J. Petretic, Geological Survey.

4/12-14D1. Drilled public-supply well; diam 26 and 16 in; casing perforated 1,361-1,378, 1,402-1,410, 1,430-1,478, and 1,560-1,655 ft below land surface in basal division of San Pedro formation. Sodium bicarbonate water. Periodic analyses over 10-yr term beginning 1932 indicate minor cyclic fluctuation in proportionate content of bicarbonate and chloride, possibly due to somewhat inconstant draft from the several zones perforated. (1) Greatest relative concentration of bicarbonate. (2) Least relative concentration of bicarbonate. (3) Average of 30 analyses between April 1933 and November 1936; 4 analyses excluded. (4) Average of 11 analyses between December 1936 and November 1937; 1 analysis excluded. (5) Average of 36 analyses between January 1938 and December 1940. (6) Fluoride 0.5 ppm, iron 0.02 ppm in solution when analyzed; analyzed by G. J. Petretic, Geological Survey. (7) Average of 29 analyses between January 1941 and July 1943; 1 analysis excluded.

4/12–14D2. Drilled unused well; diam 12 in; casing perforated 175–180 ft below land surface in unnamed upper Pleitsocene deposits, and 608–618 ft in San Pedro formation. Calcium bicarbonate water, probably a blend of native waters from the two zones perforated.

4/12–14P1. Drilled public-supply well, diam 26, 16, and 13 in; casing perforated 1,024–1,242 and 1,260–1,354 ft below land surface in basal division of San Pedro formation. Sodium bicarbonate water. Periodic analyses over 10-yr term beginning 1933 suggest very small cyclic fluctuations in proportionate content of bicarbonate and chloride. (1) Least relative concentration of bicarbonate. (2) Average of 75 analyses between March 1933 and December 1940; 10 analyses excluded. (3) Average of 25 analyses between April 1941 and July 1943; 1 analysis excluded.

4/12–15B1. Drilled public-supply well; diam 26, 16, and 13 in; casing perforated 952–1,010 ft below land surface in middle to lower part San Pedro formation (Silverado zone ?). Sodium bicarbonate water, native to the zone perforated. Periodic analyses over 8-yr term beginning 1934 suggest very small cyclic fluctuations in chemical character. (1) Average of 22 analyses between May 1935 and February 1937. (2) Average of 20 analyses between March 1937 and November 1938; 1 analysis excluded. (3) Average of 25 analyses between December 1938 and December 1940. (4) Average of 30 analyses between June 1941 and July 1943.

4/12–15D1. Drilled unused well; diam 4 in; casing perforated 256–270 ft below land surface in unnamed upper Pleistocene deposits or in uppermost part of San Pedro formation. Calcium sodium bicarbonate water, native to the zone perforated. Analysis in 1931 by California Division of Water Resources.

4/12–17N1. Drilled public-supply well; diam 26 and 16 in; casing perforated 395–570 ft below land surface in central part Silverado zone of San Pedro formation. Under continual draft yields sodium bicarbonate water, native to the zone perforated. During long shut-downs of pump, calcium bicarbonate water accumulates in well by leakage from unperforated zones; this quickly dissipates in first withdrawal, with ratio of calcium to sodium ranging widely. Periodic analyses beginning 1932. (1) Average of 14 analyses for conditions of continual draft, from June 1931 to December 1934; 15 analyses excluded; substantially the native sodium bicarbonate water. (2) Average of 18 analyses from January 1935 to December 1937; 13 analyses excluded. (3) Average of 18 analyses from January 1938 to October 1940; 15 analyses excluded. (4) Average of 14 analyses from January 1941 to July 1943; 3 analyses excluded. (5) Greatest relative concentration of bicarbonate; water substantially native to lower part Silverado zone. (6) Least relative concentration of bicarbonate.

4/12–17N2. Drilled public-supply well; diam 26 and 16 in; casing perforated 375–550 ft below land surface in central part Silverado zone of San Pedro formation. Like well 17N1, periodic analyses beginning in 1932 indicate native sodium bicarbonate water under continual draft, but with less range in bicarbonate content and somewhat more range in sodium content for such conditions. (1) Average of 20 analyses from July 1932 to September 1934, representing continual draft; 3 analyses excluded. (2) Average of 15 analyses from December 1934 to July 1937; 3 analyses excluded. (3) Average of 16 analyses from August 1937 to December 1940; 4 analyses excluded. (4) Average of 8 analyses from October 1941 to July 1943; 3 analyses excluded.

4/12–17Q1. Drilled public-supply well; diam 26 and 16 in; casing perforated 390–590 ft below land surface in central part Silverado zone of San Pedro formation, and 936–970 ft in basal division San Pedro formation. Periodic analyses from 1932–1941 show substantial range in character depending on conditions of operation and of sampling, but fall largely into two groups, as follows: (1) Average of 10 similar analyses with the greater relative concentration of sodium, water commonly native to the upper zone perforated. (2) Average of 16 similar analyses with the less relative concentration of sodium, a blend of waters native to the two zones perforated and to overlying zones not perforated.

4/12–18R1. Drilled public-supply well; diam 26 and 16 in; casing perforated 287–305 and 540–615 ft below land surface, mainly in lower part Silverado zone of San Pedro formation. Sodium bicarbonate water native to the zones perforated, but some range in ratio of sodium to calcium during first withdrawal after pump shut-down. Periodic analyses beginning 1932. (1) Average of 24 analyses from June 1931 to November 1934; 6 analyses excluded. (2) Average of 4 analyses, February 1937 and April-December 1940; 2 Analyses excluded. (3) Average of 20 analyses from April 1941 to June 1943.

4/12–20C1. Drilled public-supply well; diam 26 and 16 in; casing perforated 153–190 feet below land surface, probably in uppermost part of San Pedro formation, and 286–300, 315–330, and 390–602 feet in Silverado

Notes to table 30—*Continued*

zone of San Pedro formation. See table 31, p. 268. Periodic analyses beginning 1932 span large range in chemical character owing to inconstant proportion in which waters from the several perforated zones are blended under different conditions of operation and of sampling. These fall largely into two groups, with substantial variation in each. (1) Average of 25 similar analyses with high sodium content, a blend containing a large proportion from the lower zone. (2) Average of 34 similar analyses with relatively low sodium content, a blend containing a large proportion from the upper zones. (3) Greatest relative content of bicarbonate. (4) Least relative content of bicarbonate and nearly the least of sodium.

4/12-20D1. Drilled public-supply well; diam 12 in; casing perforated about 960–1,010 ft below land surface in basal division of San Pedro formation. Sodium bicarbonate water, which in composition is intermediate between waters native to basal division of San Pedro formation and to middle part of Silverado zone. (1) Analysis by Margaret D. Foster (*in* Collins, 1923, p. 29); (2) by Smith-Emery Company, Los Angeles.

4/12-20G1. Drilled public-supply well; diam 26 and 16 in; casing perforated 345–357, 420–500, and 707–720 ft below land surface in upper and central parts Silverado zone of San Pedro formation, and 814–828, 859–920, and 972–1,010 ft in lower part Silverado zone and underlying basal division of San Pedro formation. Periodic analyses 1932–40 span moderate range in chemical composition related to inconstant proportion in which waters are drawn from the several zones, and to conditions of sampling. (1) Greatest relative concentration of sodium and of bicarbonate. (2) Least relative concentration of sodium and nearly the greatest of bicarbonate. (3) Least relative concentration of bicarbonate.

4/12-21L1. Drilled unused well; diam 12 and 10 in; casing perforated 800–860 ft below land surface in basal part San Pedro formation. Sodium bicarbonate water, substantially native to the zone perforated. Analysis by Margaret D. Foster (*in* Collins, 1923, p. 29).

4/12-21M2. Drilled public-supply well; diam 26 and 16 in; casing perforated 725–776, 874–885, 912–934, and 952–962 ft below land surface in basal division of San Pedro formation. Sodium bicarbonate water blended from several zones in variable proportions. Periodic analyses beginning 1932 range widely in chemical character. (1) Average of 11 similar analyses [illegible] sodium content, water substantially native to basal division [illegible] analysis in 1931 by California Division of Water Resources. (2) Average of 40 similar analyses showing intermediate sodium content, blended from waters characteristic of all parts of San Pedro formation. (3) Least relative concentration of bicarbonate. (4) Least relative concentration of sodium.

4/12-21M3. Drilled unused well; diam 12 in. Probably draws from upper part of Silverado zone in San Pedro formation. Sodium bicarbonate water, native to the part of Silverado zone penetrated. Analysis in 1921 by Margaret D. Foster (*in* Collins, 1923, p. 29); that in 1931 by California Division of Water Resources.

4/12-21M4. Drilled public-supply well; diam 26, 16, 14, and 10 in; casing perforated 467–514 and 560–600 ft below land surface in central and lower parts of Silverado zone in San Pedro formation, and 755–765 and 785–792 ft in basal division of San Pedro formation. Periodic analyses beginning 1932 fall largely into two groups, with ratios of sodium to calcium of about 4 and about 1. Those with the larger content of sodium are probably from lower part of Silverado zone; those with the smaller content of sodium resemble waters native to the upper part of Silverado zone. (1), (2), (3), and (4) Averages of similar analyses with greatest relative concentration of sodium; 12 analyses averaged in (1), 15 in (2), 19 in (3), and 15 in (4). (5), (6), (7), and (8) Averages of somewhat similar analyses with low relative concentration of sodium; 11 analyses averaged in (5), 8 in (6), 8 in (7), and 10 in (8). (9) and (10) Among high-sodium analyses, greatest and least relative concentrations of bicarbonate, respectively. (11) and (12) Among low-sodium analyses, greatest and least relative concentrations of bicarbonate, respectively.

4/12-21M5. Drilled public-supply well; diam 26 and 16 in; casing perforated 208–330 and 368–610 ft below land surface, substantially throughout Silverado zone of San Pedro formation. Periodic analyses beginning 1932 span moderate range in chemical character owing to inconstant proportion in which waters from the two perforated zones are blended under different conditions of operation and of sampling. These fall largely into two groups, with substantial variation in each. (1) Average of 33 similar analyses with relatively large sodium content; water largely from lower perforated zone. (2) Average of 56 similar analyses with relatively small sodium content; water largely from upper perforated zone. (3) Sample taken after pumping 2 hr; fluoride 0.5 ppm, iron 0.02 ppm in solution when analyzed; analysis by G. J. Petretic, Geological Survey.

4/12-22F1. Test hole. Sodium calcium bicarbonate water, native to unconfined body at shallow depth. Analysis by California Division of Water Resources.

4/12-24B1. Drilled irrigation well; diam 14 in; casing perforated 327-331 ft below land surface in unnamed upper Pleistocene deposits or uppermost part San Pedro formation, and 535-554, 702-705, and 726-734 ft in San Pedro formation. Calcium bicarbonate water, probably blended from the several zones, but largely from the 535-ft zone. Hydrogen sulfide 0.3 ppm.

4/12-24M1. Drilled unused well; diam 4 in; casing perforated 300-318 ft below land surface in uppermost part San Pedro formation. Calcium bicarbonate water, native to the zone perforated.

4/12-24M2. Drilled public-supply well; casing perforated 350-410, 570-600, 632-654, 874-938, and 953-980 ft below land surface, or throughout Silverado zone of San Pedro formation. Periodic analyses over 11-yr term beginning 1932 indicate wide and rudely cyclic range in chemical character, owing to variable proportionate yield from the several zones perforated. (1) Least relative concentration of calcium (and about average content of bicarbonate); essentially characteristic of water native to lower zones perforated. (2) Least relative concentration of bicarbonate. (3) Greatest relative concentration of calcium for average concentration of bicarbonate; essentially characteristic of water native to uppermost zone perforated. (4) Greatest relative concentrations of calcium and of bicarbonate.

4/12-24M4. Drilled public-supply well; casing perforated 320-344, 380-400, 570-595, 890-910, and 930-952 ft below land surface, or throughout Silverado zone of San Pedro formation. Periodic analyses over 11-yr term beginning 1932 indicate moderately wide and somewhat cyclic range in chemical composition, owing to variable proportionate yield from the several zones perforated. (1) Greatest relative concentration of sodium and of bicarbonate; essentially characteristic of waters native to the lower perforated zones. (2) Least relative concentration of bicarbonate. (3) Least relative concentration of sodium.

4/12-25H1. Drilled unused well; diam 10 in; casing perforated 396-496 ft below land surface in upper part of Silverado zone in San Pedro formation. Calcium bicarbonate water, probably native to zone perforated; hydrogen sulfide 0.7 ppm.

4/12-26M1. Drilled domestic and stock well; diam 12 in; casing perforated 667-777 ft below land surface in lower part of Silverado zone in San Pedro formation. Sodium bicarbonate water, essentially native to the zone perforated. Analysis in 1925, hydrogen sulfide 2.1 ppm; that in 1939 by California Division of Water Resources. See table 31, p. 269.

4/12-27K1. Domestic well; diam 4 in; casing perforated 228-237 ft below land surface, probably in uppermost part of Silverado zone in San Pedro formation. Calcium sodium bicarbonate water, native to the zone perforated. Analysis by California Division of Water Resources. See table 31, p. 269.

4/12-27K2. Drilled unused well; diam 12 in; casing perforated 500-570, 695-735, 745-815 ft below land surface in lower half of Silverado zone in San Pedro formation. Sodium bicarbonate water, probably a blend of similar waters native to the zones perforated. Hydrogen sulfide 2.2 ppm.

4/12-27M1. Domestic well; diam 4 in. Probably taps upper part of Silverado zone in San Pedro formation. Sodium bicarbonate water, native to the zone perforated. Analysis by California Division of Water Resources. See table 31, p. 269.

4/12-28B1. Test hole. Water native to unconfined body at shallow depth; concentrated by evaporation from the capillary fringe. Analysis by California Division of Water Resources.

4/12-28H1. Drilled public-supply well; diam 26 and 16 in; casing perforated 768-774, 804-963, 1,086-1,148 ft below land surface in basal division of San Pedro formation. Periodic analyses beginning 1932 are largely of extremely soft sodium bicarbonate water; a relative few range widely in ratio of sodium to calcium. (1) Average of 32 similar analyses with greatest relative concentrations of sodium and of bicarbonate, water substantially native to basal division of San Pedro formation. (2) Average of 31 similar analyses with nearly the greatest relative concentration of sodium but with about average concentration of bicarbonate. (3) Greatest relative concentration of sodium and of bicarbonate. (4) Least relative concentration of bicarbonate with relatively large content of sodium. (5) Least relative concentration of bicarbonate. (6) Least relative concentration of sodium.

4/12-28H4. Drilled public-supply well; diam 26 and 16 in; casing perforated 163-175, 196-205, 322-328, 355-365, 370-394, and 442-470 ft below land surface in upper and central parts of Silverado zone in San Pedro formation. Periodic analyses 1932-37 show very wide range in chemical character, probably because native waters from the several perforated zones blend in variable proportions under different conditions of operation. (1) Greatest relative concentrations of sodium and of bicarbonate. (2) Least

Notes to table 30—*Continued*

relative concentration of bicarbonate with high sodium. (3) Greatest relative concentration of bicarbonate with low sodium. (4) Least relative concentration of sodium and of bicarbonate.

4/12-28H5. Drilled public-supply well; diam 16 in. Probably passes entirely through Silverado zone of San Pedro formation into basal division of San Pedro formation. Sodium bicarbonate water, probably blended from several zones. Analysis by California Division of Water Resources.

4/12-28H6. Drilled public-supply well; diam 26 and 16 in; casing perforated 515-528 and 542-635 ft below land surface in lower part of Silverado zone in San Pedro formation, and 796-978 ft in basal division of San Pedro formation. Periodic analyses beginning 1932 show extremely soft sodium bicarbonate water under continual draft, but a substantial range in ratio of sodium to calcium among samples taken immediately after starting pump. (1) Greatest relative concentration of bicarbonate. (2) Least relative concentration of bicarbonate. (3) Average of 48 similar analyses representing continual draft; water probably blended from those native to basal division and to lower part of Silverado zone in San Pedro formation.

4/12-28H7. Drilled public-supply well; diam 26 and 16 in; casing perforated 170-190, 444-468, and 480-494 ft below land surface in upper and central parts of Silverado zone in San Pedro formation. Periodic analyses beginning 1932 show wide range in chemical character, probably because waters native to the several perforated zones are blended in variable proportions under different conditions of operation and of sampling. (1) Average of 28 selected analyses substantially characteristic of sodium bicarbonate water native to the lowest zone perforated. (2) Greatest relative concentrations of sodium and of bicarbonate. (3) Least relative concentration of bicarbonate with maximum sodium. (4) Least relative concentration of bicarbonate. (5) Greatest relative concentration of bicarbonate with low sodium. (6) Least relative concentration of sodium.

4/12-28H8. Drilled public-supply well; diam 12 in. Probably draws from upper or middle part of Silverado zone in San Pedro formation. Sodium bicarbonate water. Analysis in 1921 by Margaret D. Foster (*in* Collins, 1923, p. 29); that in 1931 by California Division of Water Resources.

4/12-28H9. Drilled public-supply well; diam 12 in. Draws from Silverado zone of San Pedro formation (lower part ?). Sodium bicarbonate water. Average of four analyses, 1933-38.

4/12-28H10. Drilled public-supply well; diam 26 and 16 in; casing perforated 570-630 ft below land surface in lower part of Silverado zone in San Pedro formation, and 866-872, 876-900, 918-954, 1,015-1,020, and 1,028-1,032 ft in basal division of San Pedro formation. Sodium bicarbonate water, probably a blend of waters native to the several zones perforated.

4/12-32G1. Former industrial well; diam 5 (?) in. Taps undifferentiated Pleistocene deposits, probably San Pedro formation. Analysis in March 1932 represents sodium chloride water probably native to the range penetrated—essentially a diluted connate water. Analyzed by California Division of Water Resources. See table 31, p. 269.

4/12-34B1. Drilled domestic well; casing perforated 400-422 ft below land surface in San Pedro formation. Sodium bicarbonate water, native to the zone perforated and essentially identical in composition with water in lower part of Silverado zone. Analyses by California Division of Water Resources. See table 31, p. 269.

4/13-1F1. Drilled domestic and public-supply well; diam 16 in; casing perforated 385-439 ft below land surface in uppermost part of Silverado zone in San Pedro formation. Sodium bicarbonate water. Periodic analyses from 1932 to 1935 show little variation in chemical character. Average of 26 analyses; 4 analyses excluded.

4/13-2P4. Drilled stock and irrigation well; diam 14 in. Doubtless taps Gaspur zone in alluvial deposits of Recent age. Essentially native calcium bicarbonate water; incipient contamination possible. Analysis by California Division of Water Resources. See table 31, p. 270.

4/13-6J1. Domestic and stock well; diam 4 in. Taps unconfined water in unnamed upper Pleistocene deposits. Analyses by California Division of Water Resources. See table 31, p. 270.

4/13-8L1. Dug domestic and irrigation well; diam 36 in. Taps water in unconfined body at shallow depth. Sodium sulfate water, probably concentrated by evaporation or possibly by blending with saline waters. Analyses by California Division of Water Resources. See table 31, p. 270.

4/13-10F1. Observation well bored by Geological Survey; diam 1¼ in. Taps water in unconfined body at shallow depth. Sodium sulfate water concentrated by evaporation and possibly by addition of saline waters; bromide trace, iodide 0.0 ppm; electrical conductivity 14,820 micromhos. Analysis by E. W. Lohr, U. S. Geological Survey. See table 31, p. 271.

4/13-10G3. Domestic well; diam 5 in. Taps Gaspur zone of Recent age. Calcium sulfate water, markedly contaminated; bromide trace, iodide 0.0 ppm, fluoride 0.0 ppm; electrical conductivity 3,570 micromhos. Analysis by E. W. Lohr, Geological Survey. See table 31, p. 271.

4/13-12C1. Abandoned domestic and public-supply well. Probably tapped unnamed upper Pleistocene deposits. Native calcium bicarbonate water. Hydrogen sulfide 0.8 ppm.

4/13-13M1. Former domestic well; diam 6 in. Probably taps part of Silverado zone in San Pedro formation. Sodium bicarbonate water, composition characteristic of waters native to upper part of Silverado zone. Hydrogen sulfide 0.8 ppm.

4/13-14D2. Drilled public-supply well; diam 16 in; casing perforated 108-138 ft below land surface in Gaspur zone of Recent age. Calcium bicarbonate water; slightly contaminated. Analysis in 1942 by E. W. Lohr, Geological Survey; fluoride 0.3 ppm, bromide 0.0 ppm, iodide 0.0 ppm; electrical conductivity 957 micromhos. Later analyses by Smith-Emery Co., Los Angeles.

4/13-14F1. Abandoned irrigation well; diam 12 in; casing perforated 96-109 ft below land surface in Gaspur zone of Recent age. Analysis indicates blending with waters from the perched water body or contamination from surface-disposed salines. Analysis by California Division of Water Resources.

4/13-14L1. Former irrigation well; diam 10 in; casing perforated 90-116 ft below land surface in Gaspur zone of Recent age. Calcium chloride water. Analyses, by California Division of Water Resources, indicate advanced contamination. See table 31, p. 273.

4/13-14M3. Domestic well; diam 2 in. Probably taps upper part of Gaspur zone of Recent age. Calcium sulfate bicarbonate water resulting from contamination. Fluoride 0.6 ppm, bromide 0.0 ppm, iodide 0.0 ppm; electrical conductivity 2,320 micromhos. Analysis by E. W. Lohr, Geological Survey. See table 31, p. 273.

4/13-14M8. Abandoned irrigation well; diam 12 in. Taps Gaspur zone of Recent age. Calcium chloride water resulting from contamination. Analysis by California Division of Water Resources.

4/13-14P1. Observation well bored by Geological Survey; diam 1¼ in. Calcium chloride sulfate water, concentrated by evaporation from capillary [illegible] and probably contaminated by blending with saline waters. Fluoride [illegible] iodide 0.7 ppm; electrical conductivity 8,560 [illegible] See table 31, p. 274.

4/13-14Q2. Abandoned drilled well; diam 8 in; casing perforated 90-112 ft below land surface in Gaspur zone of Recent age. Sodium chloride water, substantially contaminated; sampled 118 ft below land surface. Analysis by California Division of Water Resources.

4/13-14Q4. Drilled domestic and irrigation well; casing perforated 800-900 ft below land surface in central part of Silverado zone in San Pedro formation. Sodium bicarbonate water, essentially native to upper and central parts of Silverado zone. Analyses by California Division of Water Resources. See table 31, p. 274.

4/13-15A2. Drilled public-supply well; diam 10 in; casing perforated 830-980 ft below land surface in central part of Silverado zone in San Pedro formation. Sodium bicarbonate water, native to the zone perforated. Analyses in 1931, 1937, and 1939 by California Division of Water Resources; later analyses by Smith-Emery Co., Los Angeles.

4/13-15A3. Drilled public-supply well; diam 10 in; casing perforated 100-135 ft below land surface in Gaspur zone in alluvial deposits of Recent age. Analysis in 1931, by California Division of Water Resources, indicates calcium bicarbonate water essentially native to the Gaspur zone, though perhaps incipiently contaminated. Later analyses, by Smith-Emery Co., Los Angeles, indicate definite contamination.

4/13-15B3. Drilled public-supply well; diam 12 in; casing perforated 760-780 ft below land surface in uppermost part of Silverado zone in San Pedro formation. Calcium bicarbonate water, native to the zone perforated. Analysis in 1923 (?) by Twining Laboratories; others by Smith-Emery Co., Los Angeles.

4/13-15D1. Drilled irrigation well; diam 10 in; casing perforated 257-265 and 380-395 ft below land surface in upper part of San Pedro formation. Calcium bicarbonate water, essentially native to the zones perforated. Analysis by California Division of Water Resources.

4/13-19H1. Domestic well. Probably taps unnamed upper Pleistocene deposits. Calcium chloride bicarbonate water, essentially native to zone perforated. Fluoride 0.4 ppm, bromide 0.0 ppm, iodide 0.0 ppm; electrical conductivity 849 micromhos. Analysis by E. W. Lohr, Geological Survey.

4/13-19J2. Drilled domestic well; diam 12 in. Probably taps uppermost part of Silverado zone in San Pedro formation. Sodium bicarbonate water, native to the range penetrated. Analysis by California Division of Water Resources. See table 31, p. 275.

4/13-19J4. Former domestic and irrigation well. Probably taps unnamed

Notes to table 30—*Continued*

upper Pleistocene deposits. Sodium chloride bicarbonate water, locally native to zone perforated. Analyses by California Division of Water Resources; that in 1939 suggests contamination. See table 31, p. 275.

4/13-20L1. Drilled public-supply well; diam 12 and 10 in; casing perforated 454-554 ft below land surface in upper part of Silverado zone in San Pedro formation. Sodium bicarbonate chloride water; marked contamination indicated. Analysis by California Division of Water Resources. See table 31, p. 276.

4/13-21H3. Drilled industrial well; diam 24 and 12 in; casing perforated 430-535 and 560-605 ft below land surface in upper and central parts of Silverado zone in San Pedro formation. Sodium bicarbonate water, essentially native to parts of zone perforated. Analysis in January 1931 by Los Angeles Department of Water and Power (after California Div. Water Resources Bull. 40-A); that in July 1931 by California Division of Water Resources; and that in 1932 by Richfield Oil Corp. See table 31, p. 276.

4/13-21Q1. Drilled industrial well; diam 20 and 12 in; casing perforated 435-625 and 641-661 ft below land surface in upper and central parts of Silverado zone in San Pedro formation. Sodium bicarbonate water, essentially native to the deeper part of the range perforated. Analysis by Shell Oil Co.

4/13-21R1. Drilled industrial well; diam 16 in; casing perforated 440-670 ft below land surface in upper and central parts of Silverado zone in San Pedro formation, and 761-780 ft below land surface in lower part of Silverado zone. Analysis indicates deterioration by addition of water from unnamed upper Pleistocene deposits. Analysis by Shell Oil Co.

4/13-22E1. Drilled industrial well; diam 18 in; casing perforated 415-425, 447-527, and 590-645 ft below land surface in upper and central parts of Silverado zone in San Pedro formation. Sodium bicarbonate water, essentially native to the zones perforated. Fluoride 0.2 ppm; electrical conductivity 370 micromhos. Analysis by E. W. Lohr, Geological Survey. See table 31, p. 276.

4/13-22L2. Drilled industrial well; diam 20 and 12 in; casing perforated 411-518, 549-570, and 614-716 ft below land surface in upper and central parts of Silverado zone in San Pedro formation. Sodium bicarbonate water, essentially native to upper part of Silverado zone. Analysis by Tide Water Associated Oil Co.

4/13-23C1. Jetted domestic well; diam 2 in. Taps upper part of the Gaspur zone of Recent age. Sodium chloride bicarbonate water, considerably contaminated. Fluoride 1.5 ppm, iron 0.10 ppm in solution when analyzed. Sampled while pumping about 7 gpm; analysis by G. J. Petretic, Geological Survey. See table 31, p. 276.

4/13-23G2. Drilled public-supply well; diam 26 and 16 in; casing perforated 650-900 ft below land surface in Silverado zone of San Pedro formation. (1) Formation sample during construction of well, from depth 984 ft; sodium bicarbonate water, substantially native to lower part of Silverado zone. (2), (3), and (4) Samples from well following repair of defective casing between February and April 1933; this repair shut off contaminated water which had been entering from overlying Gaspur zone in alluvial deposits of Recent age; sodium bicarbonate water, substantially native to upper part Silverado zone. Analyses by city of Long Beach.

4/13-23L3. Abandoned irrigation well; diam 5 in. Taps Gaspur zone of Recent age. Sodium bicarbonate sulfate water; considerably contaminated. Analysis by California Division of Water Resources.

4/13-26A1. Drilled well; diam 8 in; casing perforated 105-120 ft below land surface in Gaspur zone of Recent age. Calcium sodium bicarbonate water, resulting from contamination. Analyses by California Division of Water Resources.

4/13-26B1. Domestic well; diam 2 in. May reach uppermost part of Gaspur zone of Recent age. Calcium chloride bicarbonate water, resulting from marked contamination. Fluoride 0.1 ppm, bromide 0.0 ppm, iodide 0.5 ppm; electrical conductivity 1,940 micromhos. Analysis by E. W. Lohr, Geological Survey. See table 31, p. 277.

4/13-29M1. Former domestic well; diam 5 in. Taps unnamed upper Pleistocene deposits. Sodium bicarbonate chloride water, deteriorated by blending with water from deposits of similar age to the west. Analysis by California Division of Water Resources. See table 31, p. 278.

4/13-30G1. Drilled public-supply well; casing perforated 210-340 and 400-420 ft below land surface in upper part of Silverado zone in San Pedro formation. Sodium bicarbonate water, essentially native to zone perforated. Analysis by Los Angeles Department of Water and Power. See table 31, p. 278.

4/13-30K1. Drilled public-supply well. Probably taps Silverado zone in

San Pedro formation. Sodium bicarbonate water, essentially native to upper part of Silverado zone. Analyses by Los Angeles Department of Water and Power.

4/13-31E2. Drilled public-supply well; diam 16 and 12 in; casing perforated 425(?)-500 ft below land surface in central part of Silverado zone in San Pedro formation. Sodium chloride water; marked deterioration probably due to blending with shallow water. Analysis by Los Angeles Department of Water and Power.

4/13-31E3. Abandoned drilled public-supply well; diam 16 and 12 in; casing perforated 206–212, 235–240, 340–420, 440–450, 475–530, and 610–630 ft below land surface in upper and central parts of Silverado zone in San Pedro formation. Sodium bicarbonate water, locally native to zone perforated; character probably influenced by connate water in the Silverado zone to the southeast. Analysis by California Division of Water Resources.

4/13-31E4. Drilled public-supply well; diam 20 in; casing perforated 440–560 and 605–655 ft below land surface in central part of Silverado zone in San Pedro formation. Sodium bicarbonate water, local native character, probably influenced by connate water in the Silverado zone southeast of well. Analysis by Los Angeles Department of Water and Power.

4/13-33D1. Drilled public-supply well; diam 20 in; casing perforated 720–800 ft below land surface in lower part of Silverado zone in San Pedro formation. Sodium bicarbonate water. Analysis in November 1939 shows character native to the zone perforated; that in February 1933 approaches character of water native to upper part of Silverado zone; both by Los Angeles Department of Water and Power.

4/13-33D2. Drilled pupblic-supply well; diam 12 in; casing perforated 264–402 ft below land surface in upper part of Silverado zone in San Pedro formation. Sodium bicarbonate water, probably a blend of waters native to upper and lower parts of Silverado zone. Analysis by Los Angeles Department of Water and Power.

4/13-33E2. Drilled public-supply well; diam 12 in. Taps Silverado zone in San Pedro formation. Sodium bicarbonate water, probably locally native but influenced by connate water in the Silverado zone to the south. Analysis in 1931 by California Division of Water Resources; that in 1933 by Los Angeles Department of Water and Power.

4/13-33E8. Drilled public-supply well; diam 20 in. Taps upper part of Silverado zone in San Pedro formation. Sodium bicarbonate water, native to zone perforated; character probably influenced by connate water in the Silverado zone to the south. Analyses by Los Angeles Department of Water and Power.

4/13-33K1. Drilled unused well; diam 12 in; casing perforated 145–159, 162–169, and 172–179 ft below land surface in unnamed upper Pleistocene deposits or upper part of San Pedro formation, or both. Sodium chloride water, highly contaminated. Analysis by California Division of Water Resources.

4/13-34K1. Domestic well; diam 2 in. Taps Gaspur zone of Recent age. Sodium chloride water, highly contaminated. Analyses by California Division of Water Resources. See table 31, p. 278.

4/13-35M1. Former industrial well; diam 12 in. Taps Gaspur zone of Recent age. Sodium chloride water; marked contamination. Analysis by California Division of Water Resources. See table 31, p. 278.

4/13-35M3. Drilled industrial well; diam 12 in; casing perforated 115–139 ft below land surface in Gaspur zone of alluvial deposits of Recent age. Analysis in January 1923 is approximate but may indicate roughly the character of water locally native to the Gaspur; later analyses indicate marked contamination. Analysis (1) by A. R. Maas Laboratories, Los Angeles; (2) and (4) through (10) by Los Angeles Department of Water and Power (all after California Div. Water Resources Bull. 40-A); (3) by Southern California Edison Co., Ltd.; (11) by California Division of Water Resources; and (13) by E. W. Lohr, Geological Survey. Sample in 1942, analysis (13), taken after pumping 13 min at 105 gpm; fluoride, bromide, and iodide 0.0 ppm; electrical conductivity 13,500 micromhos.

4/13-35Q3. Formerly Stewart Curtis Packers, Inc. Drilled well, now abandoned; diam 12 in. Taps Gaspur zone of Recent age. Water highly contaminated. Analysis by Los Angeles Department of Water and Power (after California Div. Water Resources Bull. 40-A).

4/13-35Q4. Formerly Stewart Curtis Packers, Inc. Industrial well, now abandoned; diam 20 in. Water badly contaminated. Analysis by California Division of Water Resources.

5/9-4A1. Drilled unused well; diam 24 in. Local body of native water from undifferentiated Pleistocene deposits; character probably influenced by Tertiary rocks adjacent to the east. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div Water Resources Bull. 40-A).

5/9-8B. Drilled domestic and irrigation well. Taps upper Pleistocene deposits. Calcium bicarbonate sulfate water, possibly a blend of native waters from several zones. Hydrogen sulfide 3.8 ppm.

Notes to table 30—*Continued*

5/9-8J1. Drilled domestic and irrigation well; casing perforated 200–218 ft below land surface in upper Pleistocene deposits. Calcium bicarbonate water substantially native to the zone perforated. Hydrogen sulfide 2.5 ppm.

5/9-9C1. Drilled domestic and irrigation well. Native water from upper Pleistocene deposits. Hydrogen sulfide 4.2 ppm.

5/9-10D1. Drilled irrigation well; diam 16 in. Taps undifferentiated Pleistocene deposits. Calcium bicarbonate sulfate water; native waters of several zones may be blended.

5/9-19A1. Drilled domestic and irrigation well; diam 8 in. Calcium sulfate bicarbonate water native to uppermost part of Pleistocene deposits; essentially unconfined. Analysis by California Division of Water Resources.

5/9-19R1. Drilled irrigation well; diam 15½ in. Taps undifferentiated Pleistocene deposits. Analysis in June 1925, by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40–A), indicates essential character of native calcium sodium bicarbonate water. Later analyses, by California Division of Water Resources, show progressive deterioration owing to influx of water of poor quality, probably from a shallow local body that is highly concentrated.

5/10-2B1. Irrigation well. Native water from Talbert zone in deposits of Recent age, possibly blended with that from underlying upper Pleistocene deposits.

5/10-7J. Irrigation well. Native calcium bicarbonate water from Talbert zone in deposits of Recent age.

5/10-9A1. Domestic well; diam 2 in. Calcium bicarbonate sulfate water, substantially native to unnamed upper Pleistocene deposits. Analysis by California Division of Water Resources.

5/10-9G1. Irrigation well; diam 12 in. Native calcium bicarbonate water from Talbert zone in deposits of Recent age. Analysis in 1931 by California Division of Water Resources.

5/10-9P2. Irrigation well. Calcium bicarbonate water native to unconfined body at shallow depth. Analysis in 1931 by U. S. Department of Agriculture, Rubidoux Laboratory, Riverside, Calif. (after California Div. Water Resources Bull. 40–A); that in 1932 by California Division of Water Resources.

5/10-13B3. Drilled public-supply well; diam 16 in; casing perforated 426–438, 482–487, and 885–907 ft below land surface in undifferentiated Pleistocene deposits. Analysis in July 1938 is of hardest water among 16 samples taken periodically between May 1938 and December 1939; that in August 1938 is of softest of the 16 samples and is inferred to represent substantially native water from the deepest zone perforated. Analyses in 1938 by California Division of Water Desources.

5/10-13B4. Drilled public-supply well; diam 18 in; casing perforated 100–140 ft below land surface in undifferentiated Pleistocene deposits. Native calcium bicarbonate water from the zone perforated. Analysis by California Division of Water Resources.

5/10-13C1. Drilled public-supply well; diam 26 in; casing perforated 214–225, 470–490, 565–574, 582–596, 875–942, and 1,030–1,042 ft below land surface in undifferentiated Pleistocene deposits. Waters native to the several perforated zones probably blended. Analysis by California Division of Water Resources.

5/10-15E1. Domestic and irrigation well; diam 8 in. Probably a blend of calcium bicarbonate waters native to alluvial deposits of Recent age and Pleistocene deposits immediately underlying. Analysis by California Division of Water Resources.

5/10-16J. Domestic and irrigation well. Native calcium bicarbonate water from undifferentiated Pleistocene deposits (upper part of San Pedro formation ?). Hydrogen sulfide 1.2 ppm.

5/10-17H. Drilled irrigation and domestic well. Native water from Talbert zone in deposits of Recent age. *Hydrogen sulfide 0.3 ppm.*

5/10-18B. Drilled irrigation well. Calcium bicarbonate water, substantially native to unnamed upper Pleistocene deposits. Hydrogen sulfide 2.2 ppm.

5/10-19B. Drilled irrigation well. Probably blend of native waters, largely from Talbert zone in alluvial deposits of Recent age but in part from unnamed upper Pleistocene deposits.

5/10-21P1. Drilled domestic well. Native calcium sodium bicarbonate water, probably from alluvial deposits of Recent age. Analyses by California Division of Water Resources. See table 31, *p.* 279.

5/10-23L1. Drilled irrigation well; diam 12 in. Sodium bicarbonate water essentially native to the deepest zone reached, undifferentiated Pleistocene deposits (San Pedro formation ?). Analysis by California Division of Water Resources.

5/10-24F1. Drilled domestic and irrigation well. Calcium bicarbonate sulfate water, locally native within the range of Pleistocene deposits penetrated. Hydrogen sulfide 1.2 ppm.

5/10-25A4. Drilled irrigation well. Sodium bicarbonate water, probably a blend of waters native to several zones in undifferentiated Pleistocene deposits (San Pedro formation ?). Hydrogen sulfide 1.1 ppm.

5/10-25A5. Drilled domestic and irrigation well. Probably a blend of native waters from two or more zones in undifferentiated Pleistocene deposits. Hydrogen sulfide 0.6 ppm.

5/10-26D2. Drilled domestic and irrigation well; diam 12 in. Native calcium sodium bicarbonate water from undifferentiated Pleistocene deposits (upper part of San Pedro formation ?). Analysis by California Division of Water Resources.

5/10-27H. Drilled irrigation well. Native calcium bicarbonate water from unnamed upper Pleistocene deposits. Hydrogen sulfide 0.5 ppm.

5/10-30Q1. Drilled domestic, stock, and irrigation well; diam 7 in; casing perforated 85-138 ft below land surface in Talbert zone of alluvial deposits of Recent age. Calcium bicarbonate water. Fluoride 0.4 ppm; electrical conductivity 552 micromhos. Analysis by E. W. Lohr, Geological Survey.

5/10-32C1. Drilled domestic and irrigation well; diam 7 in. Calcium bicarbonate water native to Talbert zone in alluvial deposits of Recent age. Analysis by California Division of Water Resources. See table 31, p. 281.

5/10-32J2. Abandoned well; diam 6 in; casing perforated 149-163 ft below land surface in alluvial deposits of Recent age. Native calcium sodium bicarbonate water. Analysis by California Division of Water Resources.

5/10-34E1. Drilled unused well; diam 18 and 12 in; casing perforated 250-286 and 336-342 ft below land surface in unnamed upper Pleistocene deposits (?). Sodium bicarbonate sulfate water, probably deteriorated. Analysis by Dr. Carl Wilson, Los Angeles.

5/10-35B. Drilled irrigation well. Native calcium bicarbonate water from unnamed upper Pleistocene deposits. Hydrogen sulfide 0.2 ppm.

5/10-36J. Drilled domestic and irrigation well. Sodium bicarbonate water, possibly a blend of waters native to several zones in undifferentiated Pleistocene deposits. Hydrogen sulfide 1.1 ppm.

5/11-1C. Irrigation and domestic well. Taps undifferentiated Pleistocene deposits and probably yields blended native waters from several zones. Hydrogen sulfide 0.2 ppm.

5/11-4A1. Drilled domestic and irrigation well; diam 12 in; casing perforated 830-849 and 875-913 ft below land surface in San Pedro formation. Calcium bicarbonate water, native to the zone perforated. See table 31, p. 283.

5/11-6A1. Drilled domestic and irrigation well; diam 12 and 10 in; casing perforated 818-891 and 925-975 ft below land surface in San Pedro formation. Sodium bicarbonate water, native to the zones perforated. Hydrogen sulfide 1.0 ppm. See table 31, p. 283.

5/11-8C1. Drilled domestic well; diam 12 in; casing perforated 633-655, 685-697, and 850-870 ft below land surface in San Pedro formation. Sodium bicarbonate water, probably a blend of waters native to the several zones perforated. Analysis in 1925, hydrogen sulfide 2.0 ppm; those in 1931 and 1939 by California Division of Water Resources. See table 31, p. 284.

5/11-9G1. Drilled domestic and irrigation well; diam 12 in. Calcium bicarbonate water, essentially native to San Pedro formation (upper part). Hydrogen sulfide 0.2 ppm. See table 31, p. 284.

5/11-10H1. Drilled domestic well; diam 7 in. Native calcium bicarbonate water from the Talbert zone ("80-foot gravel") in deposits of Recent age. Analyses by California Division of Water Resources. See table 31, p. 284.

5/11-12A2. Drilled domestic and irrigation well; diam 10 in. Native water from Talbert zone in deposits of Recent age. Analyses by California Division of Water Resources.

5/11-13D1. Drilled domestic and stock well; diam 8 in. Native calcium bicarbonate water from the "80-foot gravel" in deposits of Recent age. Analysis by California Division of Water Resources. See table 31, p. 285.

5/11-13L1. Drilled irrigation well; diam 7 in; casing perforated 280-300 ft below land surface, probably in unnamed upper Pleistocene deposits. Calcium bicarbonate water native to the zone perforated. Hydrogen sulfide 2.7 ppm. See table 31, p. 285.

5/11-14C2. Drilled irrigation well; diam 8 or 10 in; casing perforated 600-700 ft below land surface, probably in San Pedro formation. Calcium bicarbonate water, presumably native. Hydrogen sulfide 0.3 ppm.

5/11-15M. Drilled irrigation well. Probably taps San Pedro formation (lower part ?). Sodium bicarbonate water, possibly a blend of native waters from several zones. Hydrogen sulfide 2.1 ppm.

5/11-17E2. Domestic well; diam 2 in; casing perforated 145-153 ft below

Notes to table 30—*Continued*

land surface in unnamed upper Pleistocene deposits (?). Calcium bicarbonate
water, native to the shallow zone perforated. Analyses by California Division
of Water Resources. See table 31, p. 286.
5/11–18P4. Observation well bored by Geological Survey; diam 1¼ in.
Highly concentrated sodium chloride water, native to unconfined body at
shallow depth. Bromide trace, iodide 0.0 ppm; electrical conductivity 76,900
micromhos. Analysis by E. W. Lohr, Geological Survey. See table 31, p. 287.
5/11–18R1. Drilled well used for filling ponds; diam 12 in. Taps San
Pedro formation and possibly upper division of Pico formation. Sodium bi-
carbonate water, native to the zone perforated. Fluoride 0.5 ppm; electrical
conductivity 349 micromhos. Analysis by E. W. Lohr, Geological Survey.
See table 31, p. 287.
5/11–21P2. Unused well; diam 6 in. Calcium bicarbonate chloride water,
native to unconfined body at shallow depth. Analysis by California Division
of Water Resources.
5/11–21Q1. Drilled domestic and irrigation well; diam 12 in. Sodium
bicarbonate water, essentially native to the deepest zone penetrated, which
is San Pedro formation (lower part). Analysis by California Division of
Water Resources. See table 31, p. 288.
5/11–21Q3. Drilled well; diam 7 in. Calcium sodium bicarbonate water,
essentially native to unnamed upper Pleistocene deposits or uppermost part
of San Pedro formation. Analysis by California Division of Water Resources.
See table 31, p. 288.
5/11–23A1. Drilled public-supply well; diam 12 in; casing perforated
discontinuously from 208 to 258 ft below land surface in unnamed upper
Pleistocene deposits or San Pedro formation. Calcium bicarbonate water
native to the zone perforated. Analyses by California Division of Water
Resources. See table 31, p. 289.
5/11–23P. Sodium bicarbonate water, probably native to upper division
of Pico formation. Hydrogen sulfide 6.8 ppm.
5/11–26H1. Domestic well; diam 7 and 4 in. Native calcium bicarbonate
water from uppermost part San Pedro formation or from overlying unnamed
upper Pleistocene deposits. Hydrogen sulfide 2.7 ppm. See table 31, p. 290.
Drilled public-supply well; diam 12 (?) in; casing per-
below land surface, uppermost perfora-
perforations in

San Pedro formation. Calcium bicarbonate water initially; later analysis
indicates contamination. Analysis in 1939 by Smith-Emery Co., Los Angeles.
Analysis in 1943 by W. F. White, Geological Survey, of sample taken after
pumping 16½ hrs at 740 gpm; fluoride 0.4 ppm; no evidence of barium
or bromide; electrical conductivity 1,110 micromhos. See table 31, p. 290.
5/11–26M2. Drilled public-supply well; diam 12 in; casing perforated
60–85, 175–180, and 254–256 ft below land surface, uppermost perforations
probably in alluvial deposits of Recent age ("80-foot gravel") and deeper
perforations in San Pedro formation. Calcium bicarbonate water; analyses
indicate incipient contamination after 1939. Analyses of Nov. 9, 1931 and
April 27, 1939 by Smith-Emery Co., Los Angeles; that of Dec. 4, 1942 by
W. F. White, Geological Survey; all others by California Division of Water
Resources. Analysis of December 1942, fluoride 0.9 ppm; no evidence of
barium, iodide, or bromide; electrical conductivity 835 micromhos. See
table 31, p. 292.
5/11–26P1. Former domestic and irrigation well; diam 6 in. Sodium bi-
carbonate water, probably native to the San Pedro formation (lower part ?).
Hydrogen sulfide 4.9 ppm.
5/11–28K1. Drilled well used to fill ponds; diam 14 in; casing perforated
293–332 and 391–396 ft below land surface in San Pedro formation and
721–749, 766–782, 810–817, and 840–848 ft in upper division of Pico forma-
tion. Sodium bicarbonate water, probably in large part from San Pedro
formation. Analysis by California Division of Water Resources. See table
31, p. 294.
5/11–29C1. Drilled public-supply well; diam 12 in; casing perforated
333–357 and 384–416 ft below land surface in San Pedro formation. Sodium
bicarbonate water, substantially native to the two zones perforated. Analysis
in October 1925, hydrogen sulfide 1.3 ppm; those in 1931 and 1939 by Cali-
fornia Division of Water Resources.
5/11–29P1. Formerly Bolsa Land Co. Drilled unused well; diam 12 in;
casing perforated 484–524 ft below land surface in lower part of San
Pedro formation. Sodium chloride water, essentially native to the range
penetrated. See table 31, p. 295.
5/11–34F. Industrial well. Taps upper part of San Pedro formation.
Calcium chloride water, contaminated. Hydrogen sulfide 1.3 ppm.
5/11–34H. Domestic and industrial well. Probably taps San Pedro forma-

tion. Calcium bicarbonate chloride water, definitely contaminated. Hydrogen sulfide 1.5 ppm.

5/11-35L1. Drilled domestic and irrigation well; diam 16 in. Taps San Pedro formation. Calcium chloride water, contaminated. Fluoride 0.3 ppm, iodide 0.0 ppm; electrical conductivity 1,590 micromhos. Analysis by E. W. Lohr, Geological Survey. See table 31, p. 296.

5/11-35P1. Drilled industrial well; diam 12 in; casing perforated 213-246 and 337-367 ft below land surface in central and lower parts of San Pedro formation. Analysis in 1931 indicates sodium bicarbonate water native to lower part San Pedro formation; those in 1937 and 1939 show contamination; all by California Division of Water Resources. See table 31, p. 296.

5/12-1D. Well used to fill ponds. Probably draws from upper part San Pedro formation. Sodium bicarbonate water, possibly a blend of waters native to several zones in the range penetrated. Hydrogen sulfide 3.8 ppm.

5/12-2J2. Drilled industrial well; casing perforated 290-326 ft below land surface in San Pedro formation (stratigraphically equivalent to upper part of Silverado zone). Sodium bicarbonate water, native to zone perforated. Hydrogen sulfide 4.5 ppm. See table 31, p. 297.

5/12-12P1. Drilled domestic and irrigation well; diam 12 in. Taps upper part of San Pedro formation. Sodium chloride water, markedly contaminated. Fluoride 0.4 ppm; no iodide; electrical conductivity 783 micromhos. Analysis by E. W. Lohr, Geological Survey. See table 31, p. 298.

5/12-12Q. Drilled irrigation well. Taps San Pedro formation, probably lower part. Sodium bicarbonate water, similar to that native in deeper part of range penetrated. Hydrogen sulfide 2.8 ppm.

5/12-13D1. Deep observation well drilled by Geological Survey on coastal side of Newport-Inglewood structural zone. Rotary-drilled well; diam 6 and 4 in; casing perforated 190-210 ft below land surface in San Pedro formation. Sodium chloride water; somewhat diluted connate water native to zone perforated. No bromide or iodide; electrical conductivity 28,020 micromhos. Analysis by E. W. Lohr, Geological Survey. See table 31, p. 299.

5/13-3D1. Industrial well; diam 3 in. Taps Gaspur zone of Recent age. Sodium chloride water indicates advanced contamination. Analyses by California Division of Water Resources. See table 31, p. 299.

5/13-3H. Oil well. Formation sample at 1,300 ft below land surface, in upper division of Pico formation. Sodium bicarbonate water, probably native to the zone locally.

5/13-6D1. Drilled industrial well; diam 26 and 16 in; casing perforated 809-888 ft below land surface in central part of Silverado zone in San Pedro formation. Sodium chloride water, locally native to the zone perforated; essentially a diluted connate water. Analyses through 1930 by Los Angeles Department of Water and Power; those in 1932-33 by California Division of Water Resources.

6/10-1E2. Drilled public-supply well; diam 16 in; casing perforated 580-945 ft below land surface in San Pedro formation. Sodium bicarbonate water, locally native to the zone perforated. Sample of April 16, 1942 withdrawn from pipe line a mile from well; analysis by E. W. Lohr, Geological Survey; fluoride 0.7 ppm; electrical conductivity 370 micromhos. Other analyses by Metropolitan Water District.

6/10-2H1. Drilled domestic, stock, and irrigation well; diam 12 and 10 in. Calcium sulfate water of high concentration, in upper Pleistocene deposits. This water is moderately extensive and has been inconstant in chemical character; however, the dissolved materials are necessarily native to the stratigraphic range penetrated. Underlain by water of good quality, as in wells 6/10-2H3, 1E2, and 3H2. Sample from storage tank; analysis by E. W. Lohr, Geological Survey; fluoride 0.2 ppm; no iodide; electrical conductivity 3,390 micromhos. See table 31, p. 300.

6/10-2H3. Drilled domestic and irrigation well; diam 10 in. Sodium bicarbonate water, locally native to the San Pedro formation in the lowest part of the range penetrated. Hydrogen sulfide 1.9 ppm.

6/10-3H2. Drilled domestic and irrigation well; diam 10 in. Sodium bicarbonate water, locally native to the San Pedro formation in the lowest part of the range penetrated. Hydrogen sulfide 3.2 ppm. See table 31, p. 300.

6/10-6B1. Drilled irrigation well; diam 10 in. Calcium bicarbonate water, native to Talbert zone in alluvial deposits of Recent age. Hydrogen sulfide 0.3 ppm. See table 31, p. 301.

6/10-7K5. Drilled public-supply well. Water native to Talbert zone in alluvial deposits of Recent age. Analysis in 1939 by California Division of Water Resources; that in 1942 by Metropolitan Water District. See table 31, p. 302.

6/10-8D2. Drilled public-supply well; diam 18 in; casing perforated 75-108 ft below land surface in Talbert zone of alluvial deposits of Recent age. Calcium sodium bicarbonate water, native to the Talbert zone in central and southern parts of Santa Ana gap but shows some affinity to native waters of the San Pedro formation (see analysis for well 8G1). Analysis of Dec. 6, 1939 by Citrus Experiment Station, Riverside, Calif. Analysis of Dec. 20, 1940 by G. J. Petretic, Geological Survey; fluoride 0.5 ppm, iron 0.02 ppm

Notes to table 30—*Continued*

in solution when analyzed. Other analyses by Dr. Carl Wilson, Los Angeles. Sept. 9, 1942 is date the latest sample was received in the laboratory. See table 31, p. 302.

6/10–8D4. Drilled public-supply well; diam 18 in. Well drilled initially 288 ft deep, through Talbert zone in alluvial deposits of Recent age and into San Pedro formation. Analytical data span wide range of conditions, as follows: (1) Bailed sample during construction, depth 96 ft; native sodium calcium bicarbonate water from Talbert zone, character shown approximately. (2) Bailed sample during construction, depth 232 ft; sodium bicarbonate water, locally native to the particular zone in the San Pedro, character shown approximately (compare with analyses for depths of 380 and 424 ft in well 6/10–10D3). (3) Bailed sample during construction, depth 270 ft; sodium sulfate water of high concentration, such as occurs widely in Pleistocene and Tertiary rocks along flank of Santa Ana Mountains and of Coyote Hills (compare with analyses for depth 725–770 ft in well 10D3 and for well 10E, which are dilute sodium chloride waters). (4) Casing perforated 211–241 ft below land surfaces in San Pedro formation; sampled during pumping test; analysis shows essential character of sodium bicarbonate water native to the zone perforated. (5) Casing perforated 86–106 ft below land surface in Talbert zone and temporary plug set below perforations; sampled during pump test; analysis shows some water from lower zone passing plug. (6) Casing filled with sand to 206 ft below land surface, with cement plug 198–206 ft, and reperforated 86–106 ft; sampled during pump test; analysis shows essential character of calcium bicarbonate water native to Talbert zone. (7) to (15) Sampled during public-supply service; analyses indicate small amount of water drawn from below plug. Sulfate content of (13) probably low. Analysis (15) of sample received in laboratory Sept. 9, 1942. Analyses (1), (2), and (3) by city of Long Beach; others by Dr. Carl Wilson, Los Angeles.

6/10–8D5. Drilled public-supply well; diam 12 in; casing perforated 78–93, 95–112, 192–197, and 207–212 ft below land surface in Talbert zone of Recent age and in San Pedro formation. Calcium bicarbonate water; native to zone or zones tapped. Analyses by Dr. Carl Wilson, Los Angeles. See table 31, p. 302.

6/10–8G1. Abandoned irrigation well; diam 12 in; casing perforated 169–178, 210–243, 278–286 ft below land surface in San Pedro formation. Analysis of January 7, 1932, by city of Los Angeles Biological Laboratory (after California Div. Water Resources Bull. 40–A), is of sodium bicarbonate water locally native to the zone tapped; later analyses, by California Division of Water Resources, show progressive deterioration.

6/10–10D3. Unused well; diam 12 in; drilled initially to 1,060 ft, into very saline water; casing plugged at 844 ft below land surface and perforated 725–770 ft in San Pedro formation. Analyses in September 1938, by Dr. Carl Wilson, on formation samples taken at 380 and 424 ft during construction of well; these are essentially identical, a sodium bicarbonate water probably native to that zone and similar to water of well 6/10–2H3. Analysis in March 1939, by University of California, of 725– to 770–ft zone during pump test; this is sodium chloride water, of diluted connate origin, locally native in the zone perforated and similar in character to water of well 6/10–10E.

6/10–10E. Former domestic and irrigation well. Sodium chloride water of diluted connate origin, essentially native to the San Pedro formation locally, in a zone underlying that tapped by well 6/10–8G1. Hydrogen sulfide 6.3 ppm.

6/10–11B1. Drilled well; diam 16 in. Well originally drilled to depth of 602 ft and casing perforated 378–438 ft below land surface in San Pedro formation; later plugged at 380 ft and perforated at 240–262 ft below land surface in upper part of San Pedro formation. Sodium bicarbonate water, native to lower part of San Pedro formation. Analyses by U. S. Engineer Laboratory. (1) Sampled at depth 242 ft (bailed sample ?). (2) Sampled at depth 500 ft (bailed sample ?). (3) Sampled during pump test, water probably from lower perforated interval. Fluoride 0.2 ppm in analysis (1), 0.1 ppm in (2), none in (3). See table 31, p. 303.

6/10–11B2. Drilled well; diam 16 in; casing perforated 271–292, 298–301, and 338–372 ft below land surface in San Pedro formation. Sodium bicarbonate water, native to zones perforated. Fluoride 0.6 ppm in analyses (1), (7), and (11); 0.1 ppm in (2); 0.9 ppm in (3); 0.2 ppm in (4); 0.3 ppm in (5); 0.5 ppm in (6) and (9); 0.4 ppm in (8); 0.7 ppm in (10). Analyses by U. S. Engineer Laboratory. See table 31, p. 303.

6/10–17C1. Drilled irrigation well; diam 12 in. Sodium chloride water, locally native to the San Pedro formation; of modified connate origin, extending eastward from a structural trap along east flank of Santa Ana

Gap (see comment on analyses for well 10D3). Analysis by California Division of Water Resources. See table 31, p. 303.

6/10–18C1. Drilled public-supply well; diam 16 in; casing perforated 100–136 ft below land surface in Talbert zone of Recent age. Analysis in September 1939, by Smith-Emery Co., Los Angeles, made shortly after well placed in operation; those in 1941 and 1942, by Metropolitan Water District, indicate less dissolved solids. See table 31, p. 303.

6/10–18C2. Drilled public-supply well, now unused; diam 16 in; casing perforated 98–143 ft below land surface in Talbert zone of alluvial deposits of Recent age. Analysis of June 3, 1931 shows probable character of native sodium calcium bicarbonate water; later analyses show incipient and advanced contamination. Analyses in 1931, 1937, and 1939 by California Division of Water Resources; that in 1940 by G. J. Petretic, Geological Survey, fluoride 0.3 ppm, iron 0.02 ppm in solution when analyzed; those in 1941 and 1942 by Metropolitan Water District. See table 31, p. 304.

6/10–18C4. Drilled public-supply well, now unused; diam 16 in; casing perforated 100–163 ft below land surface in Talbert zone of Recent age. As in well 18C2, analysis in 1931 shows probable character of native water; later analyses indicate progressive contamination. Analysis in 1934 by Dr. Carl Wilson, Los Angeles; others by California Division of Water Resources. See table 31, p. 304.

6/10–18J1. Drilled public-supply well; casing perforated 145–245 ft below land surface in San Pedro formation. Sodium chloride water, resulting from blending in increasing proportions with connate waters underlying Newport Mesa. Analyses in June 1931 and in 1939 by California Division of Water Resources; those in March 1931, in 1935, in March 1941, and in May 1944 by Smith-Emery Co., Los Angeles; others by Metropolitan Water District. See table 31, p. 305.

6/10–18J2. Drilled public-supply well; diam 18 in; casing perforated 156–256 ft below land surface in San Pedro formation. Sodium chloride water; analyses indicate blending of meteoric water with connate water in varying proportions. Analysis in October 1941 by Metropolitan Water District. That in April 1942 by E. W. Lohr, Geological Survey; fluoride 0.3 ppm, iodide 0.4 ppm; electrical conductivity 1,950 micromhos. Analysis in April 1945 by T. Downer, Geological Survey, on sample bailed from about 260 ft below land surface after pump had been idle at least one week, suggests character of connate water locally native in the San Pedro formation to the east; strontium 20 ppm, essentially no barium, fluoride 0.7 ppm, iodide 1 ppm; electrical conductivity 7,770 micromhos. Other analyses by California Division of Water Resources. See table 31, p. 305.

6/10–18J3. Drilled public-supply well; diam 12 in. Taps Talbert zone of Recent age and possibly San Pedro formation of Pleistocene age. Analysis in June 1931 indicates probable native character of water existing locally within range penetrated; later analyses indicate blending with connate waters, resulting in deterioration. Analysis in 1936 by Smith-Emery Co., Los Angeles; that in 1941 by California Department of Public Health; others by California Division of Water Resources. See table 31, p. 306.

6/10–18J6. Abandoned public-supply well; casing first perforated 194–222 and 265–314 ft below land surface in San Pedro formation, but later plugged at 101 ft and perforated 65–101 ft below land surface in Talbert zone of Recent age. Sodium chloride water, probably native to San Pedro formation through first perforations. Analysis, by Baverstock and Payne, recomputed from hypothetical constituents.

6/10–18J9. Abandoned public-supply well. Taps Talbert zone of Recent age or San Pedro formation of Pleistocene age, or both. Sodium bicarbonate chloride water, native to zone perforated. Hydrogen sulfide 3.1 ppm.

6/10–18K1. Abandoned public-supply well; diam 18 in; casing perforated 100–200 ft below land surface in Talbert zone of Recent age and in San Pedro formation of Pleistocene age. Analysis in 1929, by Los Angeles Department of Water and Power, is of calcium bicarbonate water native to zones tapped. Subsequent analyses indicate progressive deterioration; those in 1931 by California Division of Water Resources and those in 1933–36 by Dr. Carl Wilson, Los Angeles.

6/10–18K2. Abandoned public-supply well; diam 18 in; casing perforated 100–142 ft below land surface in Talbert zone of Recent age. Initially sodium bicarbonate water. Analysis in 1929 by Los Angeles Department of Water and Power; those in 1933–34, by Dr. Carl Wilson, Los Angeles, indicate advanced deterioration.

6/10–18K3. Abandoned public-supply well; diam 18 in; casing perforated 190–260, 276–306, and 312–330 ft below land surface in San Pedro formation of Pleistocene age. Analysis in August 1927 doubtless indicates character of water native to zone tapped; subsequent analyses indicate incipient and advanced deterioration. Analyses in 1927 and 1928 by Smith-Emery Co., Los Angeles; that in 1929 by Los Angeles Department of Water and Power; those in 1933 and 1934 by Dr. Carl Wilson, Los Angeles.

6/10–18K4. Abandoned public-supply well; diam 14 in. Taps Talbert

Notes to table 30—*Continued*

zone of Recent age or San Pedro formation, or both. Calcium sodium chloride water; indicative of advanced deterioration. Analysis by Dr. Carl Wilson, Los Angeles.

6/10–18K7. Abandoned public-supply well. Taps either Talbert zone of Recent age or San Pedro formation of Pleistocene age, or both. Sodium bicarbonate water, native to zone or zones tapped. Hydrogen sulfide 1.9 ppm.

6/10–18L1. Observation well bored by Geological Survey; diam 1¼ in. Sodium calcium chloride water, native to unconfined body at shallow depth. Fluoride 1.3 ppm, iodide absent; electrical conductivity 4,880 micromhos. Analysis by E. W. Lohr, Geological Survey. See table 31, p. 306.

6/11–1C1. Drilled domestic, industrial, and irrigation well; diam 10 in; casing perforated 130–146 and 168–182 ft below land surface in San Pedro formation or possibly in unnamed upper Pleistocene deposits. Calcium sodium bicarbonate water, native in the zone perforated. Analyses by California Division of Water Resources. See table 31, p. 307.

6/11–1J2. Domestic well; diam 4 in. Water native to Talbert zone in alluvial deposits of Recent age. Hydrogen sulfide 1.6 ppm. See table 31, p. 307.

6/11–1N1. Drilled domestic and irrigation well; diam 16 in. Sodium bicarbonate water, probably native to the San Pedro formation (lower part ?). Analysis in 1931 by California Division of Water Resources. Hydrogen sulfide 5.1 ppm. See table 31, p. 307.

6/11–2D1. Drilled unused well; diam 10 in. Taps upper part of San Pedro formation. Sampled at 100-ft depth. Analysis, by California Division of Water Resources, indicates advanced contamination. See table 31, p. 307.

6/11–2G1. Former public-supply well (now unused); diam 12 in; casing perforated 80–118 ft below land surface in upper part of San Pedro formation. Analysis in 1925 indicates incipient contamination; hydrogen sulfide 0.7 ppm. Later analyses indicate progressive contamination. Analyses in 1930 and 1931 by Smith-Emery Co., Los Angeles. See table 31, p. 307.

6/11–2G2. Former public-supply well (now unused); diam 12 in; casing perforated 78–126 ft below land surface in upper part of San Pedro formation. Analysis, by Smith-Emery Co., indicates advanced contamination. See table 31, p. 307.

6/11–2G4. Drilled public-supply well (now used as stand-by); casing originally perforated 90–111, 208–216, and 228–248 ft below land surface, but cemented back to 196 ft in 1924. Taps upper part of San Pedro formation. Initial analysis indicates contamination. Analysis in May 1941 on sample obtained after pumping 1 hr, by G. J. Petretic, Geological Survey; fluoride 0.2 ppm, iron 0.1 ppm in solution when analyzed. Other analyses by Smith-Emery Co., Los Angeles. See table 31, p. 308.

6/11–2J1. Drilled irrigation well, diam 7 in. Taps upper part of San Pedro formation. Calcium bicarbonate water, locally native to zone tapped. Analysis by California Division of Water Resources.

6/11–11E1. Drilled unused well (former fire-supply well) Casing perforated 50–66, 84–100, and 216–234 ft below land surface, largely and possibly wholly in San Pedro formation. Sodium chloride water, probably contaminated. Hydrogen sulfide 3.1 ppm.

6/11–11J2. Drilled irrigation well(unused when sampled, now abandoned); diam 7 in. Probably taps upper part of San Pedro formation. Sodium bicarbonate water; chloride content indicates incipient deterioration. Sample taken from 40-ft depth; analysis by California Division of Water Resources.

6/11–11J3. Abandoned domestic well, diam 7 in. Probably taps upper part of San Pedro formation. Calcium chloride water of advanced deterioration. Analysis by California Division of Water Resources.

6/11–11K1. Drilled domestic well; diam 7 in. Probably taps upper part of San Pedro formation. Calcium bicarbonate water; analysis suggests incipient deterioration. Analysis by California Division of Water Resources.

6/11–11K2. Unused well; diam 8 (?) in. Probably taps upper part of San Pedro formation. Sodium bicarbonate water; deterioration incipient. Sample taken from depth of 50 ft. Analysis by California Division of Water Resources.

6/11–12C2. Abandoned irrigation well; diam 12 in. Calcium sodium bicarbonate water; native to Talbert zone in alluvial deposits of Recent age. Hydrogen sulfide 1.4 ppm.

6/11–12E1. Drilled domestic well; diam 8 in. Taps Talbert zone of Recent age. Calcium bicarbonate water, essentially native. Analysis by California Division of Water Resources. See table 31, p. 308.

6/11–12N1. Farnsworth Fee water well 2A. Abandoned industrial well; diam 20 and 15 in. Penetrates Talbert zone of Recent age and San Pedro formation and may have yielded water from one or both. Calcium chloride water. Analysis, by California Division of Water Resources, indicates deterioration.

6/11-13G2. Drilled unused well; diam 12 in. Taps Talbert zone of Recent age. Sodium bicarbonate water; deterioration is believed incipient. (1), (3) Sampled from just below water surface. (2) Sampled 95 ft below water surface. Analyses by California Division of Water Resources.

6/11-13J1. Drilled irrigation well; diam 10 in. Taps Talbert zone of Recent age. Sodium calcium chloride water; of advanced deterioration. Analyses in 1934, 1937, and 1939 by California Division of Water Resources. Analysis of April 1942 not representative because sample collected after pumping only 2 min; by E. W. Lohr, Geological Survey; fluoride 0.4 ppm, bromide and iodide absent; electrical conductivity 768 micromhos. See table 31, p. 309.

6/11-13K2. Drilled industrial well; diam 5 in; casing perforated 115-138 ft below land surface in Talbert zone of Recent age. Sodium chloride water; of advanced deterioration. Analysis of 1942 by E. W. Lohr and that of 1944 by T. Downer, Geological Survey. Analysis of 1942, fluoride 0.2 ppm, iodide 1.0 ppm; electrical conductivity 3,860 micromhos; analysis of 1944, fluoride 1.0 ppm, very faint trace iodide, bromide 5 ppm, strontium 30 ppm, no barium; electrical conductivity 45,700 micromhos. See table 31, p. 309.

6/11-13Q1. Abandoned oil well. Plugged at about 229 ft below land surface but leakage from below sufficient to maintain water level above land surface. When drilled 8¼-in casing landed and water shut off at 4,058 ft below land surface. Well drilled to 4,980 ft, then abandoned and filled with mud. Water must come from open hole below 4,058 ft or through leak in casing. Sample taken after bailing several feet of water from well; analysis by E. W. Lohr, Geological Survey. Fluoride 0.6 ppm, bromide absent, iodide 0.5 ppm, hydroxyl 1 ppm; electrical conductivity 14,380 micromhos. See table 31, p. 310.

I-6G1. Unused irrigation well; diam 12 in; casing perforated 420-570 ft below land surface in San Pedro formation. Sodium bicarbonate water, essentially native to the zone perforated. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

I-8B1. Drilled irrigation well; diam 18 in; casing perforated 220-320 and 380-740 ft below land surface in undifferentiated Pleistocene deposits. Sodium calcium bicarbonate water, probably blended from the two zones perforated. Analyses by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

I-8H1. Drilled irrigation well. Taps undifferentiated Pleistocene deposits. Sodium sulfate chloride water of high concentration; probably a blend of waters from several zones, with dissolved constituents native to the range penetrated. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

I-9A2. Drilled irrigation well; diam 20 in. Gravel-packed well. Calcium bicarbonate water; probably blended from several zones in undifferentiated Pleistocene deposits, but substantially from deeper part of range penetrated. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

I-11B1. Drilled irrigation well. Calcium bicarbonate sulfate water; quality common in upper Pleistocene deposits in west-central part of Irvine tract; dissolved constituents essentially native in the range penetrated. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

I-43F1. Drilled irrigation well; diam 12 in; casing perforated 135-202 ft below land surface in undifferentiated Pleistocene deposits. Water of somewhat variable character, whose dissolved constituents must be essentially native to the stratigraphic range perforated. Analyses in 1920 and 1925 by Citrus Experiment Station; others by U. S. Department of Agriculture, Rubidoux Laboratory, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

I-45E1. Drilled irrigation well; diam 15 in; casing perforated 38-86 ft below land surface in upper Pleistocene deposits. Calcium sulfate bicarbonate water; locally native to shallow zone perforated. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

I-45G2. Drilled unused well; diam 12 in. Probably taps upper Pleistocent deposits. Sodium calcium bicarbonate water; essentially native in deepest zone reached. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

I-45N1. Drilled irrigation well. Taps tongue of gravel presumably deposited by antecedent of Santiago Creek, in latest Pleistocene or Recent time. Sodium sulfate water, presumably native to the tongue. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

Notes to table 30—*Continued*

I–48B1. Drilled irrigation well; casing perforated 424–428, 620–635, 660–685, 740–1,070, and 1,085–1,100 ft below land surface in undifferentiated Pleistocene deposits. Sodium bicarbonate water, probably substantially native in the 740- to 1,070-ft zone. Hydrogen sulfide 6.3 ppm.

I–62Q1. Drilled irrigation well; diam 20 in; casing perforated 410–1,100 ft below land surface in undifferentiated Pleistocene deposits. Calcium bicarbonate chloride water, probably blended from several zones. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–63A1. Drilled irrigation well; diam 20 in; casing perforated 807–1,300 ft below land surface, possibly all in Pleistocene deposits. Calcium bicarbonate water, substantially native to the zone perforated. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–63G1. Drilled unused well; diam 7⅝ in; casing perforated 172–220 ft below land surface in upper Pleistocene deposits. Sodium sulfate water, locally native to the zone perforated (?). Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–84G1. Drilled irrigation well; diam 20 in; casing perforated 235–1,235 ft below land surface, at least partly in Pleistocene deposits. Analysis in March 1920, of sample taken 800 ft below land surface during construction of well, shows sodium bicarbonate water substantially native to that zone; analysis in November 1930 is calcium bicarbonate water probably blended from several zones. Analyses by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–85A4. Drilled domestic well; diam 12½ in. Sodium chloride bicarbonate water, probably a blend from several zones in Pleistocene deposits. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–86N1. Drilled unused well; diam 8 in; casing perforated 200–318 ft below land surface in undifferentiated Pleistocene deposits. Calcium bicarbonate water, possibly blended from several zones. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–86R1. Drilled irrigation well; diam 16 in; casing perforated 60–520 ft below land surface in undifferentiated Pleistocene deposits. Sodium calcium sulfate water, probably blended from several zones in the range perforated. Analysis by Citrus Expriment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–88C1. Drilled irrigation well; casing perforated 284–294 ft below land surface in undifferentiated Pleistocene deposits. Sodium chloride water, substantially native to the zone perforated. Hydrogen sulfide 3.2 ppm.

I–102J1. Drilled unused well; diam 15 in; casing perforated 255–299 ft below land surface in undifferentiated Pleistocene deposits. Sodium chloride bicarbonate water, locally native (?) to the zone perforated. Analyses by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–106B. Drilled domestic well. Sodium sulfate chloride water, probably blended from several zones in Pleistocene deposits and possibly undifferentiated Tertiary rocks below.

I–121C1. Drilled irrigation well; diam 20 in. Sodium calcium sulfate chloride water, probably blended from several zones in Pleistocene deposits and possibly in underlying Tertiary rocks. Analysis by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–123K1. Drilled irrigation well. Sodium chloride bicarbonate water, probably blended from several zones in the range perforated. Analyses in 1925 by Citrus Experiment Station; that in 1928 by U. S. Department of Agriculture, Rubidoux Laboratory, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–140G1. Drilled irrigation well; diam 12 in. Calcium bicarbonate sulfate water; analyses suggest variable blend of waters from several zones in Pleistocene deposits. Analyses in 1927 by Citrus Experiment Station; that in 1928 by U. S. Department of Agriculture, Rubidoux Laboratory, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–142K1. Drilled irrigation well; diam 15 in; casing perforated 60–220 ft below land surface, probably in Pleistocene deposits in large part. Sodium calcium sulfate water; dissolved constituents essentially native within the range penetrated. Analyses by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40–A).

I–156C1. Drilled irrigation well; diam 12 in; casing perforated 200–420 ft below land surface, probably in Pleistocene deposits in large part. Sodium sulfate chloride water; dissolved constituents essentially native to the range perforated but waters native to several zones may have been blended in samples. Analyses by Citrus Experiment Station, Riverside, Calif. (after California Div. Water Resources Bull. 40-A).

[1] Since 1931 and 1932, the city of Long Beach has analyzed a monthly sample of water from each of its 30 public-supply wells active at the time. These wells are in Ts. 3 and 4 S., Rs. 12 and 13 W. This comprehensive analytical record is only summarized in this report, by selected analyses or averages of analyses for the several wells. Except as otherwise indicated, all analyses for these public-supply wells were made in the municipal Chemical and Physical Testing Laboratory, by the late D. P. Shuler and by E. H. Miller.

[2] The seven public-supply wells in the Citizens field at Long Beach—in secs. 20 and 21—are closely spaced, are diversely perforated in zones that range through all the Silverado zone of the San Pedro formation into the basal division of the San Pedro formation, and are pumped in rotation under a variable schedule of heavy withdrawals. The waters native to the several zones range substantially in chemical character. Under such conditions: (1) non-pumping wells act as conduits interconnecting the several water-bearing zones, so that a pumping well may draw water from several zones even though not perforated in all; (2) the proportionate volume of water drawn from any one zone by a particular well may range widely, especially during the first withdrawal after a shut-down of the pump in that well; and (3) even if stabilized after prolonged pumping, the proportionate volumes drawn from the several zones by a particular well may vary for successive terms of withdrawal, owing to the inconstant schedule of withdrawals from other wells in the field and in the vicinity. Thus, the chemical character of individual samples from a particular well in the field may range widely according to the schedule of operation, and especially the lapse of time from starting of pump to taking sample.

[3] The public-supply wells in the Alamitos field at Long Beach—initially 12 wells, in sec. 28—are very closely spaced, are diversely perforated in zones that range through all the Silverado zone of the San Pedro formation into the basal division of the San Pedro formation, and are heavily pumped in rotation under a variable schedule of withdrawals. Thus, the chemical character of individual samples from a particular well may range widely according to the schedule of operation, and especially the lapse of time from starting of pump to taking of sample.

TABLE 31.—*Partial chemical analyses of water from wells in the coastal zone, 1941–45*

[Explanation of certain "remarks": Time intervals are those elapsed after pump started. "Bailed" indicates sample taken at or just below water surface in idle well. Distances in feet indicate depth of sample below measuring point at land surface.]

Well	Date	Chloride (Cl) (ppm)	Soap hardness as $CaCO_3$ (ppm)	Specific conductance (K x 10^6 at 25°C)	Temperature (°F)	Remarks
			T. 3 S., R. 12 W.			
3/12-31C3	May 10, 1941	89	335	875		
31E4	do	28	185	520		
31G2	do	12	185	415		
31G3	May 20, 1941	13	175	417		
31H1	May 10, 1941	12	185	412		
			T. 3 S., R. 13 W.			
3/13-31A1	Jan. 28, 1941	67	215	701		
	June 26, 1941	67	185	706		
	Mar. 25, 1942	115	225	876		
	July 17, 1942	159	300	1,070	70	
	Nov. 4, 1942	87	270	802	69	
31B3	Jan. 28, 1941	170	415	1,260		
31B4	Jan. 30, 1941	28	200	556		
	June 26, 1941	30	155	573	70	
	Sept. 16, 1941	26	190	560		
	Nov. 7, 1941	27	195	560	71	
	Jan. 9, 1942	27	165	565	71	
	Nov. 4, 1942	26	195	561		
	Oct. 26, 1943	25	165	556		
31B5	Jan. 28, 1941	28	165	515		
31C1	Jan. 30, 1941	23	155	485		
	Nov. 4, 1942	25	210	575		
	Oct. 26, 1943	27	130	574		
3/13-31F1	Jan. 28, 1941	205	650	1,680		
31F2	June 27, 1941	127	320	1,020		
	Mar. 25, 1942	172	425	1,200		
	Oct. 26, 1943	178	310	1,280		
31F3	Jan. 28, 1941	174	475	1,460	70	
31F4	do	29	150	559		
31H2	do	236	490	1,390		
	June 26, 1941	363	545	1,940		
	Mar. 24, 1942	290	475	1,700		
31H3	Jan. 28, 1941	89	315	921		
31H4	do	241	375	1,300		
	June 26, 1941	260	415	1,480		
	Sept. 16, 1941	264	400	1,440		
	Nov. 7, 1941	267	400	1,470		
	Jan. 9, 1942	253	400	1,440		
	Apr. 10, 1942	253	550	1,450		See table 30, p. 217.
	July 17, 1942	257	550	1,510	72	
	Nov. 4, 1942	249	525	1,550	70	
31H5	Jan. 28, 1941	232	450	1,290		
	June 26, 1941	288	425	1,630	66	
	Nov. 4, 1942	269	550	1,590		
31L1	June 26, 1941	26	140	480	76	

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 3 S., R. 13 W.—Continued			
3/13-31L2	Jan. 28, 1941	92	300	983		
31L3	do	151	440	1,360		
	June 27, 1941	163	415	1,540		
3/13-32C1	Jan. 28, 1941	110	265	906		
	July 17, 1942	138	250	1,020	68	
	Nov. 3, 1942	126	375	997		
32C2	Jan. 28, 1941	24	105	408		
32F3	do	53	240	657		
	July 17, 1942	44	165	638		
	Nov. 4, 1942	48	195	635		
3/13-33A2	June 26, 1941	31	120	545	72	
	Sept. 16, 1941	30	165	552	72	
	Nov. 7, 1941	31	175	557		
	Jan. 9, 1942	30	170	560	69	
3/13-34B1	Apr. 28, 1941	25	160	476		
34D2	June 26, 1941	27	135	518	72	See table 30, p. 217.
3/13-35B3	Jan. 27, 1941	28	240	610		
	Oct. 29, 1942	27	240	617		
35H1	Jan. 27, 1941	28	190	541		
	June 26, 1941	30	195	544	66	
	Nov. 6, 1941	28	165	522		
	Jan. 7, 1942	30	170	559		
	Oct. 29, 1942	29	205	545		
35J2	Jan. 27, 1941	28	175	546		
	June 26, 1941	28	155	549		
	Oct. 29, 1942	24	190	528		
	Oct. 26, 1943	27	155	534		
35N1	Jan. 26, 1941	98	325	971		
	Oct. 29, 1942	89	370	950		
	Oct. 26, 1943	73	205	876		
3/13-36Q2	Feb. 4, 1941	35	165	546		
	June 27, 1941	34	165	552	70	
	Sept. 17, 1941	31	150	539		
	Nov. 6, 1941	32	145	545		
	Jan. 7, 1942	32	145	544		
			T. 4 S., R. 11 W.			
4/11-19A2	May 20, 1941	17	155	436		
19B2	do	17	135	437		
19H2	May 16, 1941	22	40	269		
19J1	do	20	140	457		
	July 10, 1942	17	145	469	68	
19K2	May 16, 1941	15	110	408		See table 30, p. 219.
19L1	May 15, 1941	18	145	439		
19L2	do	34	170	583		
19L3	do	18	155	459		
19L4	do	18	130	403		
19M1	do	13	105	375		
19N1	do	17	140	403		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 4 S., R. 11 W.—Continued						
4/11-19P1	May 16, 1941	114	320	905		
19P2	do	56	185	590		
4/11-28J1	May 12, 1941	22	165	455		See table 30, p. 219.
28L1	May 20, 1941	25	65	323		
4/11-29D1	May 16, 1941	17	145	459		
29J1	May 12, 1941	18	140	412		
29L1	do	17	160	459		
29L3	July 14, 1942	17	180	462		
4/11-30K1	May 15, 1941	17	160	454		
30M1	do	19	130	433		
4/11-31F1	May 12, 1941	16	50	378	78	See table 30, p. 219.
	Jan. 15, 1942	12	40	381	78	Well flowing.
31F2	May 12, 1941	16	165	444		
4/11-32G1	do	18	185	455		
32H1	do	18	185	452		
32M1	do	17	145	422		
4/11-33D1	do	20	165	500		
33H1	do	19	145	418		
T. 4 S., R. 12 W.						
4/12-4J2	Jan. 10, 1942	12	135	413	66	Well flowing.
4J3	do	12	155	410	66	Do
	July 15, 1942	10	180	407	68	Do
	Apr. 3, 1943	11	100	382	65	Do.
4P1	June 23, 1942	92	380	1,500	72	
4/12-5B2	Apr. 21, 1941	18	165	448		
5E2	do	22	165	454		
5F1	do	65	325	760		
5G2	do	14	120	353	69	Sulfide odor.
5H1	do	15	145	385		
5H2	do	16	165	401		
5M1	Apr. 22, 1941	32	45	397		Yellowish and turbid.
5M2	do	15	145	404		
4/12-6G1	Apr. 24, 1941	16	170	422		
6K1	Nov. 1, 1940	29	30		89	See table 30, p. 220.
6Q1	Apr. 24, 1941	56	85	578		
	July 15, 1942	26	140	448		
	Oct. 5, 1942	24	130	427		
6R1	Oct. 2, 1941	30	115	431		
4/12-7A1	Apr. 24, 1941	19	100	344		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
		T. 4 S., R. 12 W.—Continued				
4/12-8P2	Apr. 25, 1941	13	120	338	----	
	Jan. 10, 1942	11	110	337	----	
	Mar. 21, 1942	11	100	340	----	
	Oct. 28, 1942	9	105	340	----	
4/12-13A1	Apr. 15, 1941	10	150	358	----	
13B1	Aug. 14, 1941	14	175	442	66	
13J1	Apr. 15, 1941	20	150	465	----	
4/12-14A1	Apr. 16, 1941	11	150	368	----	
14B1	Aug. 2, 1943	21	60	382	79	0 time. See table 30, p. 220.
		8.6	130	341	67	15 sec.
		8.2	125	340	67	30 sec.
		7.4	125	339	67	45 sec.
		----	120	341	67	1 min.
		7.4	120	341	67	2 min.
		8.0	120	337	67	3 min.
		7.4	110	326	68	4 min.
		8.0	80	311	70	5 min.
		----	75	308	71	6 min.
		----	75	312	71	8 min.
		7.5	80	309	71	10 min.
		8.0	80	313	71	15 min.
		7.4	90	318	71	20 min.
		8.5	90	323	71	25 min.
		----	95	325	70	30 min.
		7.8	95	328	70	35 min.
		8.0	95	325	70	40 min.
		8.0	105	333	70	45 min.
		8.3	110	337	70	50 min.
		9.2	120	357	70	55 min.
		----	120	347	70	1 hr.
		10	120	356	70	1 hr 5 min.
		8.8	115	352	69	1 hr 10 min.
		10	125	357	69	1 hr 15 min.
		----	120	369	69	1 hr 20 min.
		----	125	364	69	1 hr 25 min.
		----	135	365	69	1 hr 30 min.
		----	130	364	69	1 hr 35 min.
		----	135	371	69	1 hr 40 min.
		----	125	363	69	1 hr 45 min.
		9.0	145	370	69	1 hr 55 min.
		----	135	369	69	2 hr 10 min.
		8.0	130	362	69	2 hr 25 min.
		----	135	361	69	2 hr 40 min.
		----	130	362	69	2 hr 55 min.
		----	130	362	69	3 hr 25 min.
		7.6	140	362	69	4 hr 25 min.
		----	140	370	69	5 hr 35 min.
		----	130	360	69	9 hr 3 min.
	Aug. 3, 1943	----	130	363	69	13 hr 52 min.
		7.2	130	364	69	21 hr 39 min.
		7.6	140	361	----	36 hr 3 min.
	Aug. 4, 1943	----	140	363	----	45 hr 4 min.
		8.0	140	364	69	56 hr 10 min.
	Aug. 5, 1943	----	140	364	69	70 hr 9 min.
		----	145	363	70	76 hr 41 min.
	Aug. 6, 1943	----	140	336	70	101 hr 18 min.
	Aug. 7, 1943	----	140	363	69	125 hr 23 min.
	Aug. 8, 1943	7.6	140	364	69	151 hr 27 min.
	Aug. 10, 1943	----	150	364	69	176 hr 30 min.
	Aug. 12, 1943	----	140	365	68	200 hr 51 min.
	Aug. 15, 1943	----	135	365	69	270 hr 2 min.
	Aug. 18, 1943	----	140	363	69	340 hr 8 min.
	Aug. 21, 1943	----	140	366	68	411 hr 7 min.
	Aug. 24, 1943	----	145	368	69	483 hr 11 min.
	Aug. 28, 1943	----	140	369	----	580 hr 56 min.
	Sept. 3, 1943	----	----	359	69	701 hr 35 min.
	Sept. 6, 1943	----	----	360	68	771 hr 4 min.
	Sept. 21, 1943	----	----	366	68	1,128 hr 12 min.
14C1	Nov. 4, 1940	8	150	----	68	See table 30, p. 220.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
		T. 4 S., R. 12 W.—Continued				
4/12-14C2	June 23, 1942	23	320	818	70	
14C3	do	19	285	682	70	
14D1	Nov. 1, 1940	29	15	------	95	Yellowish. See table 30, p. 220.
14D3	Apr. 18, 1941	13	150	367	------	
14F1	Apr. 16, 1941	9	145	363	------	
14H1	do	9	145	355	------	
14P2	do	10	145	361	------	
14Q2	Mar. 21, 1942	9	85	320	------	
4/12-15C1	June 23, 1942	95	425	1,180	70	
15K2	Apr. 18, 1941	11	140	345	------	
4/12-16C1	June 23, 1942	79	100	1,020	74	
4/12-17P2	Apr. 28, 1941	24	105	356	------	
4/12-20C1	Sept. 1, 1943	12	95	355	------	1 min. See table 30, p. 221.
		15	95	337	------	1 min 15 sec.
		15	90	339	------	1 min 30 sec.
		14	90	335	------	1 min 45 sec.
		14	90	335	------	2 min.
		14	80	339	------	3 min.
		14	80	330	74	4 min.
		14	75	328	75	6 min.
		15	80	328	75	10 min.
		------	75	329	75	15 min.
		------	75	329	76	20 min.
		16	65	329	76	25 min.
		------	70	330	76	35 min.
		------	60	------	77	50 min.
		23	60	------	77	55 min.
		------	60	333	77	1 hr 5 min.
		22	55	331	77	1 hr 20 min.
		------	55	332	77	1 hr 50 min.
		------	55	332	78	2 hr 20 min.
		24	55	332	78	2 hr 50 min.
		------	50	333	78	3 hr 20 min.
		25	50	333	78	3 hr 50 min.
		------	50	333	79	4 hr 5 min.
		24	50	333	79	4 hr 20 min.
		------	45	333	79	4 hr 35 min.
		25	45	333	79	4 hr 50 min.
		------	50	333	79	5 hr 20 min.
		------	50	333	79	5 hr 35 min.
		24	45	332	79	8 hr 55 min.
	Sept. 7, 1943	------	45	326	80	140 hr 35 min.
	Sept. 13, 1943	------	30	330	80	Pumping intermittently.
	Sept. 27, 1943	26	30	326	80	Do.
20L1	May 1, 1941	23	45	376	80	Yellowish.
4/12-21A2	Apr. 17, 1941	9	80	276	------	
21M5	Nov. 2, 1940	21	30	------	82	See table 30, p. 222.
21P2	May 2, 1941	26	45	310	------	Yellowish.
4/12-22L1	Apr. 17, 1941	9	140	347	------	
22P1	do	17	50	376	------	
22R1	do	11	100	340	------	
4/12-23A1	Apr. 16, 1941	11	155	364	------	
23K1	do	10	150	370	------	
	Jan. 7, 1942	7	135	366	------	

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 4 S., R. 12 W.—Continued						
4/12-23K1-con.	Mar. 21, 1942	10	150	369		
	Oct. 27, 1942	8	155	375		
23L1	Apr. 16, 1941	14	100	330		
23M1	Apr. 17, 1941	9	135	350		
23M2	June 23, 1942	25	415	1,750		
4/12-24C1	Sept. 22, 1941	10	135	397	71	
24J1	do	13	105	421	73	
24K4	June 23, 1942	41	375	1,430	73	Bailed.
24M5	Apr. 16, 1941	10	145	366		
24M6	do	13	125	376		
4/12-25M1	July 15, 1942	15	100	417	76	
4/12-26A1	Apr. 16, 1941	12	140	394		
26D1	Apr. 17, 1941	11	90	317		
26J1	Apr. 14, 1941	17	125	429		
	Apr. 3, 1942	17	50	351		
26K1	June 23, 1942	15	160	474	70	Do
26M1	Apr. 14, 1941	13	100	362		See table 30, p. 223.
26R1	do	15	135	417	74	
4/12-27K1	do	11	100	330		Do
27M1	do	18	60	326		Do
27M4	June 23, 1942	189	190	810	70	
4/12-30B1	Mar. 18, 1942	261	280	1,180		
4/12-32G1	May 10, 1941	740	505	2,360		Bailed. See table 30, p. 223.
4/12-33A1	Apr. 19, 1941	17	55	378		
	Nov. 6, 1941	16	45	389		
	Jan. 7, 1942	17	45	386		
4/12-34B1	May 2, 1941	18	45	325		Yellow'sh. See table 30, p. 223.
34H1	do	16	60	344		
34J2	Dec. 31, 1942	13	85	375	75	
4/12-35C1	Apr. 14, 1941	15	135	410		
	Jan. 7, 1942	15	115	417		
	Oct. 27, 1942	11	130	406		
35Q1	May 2, 1941	18	55	345		
4/12-36G1	Apr. 14, 1941	18	135	427	70	Well flowing.
T. 4 S., R. 13 W.						
4/13-1C1	June 26, 1941	31	160	544		
	Mar. 24, 1942	28	170	540		
	Oct. 26, 1943	28	170	539		
1F2	Feb. 3, 1941	29	165	519		
	Oct. 26, 1943	27	130	513		
1M1	Feb. 3, 1941	97	340	1,060		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 4 S., R. 13 W.—*Continued*			
4/13-1M1-con.	July 15, 1942	97	465	1,290	70	
	Oct. 28, 1942	97	440	1,240		
1P1	Feb. 3, 1941	60	200	655		
	June 27, 1941	56	115	634		
	Sept. 17, 1941	55	160	659		
	Nov. 6, 1941	53	190	635		
	Jan. 7, 1942	54	180	644		
	July 15, 1942	53	205	645	73	Bailed.
	Oct. 28, 1942	51	220	639		
1P2	Feb. 3, 1941	56	225	645		
	July 15, 1942	53	200	632	72	
	Oct. 29, 1942	29	50	407	76	
1P4	Nov. 6, 1941	30	150	500		
	Jan. 7, 1942	31	145	514	71	
	Mar. 24, 1942	32	160	511	70	
	Oct. 28, 1942	30	175	503	70	
4/13-2J2	Jan. 17, 1941	113	400	1,210		
	Nov. 6, 1941	109	375	1,250		
	Jan. 8, 1942	124	415	1,320		
	Mar. 24, 1942	129	425	1,320		
	July 16, 1942	111	415	1,210	68	
	Oct. 29, 1942	120	450	1,310		
	Oct. 26, 1943	113	240	1,250		
2J3	Aug. 13, 1941	84	275	835		
	July 24, 1942	63	255	765		
	Sept. 21, 1942	61		750	69	
	Nov. 3, 1942	62	265	743	67	
	May 24, 1943	57	230	685	68	
2J4	Jan. 17, 1941	28	165	504	67	Bailed.
2K1	Sept. 10, 1941	185	540	1,590		Do.
	Jan. 22, 1942	79	285	937	67	Do.
	Mar. 28, 1942	72	245	916		Do.
	Aug. 5, 1942	68	525	1,360	69	Do.
	Dec. 22, 1942	63	585	1,250	67	
2N1	Jan. 17, 1941	38	240	636		
	Oct. 29, 1942	28	205	582		
	Oct. 26, 1943	30	195	607		
2P1	July 16, 1942	90	335	951		
	Oct. 26, 1943	83	220	904		
2P2	Jan. 17, 1941	73	250	850		
2P3	May 21, 1943	53	225	737	68	12 hr daily for 5 days.
2P4	Oct. 26, 1943	32	125	566		See table 30, p. 224.
4/13-3R1	Feb. 24, 1944	144	290	1,230		
4/13-6J1	Jan. 30, 1941	29	195	546		Do
6J2	do	63	215	635	68	Bailed.
	July 17, 1942	26	185	551	71	
6K1	Jan. 30, 1941	85	215	708		
	Nov. 3, 1942	137	315	950	69	
6K2	Jan. 30, 1941	120	240	819		
	June 26, 1941	195	395	1,170		
	Sept. 16, 1941	131	280	901		
	Nov. 7, 1941	121	230	871		
	Jan. 9, 1942	127		906		
	July 17, 1942	147	320	975		
4/13-8L1	Jan. 27, 1941	496	390	3,160	67	Bailed. See table 30, p. 224.
	Nov. 7, 1941	109	150	1,020		Bailed.
	Jan. 9, 1942	244	315	2,170	55	Do
	Mar. 24, 1942	318	515	2,830	65	Do

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 4 S., R. 13 W.—Continued						
4/13-9H1	Jan. 27, 1941	30	170	505	----------	
	Mar. 25, 1942	32	165	531	73	
4/13-10A1	Jan. 17, 1941	141	375	1,110	----------	
10B1	Sept. 16, 1941	174	525	1,700	----------	
	Mar. 24, 1942	180	565	1,830	66	
	Sept. 21, 1942	150	465	1,500	68	
10B2	Nov. 3, 1942	124	455	1,200	68	
10C1	June 12, 1944	23	110	464	----------	
10F1	Sept. 10, 1941	840	2,000	16,000	72	Bailed.
	Jan. 22, 1942	1,180	3,200	13,400	66	Do.
	Mar. 28, 1942	1,230	----------	13,600	----------	Do.
	Apr. 21, 1942	1,050	2,500	13,400	63	Bailed. See table 30, p. 224.
	Aug. 5, 1942	841	2,250	11,900	69	Bailed.
10G1	Jan. 16, 1941	135	350	980	----------	
	Jan. 8, 1942	132	350	1,190	----------	
	Mar. 24, 1942	133	390	1,190	----------	
	Apr. 17, 1942	135	305	1,210	----------	
	July 16, 1942	138	425	1,260	----------	
	Nov. 3, 1942	137	450	1,230	----------	
10G2	Jan. 16, 1941	788	1,850	3,860	----------	
	Jan. 8, 1942	533	1,500	4,380	----------	
	Mar. 24, 1942	498	1,500	3,970	----------	
	Apr. 13, 1942	489	1,400	3,720	----------	
	July 16, 1942	466	1,450	3,710	----------	
10G3	Jan. 16, 1941	520	1,450	3,620	----------	
	Jan. 8, 1942	538	1,250	3,1[illegible]0	----------	
	Mar. 24, 1942	574	1,400	3,390	----------	
	Apr. 13, 1942	598	1,550	3,400	----------	
	----do----	590	1,600	3,410	----------	See table 30, p. 224.
	July 16, 1942	568	1,550	3,410	----------	
	Nov. 3, 1942	585	1,500	3,430	----------	
10G4	Apr. 13, 1942	611	1,600	4,320	----------	
	July 16, 1942	497	1,600	3,650	----------	
	Nov. 3, 1942	444	1,400	3,650	----------	
10H1	Jan. 16, 1941	117	400	1,030	67	
10H2	Jan. 17, 1941	366	825	2,500	----------	
	June 26, 1941	411	790	2,560	----------	
	Mar. 24, 1942	198	425	1,440	----------	
10H3	Jan. 17, 1941	137	375	1,160	----------	
10J4	Jan. 16, 1941	305	665	2,000	----------	
	June 26, 1941	325	690	2,280	68	
	Sept. 17, 1941	215	425	1,650	----------	
	Nov. 7, 1941	166	365	1,400	----------	
	Jan. 8, 1942	174	390	1,400	----------	
	Mar. 24, 1942	239	500	1,750	----------	
	Oct. 29, 1942	176	475	1,490	----------	
10N1	Jan. 16, 1941	45	190	654	----------	
10R1	Sept. 10, 1941	2,750	4,500	15,900	73	Bailed.
	Jan. 22, 1942	2,880	4,800	15,400	67	Do.
	Mar. 28, 1942	1,060	----------	10,500	----------	Do.
	Aug. 5, 1942	2,340	4,750	13,700	72	Do.
	Dec. 22, 1942	4,700	----------	21,400	71	Do.
4/13-11B1	Sept. 10, 1941	1,430	2,300	4,920	----------	Do.
	Jan. 22, 1942	443	900	2,480	----------	Do.
11B2	Aug. 5, 1942	746	2,250	4,770	72	Do.
	Dec. 22, 1942	600	2,250	4,990	69	Do.
11B3	----do----	267	790	1,840	69	

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hard-ness	Sp cond	Temp	Remarks
T. 4 S., R. 13 W.—Continued						
4/13-11C1	Aug. 5, 1942	93	315	2,100	72	Bailed.
	Dec. 22, 1942	244	235	1,990	69	Do.
11D1	Jan. 17, 1941	136	375	1,200	65	Do.
	Oct. 29, 1942	118	365	1,170		Do.
11D2	Sept. 10, 1941	587	550	3,390		Do.
	Jan. 22, 1942	230	900	3,020	67	Do.
	Mar. 28, 1942	206	750	2,910		Do.
	Aug. 5, 1942	233	1,200	3,150	72	Do.
	Dec. 22, 1942	244	1,160	3,180	69	Do.
11E1	Jan. 16, 1941	86	325	960	67	
	July 23, 1942	69	125	876	68	
	Oct. 29, 1942	73	290	899		
11E2	Jan. 17, 1941	86	325	943		
11F1	Sept. 10, 1941	3,110	4,150	12,700		Do.
	Jan. 22, 1942	2,930	5,400	15,200	68	Do.
	Mar. 28, 1942	3,460		14,000		Do.
	Aug. 5, 1942	3,680	5,100	13,800	71	Do.
	Dec. 22, 1942	3,360		16,300	69	Do.
11J1	Jan. 17, 1941	100	315	983		
11K1	do	133	315	1,040		
	June 26, 1941	124	275	1,060		
	July 16, 1942	114	345	1,070	72	
11K5	Sept. 10, 1941	449	2,000	4,180	73	Do.
	Jan. 22, 1942	117	320	1,140	67	Do.
	Mar. 28, 1942	107	205	868		Do.
	Aug. 5, 1942	1,130	2,650	5,620	70	Do.
	Dec. 22, 1942	759	2,300	5,220	68	Do.
11L2	Jan. 17, 1941	130	375	1,170		
	June 27, 1941	125	275	1,040		
	Sept. 17, 1941	118	310	1,050		
	Jan. 8, 1942	118	375	1,160		
11L3	Sept. 10, 1941	442	315	5,090	78	Do.
	Jan. 22, 1942	146	240	3,690	67	Do.
	Mar. 28, 1942	198	190	3,700		Do.
	Aug. 5, 1942	235	375	3,810	72	Do.
	Dec. 22, 1942	205	250	3,640	70	Do.
11P1	Sept. 10, 1941	400	1,500	4,500	78	Do.
	Jan. 22, 1942	585	1,850	5,000	66	Do.
	Mar. 28, 1942	439	1,500	3,870		Do.
	Aug. 5, 1942	392	1,500	3,530	74	Do.
	Dec. 22, 1942	440	1,450	3,650	72	Do.
4/13-12A1	Feb. 4, 1941	37	200	571		
	July 15, 1942	30	165	520		
	Oct. 29, 1942	29	165	517	68	
12E1	Feb. 3, 1941	28	55	348		
12H1	do	28	85	448		
	Oct. 29, 1942	26	80	444		
4/13-13N1	May 9, 1941	119	55	508		80 ft (27 ft below static water level).
		121	65	541		90 ft.
		153	85	621		100 ft.
		2,310	1,850	6,490		110 ft.
		2,190	1,750	6,290		120 ft.
		3,000	2,500	8,330		130 ft.
		3,050	2,450	8,550		140 ft.
		3,070	2,350	8,330		160 ft.
		3,080	2,500	8,550		170 ft.
		3,050	2,600	8,470		180 ft.
		3,080	2,400	8,470		190 ft.
		2,700	2,250	7,520		200 ft (6 ft above bottom of well).

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 4 S., R. 13 W.—Continued			
4/13-14B2	Jan. 14, 1941	161	425	1,230		
	Nov. 3, 1942	201	575	1,610		
14D2	Apr. 13, 1942	98	350	937	66	See table 30, p. 224.
14F2	Jan. 14, 1941	238	560	1,830		
	Sept. 18, 1941	276	515	2,020	65	6 hr.
	May 24, 1943	49	540	2,010		
14F3	Sept. 10, 1941	217	425	2,370		Bailed.
	Jan. 22, 1942	218	440	2,110	68	Do.
	Mar. 28, 1942	223	375	2,100		Do.
	Aug. 5, 1942	229	515	2,320	72	Do.
	Dec. 22, 1942	288	700	2,660	71	Do.
14G1	June 10, 1941	420	280	1,990	66	
	June 26, 1941	1,260	1,050	4,230	66	0 time.
		1,270	1,050	4,270	66	½ hr.
	Sept. 2, 1941	1,190	920	3,940	67	5 hr.
		1,190	920	3,830	67	5½ hr.
		1,190	960	3,860	67	6 hr.
		1,190	960	3,980	67	7 hr.
14K3	Jan. 14, 1941	413	665	1,870	66	
	June 26, 1941	348	525	1,810		
14K5	Jan. 14, 1941	221	115	1,490	66	Bailed.
	May 3, 1941	212	85	1,350		Do.
	May 9, 1941	211	80	1,490		25 ft (2½ ft below static water level).
		212	85	1,500		30 ft.
		207	85	1,490		35 ft.
		210	80	1,490		40 ft.
		209	110	1,500		45 ft (5 ft above bottom of (well).
	July 16, 1942	209	60	1,400	70	Bailed.
	Nov. 22, 1942	431	725	1,750	71	Do.
14K6	Sept. 10, 1941	166	185	994	76	Do.
	Jan. 22, 1942	198	225	925	67	Do.
	Mar. 28, 1942	224	250	1,140		Do.
	Aug. 5, 1942	321	440	1,420	71	Do.
14L1	May 13, 1941	296	265	1,400		30 ft (7 ft below static water level). See table 30, p. 224.
		327	340	1,470		35 ft.
		329	350	1,540		45 ft.
		325	320	1,540		55 ft.
		324	400	1,530		65 ft.
		435	615	2,150		75 ft.
		426	615	2,120		95 ft.
		431	675	2,200		105 ft.
		430	750	2,230		107 ft (8 ft above bottom of well).
14M2	Jan. 13, 1941	87	375	932		
14M3	Jan. 14, 1941	299	900	1,740		
	Apr. 13, 1942	304	975	2,200		See table 30, p. 224.
14M4	Aug. 28, 1941	432	525	2,550		
14M5	Jan. 13, 1941	128	515	1,490		
	June 27, 1941	136	415	1,440		
	Sept. 17, 1941	195	500	1,660		
	Nov. 7, 1941	178	550	1,670		
	Jan. 8, 1942	174	500	1,700		
	Mar. 24, 1942	159	540	1,640		
	July 16, 1942	161	675	1,670		
	Nov. 3, 1942	178	615	1,750	68	
14N3	Aug. 28, 1941	234	525	1,930		
	Sept. 3, 1941	330	750	2,120	66	0 time.
		330	725	2,120	66	15 sec.
		361	800	2,250	66	30 sec.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
		T. 4 S., R. 13 W.—Continued				
4/13-14N3-con.	Sept. 3, 1941	385	825	2,350	66	45 sec.
		394	800	2,240	66	1 min.
		394	800	2,230	66	2 min.
		397	800	2,230	66	3 min.
		395	800	2,280	66	5 min.
		399	750	2,370	66	10 min.
		399	775	2,430	66	20 min.
		399	775	2,400	66	30 min.
		403	750	2,420	66	1 hr.
		400	750	2,410	66	1 hr 45 min.
		403	750	2,390	66	2 hr.
		402	750	2,400	66	2 hr 30 min.
14P1	Sept. 10, 1941	610	1,900	4,470	72	Bailed.
	Nov. 17, 1941	688	1,400	3,770		Do.
	Jan. 22, 1942	748		4,330	68	Do.
	Mar. 28, 1942	1,650	2,700	6,810		Do.
	Apr. 22, 1942	2,190	3,700	8,190	66	Bailed. See table 30, p. 224.
	Aug. 5, 1942	2,240	3,250	7,930	72	Bailed.
	Dec. 22, 1942	2,200	3,700	8,530	69	Do.
14Q3	May 3, 1941	44	145	610		
	May 9, 1941	59	160	709		25 ft (4½ ft below static water level).
		88	165	840		30 ft.
		129	165	917		35 ft.
		81	160	781		40 ft (sampler may have tripped prematurely).
		285	125	1,370		45 ft.
		293	125	1,400		50 ft.
		292	120	1,330		50 ft.
		299	120	1,400		54 ft (1.3 ft above bottom of well).
14Q4	June 10, 1941	25	95	382		See table 30, p. 224.
	June 26, 1941	27	80	481		
	Sept. 17, 1941	23	75	388		
	Nov. 7, 1941	22	70	[illegible]		
4/13-15E1	May 9, 1941	138	395	1,160		26 ft (1½ ft below static water level).
		139	385	1,130		30 ft.
		148	380	1,160		40 ft.
		228	505	1,420		50 ft.
		244	535	1,460		60 ft.
		249	555	1,470		70 ft.
		251	500	1,500		80 ft.
		252	565	1,490		95 ft.
		329	750	1,910		100 ft.
		379	875	2,180		109 ft (12.5 ft above bottom of well).
15E2	Jan. 16, 1941	76	250	893		
	May 9, 1941	54	265	752		
	Jan. 8, 1942	215	525	1,740		
	Mar. 24, 1942	192	550	1,580		
	July 17, 1942	51	270	777	68	
	Oct. 5, 1942	46	185	734		
	Nov. 4, 1942	86	335	1,000		
	Oct. 26, 1943	45	180	724		
15H1	Jan. 14, 1941	79	275	855		
15J1	do	34	180	543		
15K1	do	151	315	970		
	June 27, 1941	175	465	1,260	66	
	Sept. 17, 1941	174	405	1,210	65	
	Nov. 7, 1941	177	400	1,260		
	Jan. 8, 1942	166	365	1,210		
	Nov. 3, 1942	212	500	1,440	69	
15N1	do	25	24	750	38	
15P1	June 27, 1941	26	75	363	73	
	Mar. 24, 1942	29	100	456		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
		T. 4 S., R. 13 W.—Continued				
4/13-15P1-con.	Nov. 3, 1942	77	340	983	69	
15P3	Jan. 16, 1941	34	65	583	----------	
15Q1	----do----	213	475	1,460	----------	
15R1	May 6, 1941	92	295	966	----------	
15R2	----do----	75	215	787	----------	Bailed.
	Aug. 28, 1941	73	245	938	----------	
	Sept. 3, 1941	73	300	818	66	0 time.
		72	300	773	66	1 min.
		72	300	877	66	3 min.
		71	300	836	66	8 min.
		73	310	926	66	20 min.
		72	300	905	66	1 hr.
		73	290	890	66	2 hr 30 min.
		73	300	840	66	5 hr.
	Sept. 17, 1941	74	275	941	67	
4/13-16A1	Jan. 16, 1941	47	275	661	----------	
	June 27, 1941	47	185	766	----------	
	Sept. 17, 1941	54	240	742	----------	
	Nov. 7, 1941	44	235	732	----------	
	Jan. 9, 1942	42	210	700	----------	
	July 17, 1942	41	235	700	----------	
	Nov. 4, 1942	43	245	706	----------	
	Oct. 26, 1943	41	175	681	----------	
4/13-17C1	Jan. 30, 1941	26	200	502	----------	
	June 26, 1941	26	170	543	----------	
4/13-18J2	June 26, 1941	409	465	1,760	----------	
	Sept. 17, 1941	355	450	1,600	----------	
	Nov. 10, 1941	367	450	1,630	----------	
	Jan. 9, 1942	361	450	1,630	----------	
	Mar. 25, 1942	363	465	1,590	----------	
	Nov. 4, 1942	338	565	1,710	----------	
18N1	Jan. 31, 1941	25	130	414	----------	
4/13-19D1	Jan. 30, 1941	29	135	423	----------	
19E1	----do----	29	130	457	----------	
19H1	Jan. 31, 1941	113	200	748	----------	
	June 27, 1941	117	225	784	----------	
	Mar. 25, 1942	151	300	861	----------	
	Apr. 22, 1942	130	325	829	----------	See table 30, p. 225.
	July 17, 1942	121	245	800	----------	
	Nov. 4, 1942	110	240	771	----------	
19H2	Jan. 31, 1941	62	180	592	----------	
19H3	----do----	84	205	658	----------	
19H4	----do----	25	100	400	----------	
19H5	----do----	103	225	725	----------	
19J2	----do----	26	115	423	----------	See table 30, p. 225.
	June 27, 1941	26	105	419	----------	
	Sept. 17, 1941	24	105	402	----------	
	Nov. 10, 1941	25	95	410	----------	
	Jan. 9, 1942	25	250	413	----------	
	July 17, 1942	24	----------	413	----------	
	Nov. 4, 1942	23	120	410	----------	
19J4	Jan. 31, 1941	351	440	1,560	70	Do.
	June 27, 1941	365	390	1,610	----------	
	Sept. 17, 1941	365	325	1,560	----------	
	Nov. 10, 1941	359	400	1,620	----------	
	Jan. 9, 1942	354	375	1,610	73	
	Mar. 25, 1942	355	440	1,620	70	
	July 17, 1942	364	465	1,650	72	
	Nov. 4, 1942	362	500	1,670	69	

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 4 S., R. 13 W.—Continued			
4/13-19R1	Jan. 31, 1941	34	130	434	----------	
4/13-20K1	----do----	26	110	408	----------	
	June 27, 1941	27	110	407	----------	
	Sept. 17, 1941	25	100	405	----------	
	Nov. 10, 1941	27	100	410	----------	
	Jan. 9, 1942	27	95	414	----------	
	Oct. 26, 1943	23	85	412	----------	
20L1	Jan. 31, 1941	116	200	697	----------	See table 30, p. 225.
	June 27, 1941	113	190	697	----------	
	Sept. 17, 1941	107	165	684	----------	
	Nov. 10, 1941	107	160	682	----------	
	Jan. 9, 1942	111	170	691	----------	
	Mar. 25, 1942	108	185	691	----------	
	Nov. 4, 1942	102	210	684	----------	
20R1	Jan. 31, 1941	75	165	577	----------	
	June 27, 1941	86	160	605	----------	
	Oct. 26, 1943	58	110	528	----------	
4/13-21H3	June 27, 1941	38	170	545	72	Do.
	Sept. 17, 1941	50	155	580	73	
	Nov. 4, 1942	24	85	393	69	
	Oct. 26, 1943	24	60	397	80	Yellowish.
21H4	June 27, 1941	49	130	554	77	
21J1	----do----	30	65	396	80	
	Nov. 7, 1941	31	90	434	----------	
	Jan. 10, 1942	35	75	393	76	
4/13-22E1	June 27, 1941	29	75	452	76	
	Sept. 17, 1941	23	60	354	77	
	Nov. 7, 1941	23	70	358	----------	
	Jan. 10, 1942	27	75	377	77	
	Mar. 25, 1942	24	80	360	76	
	Apr. 10, 1942	25	80	403	77	See table 30, p. 225.
	Nov. 4, 1942	24	125	362	69	
22G1	Jan. 16, 1941	109	390	1,030	----------	
	May 6, 1941	125	350	1,070	----------	
22G2	Jan. 16, 1941	281	1,050	3,370	----------	
	May 6, 1941	271	900	3,310	----------	
22J1	Jan. 16, 1941	489	725	2,170	----------	
22K1	----do----	26	75	359	----------	
22Q1	Feb. 26, 1941	92	325	877	----------	
22R1	Jan. 14, 1941	195	415	1,380	----------	
	Nov. 7, 1941	278	550	2,000	----------	
	Jan. 8, 1942	290	640	2,150	----------	
	Mar. 24, 1942	318	675	2,210	----------	
	July 17, 1942	358	725	2,260	68	
	Nov. 3, 1942	383	800	2,360	----------	
4/13-23C1	Jan. 13, 1941	388	415	2,250	----------	
	Feb. 26, 1941	343	490	2,230	----------	
	May 17, 1941	380	590	----------	67	See table 30, p. 225.
	June 10, 1941	452	340	2,500	----------	
	Nov. 7, 1941	443	400	2,140	----------	
	Jan. 8, 1942	355	450	2,320	----------	
	Mar. 24, 1942	351	475	2,260	----------	
	Nov. 3, 1942	500	450	2,180	69	
23C2	Jan. 13, 1941	270	485	1,780	----------	
	June 26, 1941	369	625	2,520	----------	
	Sept. 17, 1941	175	538	1,580	----------	
	Nov. 7, 1941	284	600	2,310	----------	
	Jan. 8, 1942	292	450	2,120	----------	
	Mar. 24, 1942	119	400	1,460	----------	
	Nov. 3, 1942	211	700	2,160	----------	

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 4 S., R. 13 W.—Continued						
4/13-23F2	Sept. 10, 1941	352	400	2,440	71	Bailed.
	Jan. 22, 1942	249	390	2,140	68	Do.
	Mar. 28, 1942	441	475	2,690		Do.
	Aug. 5, 1942	294	650	2,440	71	Do.
	Dec. 22, 1942	249	750	2,440	70	Do.
23G1	May 3, 1941	104	145	535		Do.
23P2	Sept. 10, 1941	454	575	2,270	74	Do.
	Nov. 17, 1941	218	450	1,580		Do.
	Jan. 22, 1942	190	265	1,470	67	Do.
	Mar. 28, 1942	221	390	1,540		Do.
4/13-24E1	Oct. 4, 1941	949	615	3,070		Do.
24E2	do	183	215	1,290		Do.
24G2	do	136	65	690		Do.
24M1	do	468	25	5,360		Do.
24N2	do	1,210	1,200	9,080		Do.
24Q1	do	5,120	30	19,800		Bailed; yellowish.
24Q2	do	8,820	800	21,800		Bailed.
4/13-26B1	Feb. 26, 1941	370	725	2,090		
	June 26, 1941	686	1,050	2,900		
	Sept. 17, 1941	748	1,000	2,830		
	Nov. 7, 1941	548	775	2,550		
	Jan. 8, 1942	366	650	2,010		
	Mar. 24, 1942	356	650	2,000		
	Apr. 21, 1942	348	750	1,880		See table 30, p. 226.
26B2	Feb. 26, 1941	58	180	702		
	June 26, 1941	210	425	2,430		
	Sept. 17, 1941	712	1,100	5,930		
	Nov. 7, 1941	705	1,000	6,660		
	Jan. 8, 1942	675	1,000	6,590		
	Mar. 24, 1942	517	875	5,720	67	
	July 16, 1942	298	600	3,280		
	Nov. 3, 1942	556	900	5,870		
26E2	Jan. 13, 1941	89	385	923		
26F2	do	1,260	1,500	4,220		
	June 27, 1941	953	1,050	3,740		
	Sept. 17, 1941	1,100	1,200	3,830		
	Nov. 7, 1941	1,530	1,500	5,160		
	Jan. 8, 1942	1,440	1,400	5,080		
	Mar. 24, 1942	1,579	1,550	5,110		Bailed.
	July 23, 1942	1,810	2,000	5,910		
	July 29, 1942	1,720	2,250	5,780		
	Nov. 3, 1942	1,920	2,150	6,460		
26G1	Feb. 26, 1941	54	295	879		
26L1	Sept. 10, 1941	415	900	2,690	74	Do.
	Nov. 17, 1941	233	875	2,340		Do.
	Jan. 22, 1942	206	1,000	2,190	66	Do.
	Mar. 28, 1942	296	750	2,250		Do.
	Aug. 5, 1942	274	1,150	2,390	71	Do.
	Dec. 22, 1942	306	1,150	2,480	70	Do.
26P2	Jan. 8, 1941	72	115	538	66	Do.
26P4	Jan. 9, 1941	66	330	840		
26P5	do	44	240	645		
26P6	Sept. 10, 1941	382	275	1,940	72	Do.
	Jan. 22, 1942	168	180	1,930	67	Do.
	Mar. 28, 1942	204	175	2,120		Do.
	Aug. 5, 1942	101	365	1,810	72	Do.
	Dec. 22, 1942	75	325	1,830	71	Do.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 4 S., R. 13 W.—Continued			
4/13-26Q2	Jan. 9, 1941	163	225	893	----	
	Dec. 22, 1942	79	305	875	69	
26Q4	Jan. 9, 1941	55	260	738	----	
26Q5	----do----	50	175	575	----	
4/13-27K1	Jan. 13, 1941	31	160	426	66	Bailed.
27M1	----do----	67	95	515	72	
27M3	----do----	118	135	669	71	
4/13-28N1	Jan. 9, 1941	78	120	583	----	
28N2	----do----	78	120	576	----	
4/13-29A1	Mar. 17, 1942	70	105	540	----	
29B1	Jan. 31, 1941	63	135	513	71	Do.
29C1	----do----	30	130	401	----	
29E1	Jan. 10, 1941	83	170	594	----	
29E2	Jan. 31, 1941	229	275	1,040	----	
29M1	Jan. 9, 1941	176	260	897	----	Bailed. See table 30, p. 226.
4/13-30D1	Jan. 10, 1941	116	105	584	----	
30G1	Apr. 24, 1944	30	80	434	----	About 1 week. See table 30, p. 226.
4/13-31L1	Nov. 16, 1942	689	210	2,280	----	50 ft (3.9 ft below static water level).
		698	245	2,290	----	80.5 ft.
		1,170	350	2,970	----	86.5 ft.
		891	315	2,840	----	88 ft.
		1,230	550	3,590	----	88.5 ft.
		1,640	625	3,870	----	89 ft.
		1,650	900	4,920	----	95 ft.
		1,850	1,100	5,550	----	105 ft.
		2,020	1,150	5,960	----	125 ft.
		2,150	1,200	6,230	----	141 ft.
		2,140	1,150	6,300	----	142 ft.
		2,190	1,300	6,300	----	144 ft.
		2,450	1,500	7,180	----	150 ft.
		2,620	1,700	7,880	----	175 ft.
		2,650	1,650	7,750	----	200 ft.
		2,560	1,600	7,950	----	300 ft.
		2,570	1,650	7,900	----	400 ft.
		836	375	2,830	----	500 ft (sampler may have tripped prematurely).
		1,080	450	3,490	----	600 ft (sampler may have tripped prematurely).
		2,550	1,600	7,850	----	625 ft (5 ft above bottom of well).
4/13-32D1	May 8, 1941	32	195	637	----	Bailed.
4/13-34K1	Jan. 8, 1941	2,630	1,450	7,690	65	Bailed. See table 30, p. 227.
	June 27, 1941	2,620	1,950	7,840	65	Bailed.
4/13-35B1	Jan. 9, 1941	67	215	921	67	
35C2	----do----	65	235	709	----	
35F1	----do----	40	215	645	----	
	June 27, 1941	40	220	700	----	
	Mar. 25, 1942	39	230	678	----	
	Nov. 3, 1942	42	245	681	70	
35M1	Jan. 8, 1941	778	360	3,260	72	Bailed. See table 30, p. 227.
35M3	Apr. 28, 1942	4,390	3,250	12,800	69	See table 30, p. 227.
35Q1	Jan. 8, 1941	3,890	515	10,900	65	Bailed.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 5 S., R. 10 W.			
5/10-19A2	May 21, 1941	29	200	559	....	
19B1	May 20, 1941	28	200	546	....	
19C1	Mar. 19, 1941	23	200	519	64	
19D1	May 22, 1941	46	525	1,100	....	Bailed.
19F1	May 21, 1941	27	185	518	....	
19K1	May 22, 1941	20	165	463	....	
19M1	Feb. 27, 1941	29	210	538	....	
5/10-20A2	May 21, 1941	31	190	546	....	
	Oct. 28, 1942	42	265	658	....	
20A3	May 21, 1941	42	255	654	....	
	July 7, 1942	41	295	695	66	
20A4	May 21, 1941	31	195	538	....	
20B1	----do.----	32	200	549	....	
	Sept. 17, 1941	29	185	542	....	
	Nov. 8, 1941	31	195	560	....	
	Mar. 19, 1942	30	220	577	....	
	Oct. 28, 1942	31	190	522	....	Do.
20B2	May 22, 1941	30	200	539	....	
20C1	May 21, 1941	31	255	680	....	
20D1	Mar. 19, 1942	48	490	1,220	65	
20H3	May 21, 1941	43	225	627	....	
20J2	May 22, 1941	37	215	594	64	
20L1	----do.----	28	195	523	....	
20N1	----do.----	31	215	568	....	
5/10-21A1	May 23, 1941	34	220	580	....	
21B1	----do.----	44	275	658	....	
21B2	----do.----	62	305	1,220	....	Do.
21C1	----do.----	43	255	647	....	
21D1	May 21, 1941	39	175	495	64	
21F2	May 23, 1941	38	200	606	65	
	July 23, 1942	41	225	643	70	
21G1	May 23, 1941	33	215	549	....	
21J1	----do.----	29	205	552	....	
21J2	----do.----	31	200	559	....	
21L1	----do.----	33	220	568	....	
21N2	----do.----	32	185	629	....	
21P1	----do.----	25	180	498	....	See table 30, p. 228.
5/10-28C2	May 26, 1941	26	190	515	....	
5/10-28E1	----do.----	25	185	510	....	
28F1	----do.----	19	190	495	....	
28L2	----do.----	20	175	485	....	
28M2	----do.----	31	175	562	....	

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 5 S., R. 10 W.—Continued						
5/10-28R1	May 26, 1941	21	185	513		
5/10-29B1	May 27, 1941	35	235	604		
29C1	do	29	205	532		
29D1	do	37	205	604		
29E1	do	30	175	472		
29J1	May 26, 1941	33	200	535		
29K1	Sept. 22, 1941	52	260	839	65	
29L1	May 27, 1941	36	25	617		
29L2	do	47	255	651		
29M2	do	239	205	2,440		Bailed.
	July 7, 1942	27	210	531		Do.
29M4	May 27, 1941	25	180	568		
29M5	do	28	185	526		
29M6	do	30	200	552		
29P1	May 28, 1941	15	155	439		
29P2	May 27, 1941	17	165	465		
29P3	do	43	320	775		
29Q1	Sept. 22, 1941	31	205	579		
29R2	May 26, 1941	22	190	487		
29R3	do	23	195	483		
29R4	do	52	225	685		
29R5	May 27, 1941	37	230	639		
5/10-30B3	May 28, 1941	29	55	276		Do.
30C3	June 6, 1941	28	145	525	64	
	Mar. 19, 1942	25	175	521	64	
30C4	May 22, 1941	28	145	420		
30E1	Oct. 1, 1941	26	145	426		
30E2	May 29, 1941	31	180	524		
30F1	May 28, 1941	29	190	526		
30H2	May 27, 1941	32	215	575		
30H3	do	33	210	575		
30K2	May 28, 1941	33	180	485		
30P2	do	28	185	510		
30P3	do	23	170	478		
30P4	do	21	170	472		
30Q1	do	29	190	532		
	Apr. 9, 1942	27	220	551		See table 30, p. 228.
30Q2	May 28, 1941	18	175	469		
30R2	Oct. 1, 1941	29	135	462		
5/10-31A2	June 2, 1941	33	195	543		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 5 S., R. 10 W.—Continued						
5/10-31A6	May 27, 1941	27	190	505		
31A7	June 2, 1941	31	225	571		
31A8	May 28, 1941	23	175	485		
31A9	do	25	175	495		
31A10	June 2, 1941	31	215	568		
31A11	May 28, 1941	27	185	521		
31B2	June 2, 1941	29	195	539		
31B3	May 29, 1941	29	190	549		
31B4	June 2, 1941	29	195	532		
31C1	May 29, 1941	17	150	435		
31C2	do	29	175	481		
31C4	do	30	185	541		
31D1	do	25	175	485		
31D2	do	26	170	498		
31D3	do	27	180	513		
31D4	do	28	110	389		
31D5	do	27	180	508		
31E1	do	33	50	244		
31F1	do	24	95	372		Bailed.
31F3	do	28	170	523		
31J1	do	23	185	505		
31K1	do	21	175	474		
31L1	do	19	85	328		Do.
31L2	do	21	175	481		
31M1	Aug. 20, 1941	23	175	487	65	
31N1	June 5, 1941	17	60	213		Do.
31P1	May 29, 1941	19	30	186		Do.
31Q1	June 5, 1941	19	140	442		
31R3	June 2, 1941	33	205	578		
	Mar. 18, 1942	30	195	557		
31R4	June 2, 1941	36	135	442		
5/10-32B3	June 4, 1941	30	215	568		
32C1	do	34	185	568		See table 30, p. 228.
32C2	do	41	175	529		
32C3	do	37	205	599		
32C4	do	39	225	606		
32C6	do	41	255	678		
32D2	June 2, 1941	35	200	565		
32D3	June 4, 1941	41	255	690		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
		T. 5 S., R. 10 W.—Continued				
5/10-32D4	June 4, 1941	41	255	704		
32E1	June 2, 1941	29	370	1,140		Bailed.
32F1	do	28	205	568		
32F4	June 4, 1941	28	205	543		
32J1	June 2, 1941	15	115	394		
32K1	do	43	235	651		
32K2	do	63	275	842		
	July 6, 1942	46	265	733		
	Oct. 28, 1942	43	250	702		Do.
32L1	June 2, 1941	69	305	797		
32L2	do	31	140	439		Do.
32P1	do	27	75	247		Do.
5/10-33A1	Aug. 14, 1941	13	135	419		
33C1	June 4, 1941	17	90	352		
33H1	do	15	80	293		Do.
33N1	June 5, 1941	18	100	400		
33P1	do	19	115	420		
33Q1	do	46	385	939		
5/10-34D1	June 4, 1941	20	165	513		
	Mar. 18, 1942	18	175	494	67	
34D2	June 4, 1941	16	90	362		
34G1	June 5, 1941	20	155	472		
34H1	do	20	145	444		
34J1	do	183	665	1,900		
	July 6, 1942	203	600	1,650		
34K1	June 5, 1941	104	435	1,150		
	July 6, 1942	41	280	679		
34Q1	June 5, 1941	21	185	552		
		T. 5 S., R. 11 W.				
5/11-2A1	Apr. 2, 1941	21	180	474		
2A2	do	22	195	485		
	July 8, 1941	22	180	498		
	Sept. 18, 1941	18	165	486		
	Nov. 12, 1941	20	175	491		
	Jan. 13, 1942	17	165	490		
2B2	Mar. 26, 1941	21	185	452		
2D1	Mar. 19, 1941	23	170	411		
2D2	do	24	160	396		
	July 8, 1941	34	205	556		
2E3	Mar. 19, 1941	17	195	507		
2E4	do	16	175	426		
2F2	Apr. 2, 1941	19	165	437		
	July 8, 1941	21	170	464		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 5 S., R. 11 W.—Continued						
5/11-2G2	Apr. 2, 1941	21	190	467		
2H1	Mar. 26, 1941	25	215	495		
2K1	----do----	103	390	1,400		Bailed.
	Nov. 12, 1941	16	45	178		Do.
2K2	Mar. 26, 1941	24	205	500		
2K4	Apr. 2, 1941	29	180	472		
2K5	Sept. 23, 1941	16	130	460	67	
	Jan. 14, 1942	16	110	377		
2L1	Mar. 26, 1941	23	195	463		
	Sept. 18, 1941	18	145	469	68	
2Q2	Mar. 26, 1941	19	190	437		
2Q4	Apr. 2, 1941	20	170	464		
2Q5	----do----	27	195	523		
5/11-3A2	Mar. 21, 1941	16	150	403		
3A3	Mar. 26, 1941	25	210	493		
3H1	Mar. 20, 1941	17	155	409		
3L1	Mar. 19, 1941	23	185	472		
3N1	----do----	28	185	622		
3N2	Mar. 20, 1941	16	150	383		
	July 8, 1941	17	140	416		
	July 7, 1942	16	155	428		
3N3	Mar. 20, 1941	129	180	1,320		
	July 8, 1941	32	150	628		
	Sept. 18, 1941	26	95	500		
	Nov. 12, 1941	41	145	630		
	Jan. 13, 1942	103	145	1,110		
	Mar. 19, 1942	58	155	765		
	July 7, 1942	29	175	551		
	Oct. 29, 1942	53	145	671		
3N4	Mar. 20, 1941	89	150	1,190		
	Sept. 22, 1941	15	135	437		
	Mar. 19, 1942	16	140	436		
	July 7, 1942	14	175	439		
	Oct. 29, 1942	16	155	443		
3P2	Mar. 20, 1941	21	190	446		
5/11-4A1	Mar. 19, 1941	16	150	385		See table 30, p. 229.
5/11-5A1	----do----	19	160	408		
5Q1	Mar. 20, 1941	17	160	403		
5/11-6A1	----do----	16	145	400		See table 30, p. 229.
	July 8, 1941	18	80	376		
	Aug. 11, 1941	16	65	372		
	Aug. 14, 1941	16	70	385	74	
	Jan. 15, 1942	14	100	408	68	Well flowing.
	Mar. 20, 1942	14	80	377	74	
	July 10, 1942	13	75	380	74	
6D3	Mar. 20, 1941	17	130	380		
	July 8, 1941	16	135	421		
	Mar. 20, 1942	15	140	422		
5/11-7A1	Mar. 19, 1941	18	160	432		
7G1	Sept. 8, 1941	4,860	3,500	13,400	68	Bailed.
	Nov. 17, 1941	4,730	3,250	12,800		Do.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 5 S., R. 11 W.—Continued						
5/11-7G1-con.	Jan. 21, 1942	4,360		12,100	67	Bailed.
	Mar. 27, 1942	4,500	3,250	12,100		Do.
7L1	Mar. 19, 1941	16	150	403		
	Apr. 28, 1944	13	100	409	68	Well flowing.
5/11-8C1	Mar. 19, 1941	16	45	357		See table 30, p. 229.
8M1	do	22	155	400		
5/11-9A3	Sept. 30, 1941	15	145	437		Bailed.
9A4	Apr. 2, 1941	18	150	435		
9B1	Apr. 3, 1941	16	170	442		
9F1	Mar. 26, 1941	15	165	398		
9G1	do	21	140	437		See table 30, p. 229.
5/11-10A1	Mar. 19, 1941	25	25	199		Bailed.
	Mar. 19, 1942	21	20	219		Do.
10A4	Mar. 19, 1941	19	180	454		
	July 8, 1941	19	165	463		
	Sept. 18, 1941	17	165	486		
	Nov. 10, 1941	19	155	448		
	Jan. 13, 1942	17	145	465		
10A7	Mar. 26, 1941	17	370	724		
10B2	do	15	165	417		
10B3	do	17	165	418		
10B6	do	16	160	413		
10B8	do	18	165	412		
10B9	do	19	175	448		
10C1	Mar. 20, 1941	17	165	410		
10C3	Mar. 26, 1941	16	165	415		
10C7	Apr. 2, 1941	17	145	388		
10C8	do	16	145	402		
10C9	do	12	135	420		
10D1	do	18	140	422		
10D3	do	18	155	429		
10D5	July 8, 1941	22	185	475		
10F1	Apr. 2, 1941	21	185	459		
10F2	do	17	165	408		
10F3	do	16	175	418		
10F5	Apr. 3, 1941	15	170	410		
10F6	Apr. 2, 1941	20	170	448		
10F7	do	15	165	395		
10G1	Mar. 19, 1941	18	165	419		
10H1	do	20	145	407		See table 30, p. 229.
10J2	do	20	185	474		
10K1	Mar. 26, 1941	18	180	442		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
		T. 5 S., R. 11 W.—Continued				
5/11-10L1	Apr. 3, 1941	18	160	437		
10Q1	Mar. 7, 1941	18	175	435		
10R1	Mar. 19, 1941	27	210	526		
5/11-11B1	Mar. 26, 1941	33	240	578		
11B2	do	23	205	490		
11B3	do	27	220	530		
11B4	do	29	225	546		
11K1	Mar. 25, 1941	25	210	505		
11M1	Mar. 19, 1941	17	135	352		
11P1	Sept. 26, 1941	24	95	327		
5/11-13A2	Mar. 24, 1941	22	185	452		
13A3	do	41	185	521		
13C1	Mar. 25, 1941	31	210	498		
13C2	do	37	280	676		
13D1	do	18	190	448		See table 30 p. 229.
13D4	do	31	215	531		
13E1	do	29	205	481		
13F1	do	29	255	613		
13J2	Mar. 24, 1941	96	360	926		
13L1	Mar. 25, 1941	23	185	450		See table 30 p. 229.
13L2	Mar. 19, 1942	20	165	454	64	
13M1	Mar. 25, 1941	33	260	632		
5/11-14A1	do	27	245	578		
14A4	do	27	260	606		
14A6	do	27	225	543		
14B1	do	75	70	319		
14E1	Mar. 7, 1941	27	200	524		
14G1	Mar. 25, 1941	28	230	529		
14H2	do	31	205	500		
14H3	Oct. 1, 1941	31	90	351		
	Mar. 19, 1942	31	200	552	65	Bailed.
14J1	Mar. 29, 1941	30	205	529		
	Mar. 19, 1942	26	195	553	65	
14M1	Mar. 7, 1941	17	160	420		
14Q1	Mar. 25, 1941	41	445	952		
5/11-15A2	Mar. 7, 1941	33	265	635		
15D1	Mar. 19, 1942	16	155	429	65	
15D2	Mar. 7, 1941	17	60	287		
15J1	do	17	160	413		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 5 S., R. 11 W.—Continued			
5/11-15M2	Mar. 7, 1941	18	160	404		
5/11-16A2	Mar. 19, 1942	15	145	412	65	
16B1	Mar. 7, 1941	19	170	448		
16C2	Mar. 11, 1941	18	35	339		
16D1	do	23	40	969	65	Bailed.
16M1	do	18	165	433		
16M2	do	19	35	368		
5/11-17E1	Mar. 14, 1941	18	180	444		
17E2	Mar. 20, 1941	17	165	417		See table 30, p. 229.
17H3	Mar. 11, 1941	20	170	450		
	Oct. 30, 1942	17	165	459		
17J1	Mar. 11, 1941	19	180	450		
	Jan. 14, 1942	14	35	340	68	Well flowing.
17J2	June 28, 1941	19	165	450		
	Sept. 18, 1941	14	155	446		
	Nov. 8, 1941	17	150	440		
	Jan. 14, 1942	15	155	439		
	Oct. 30, 1942	15	180	453		
17P2	Jan. 14, 1942	19	55	249	68	Do.
17P3	Mar. 13, 1941	17	115	380		
5/11-18A1	Mar. 19, 1941	15	35	293		
18B1	Aug. 23, 1941	974	400	3,330	68	Bailed.
	Sept. 9, 1941	625	275	2,270	68	Do.
	Nov. 15, 1941	461	175	1,650		Do.
	Jan. 21, 1942	100	135	1,080	66	Do.
	Mar. 27, 1942	478	200	1,730		Do.
	Aug. 5, 1942	271		1,010	70	Do.
18G1	Aug. 23, 1941	2,730	1,500	8,580	72	Do.
	Sept. 9, 1941	2,430	1,300	7,710		Do.
	Nov. 15, 1941	1,260	750	4,300		Do.
	Jan. 21, 1942	1,620	1,050	5,600	66	Do.
	Mar. 27, 1942	1,460	800	4,650		Do.
	Aug. 5, 1942	931	650	3,050	73	Do.
18G2	Aug. 23, 1941	4,350	2,500	12,300	68	Do.
	Sept. 8, 1941	2,720	1,550	8,310		Do.
	Nov. 15, 1941	795	500	2,770		Do.
	Jan. 21, 1942	703	350	2,790	66	Do.
	Mar. 27, 1942	960	450	2,990		Do.
	Aug. 5, 1942	417	215	1,500	72	Do.
18H1	Mar. 20, 1941	17	155	405	68	Do.
18N1	July 21, 1941	4,000	1,100	12,600		0 time.
		17,000	6,750	37,000		10 min.
		17,200	7,250	38,500		25 min.
		17,700	7,000	28,300		40 min.
		18,100	7,500	38,300		55 min.
		17,900	7,500	38,300		70 min.
		18,200	7,500	39,000		80 min.
18P1	do	540	235	2,560		0 time.
		266	125	1,450		4 min.
		146	125	739		9 min.
		106	155	637		17 min.
		79	150	585		31 min.
		56	145	543		47 min.
		46	145	529		62 min.
		39	145	489		72 min.
		35	135	411		82 min.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
		T. 5 S., R. 11 W.—Continued				
5/11-18P2	Aug. 22, 1941	14,300	6,550	32,500	----------	Bailed.
	Sept. 8, 1941	18,500	7,500	41,200	----------	Do.
	Nov. 15, 1941	19,400	8,250	41,700	----------	Do.
	Jan. 21, 1942	16,400	----------	35,700	----------	Do.
	Mar. 27, 1942	18,400	6,750	40,000	----------	Do.
	Aug. 5, 1942	18,600	----------	40,000	----------	Do.
18P3	Aug. 23, 1941	10,600	5,950	25,500	----------	Do.
	Sept. 8, 1941	4,520	2,500	13,000	----------	Do.
	Nov. 15, 1941	1,850	1,150	5,790	----------	Do.
	Jan. 21, 1942	----------	850	5,070	67	Do.
	Mar. 2, 1942	1,240	----------	3,860	67	Do.
	Mar. 27, 1942	1,290	625	4,170	----------	Do.
	Aug. 5, 1942	977	650	3,260	72	Do.
18P4	Sept. 8, 1941	42,100	14,500	76,100	----------	Do.
	Nov. 15, 1941	33,400	11,500	62,300	66	Do.
	Jan. 21, 1942	35,100	----------	66,700	----------	Do.
	Mar. 27, 1942	42,000	----------	77,000	----------	Do.
	Apr. 17, 1942	31,500	15,000	66,100	67	Bailed. See table 30, p. 229.
	Aug. 5, 1942	39,700	----------	71,000	74	Bailed.
18P5	----do----	350	220	1,350	72	Do.
18P6	----do----	591	355	2,280	72	Do.
18R1	Apr. 2, 1941	15	35	339	----------	Yellowish. Well flowing.
	Mar. 18, 1942	14	30	347	79	Do.
	Apr. 25, 1942	14	40	348	80	Yellowish. Well flowing. See table 30, p. 229.
5/11-19D2	Sept. 8, 1941	26,900	11,000	53,600	68	Bailed.
	Nov. 14, 1941	29,300	12,500	56,000	----------	Do.
	Jan. 21, 1942	25,300	----------	52,500	66	Do.
	Mar. 27, 1942	28,300	----------	55,600	----------	Do.
	Aug. 5, 1942	28,300	----------	55,600	69	Do.
5/11-20C1	Mar. 14, 1941	18	140	354	----------	Do.
20D1	Apr. 2, 1941	17	140	412	----------	Well flowing.
20E1	Mar. 17, 1941	17	155	418	67	Do.
	Jan. 23, 1942	16	145	440	65	Do.
20E2	Jan. 9, 1942	14	150	449	66	Do.
20E3	----do----	20	145	455	67	Do.
20G1	Mar. 11, 1941	17	175	450	----------	
20G2	----do----	17	25	346	----------	Well flowing. Sulfide odor.
20G3	----do----	44	55	969	63	Bailed; yellowish.
	July 8, 1942	41	60	1,020	67	Do.
20H2	Mar. 11, 1941	17	95	369	----------	
20J1	----do----	15	80	357	----------	
20J2	----do----	103	295	799	----------	Bailed.
	June 28, 1941	106	290	821	----------	Do.
	Sept. 18, 1941	105	200	830	----------	Do.
	Nov. 8, 1941	110	285	856	----------	Do.
	Jan. 14, 1942	109	255	855	66	Well flowing.
	Mar. 20, 1942	108	290	858	68	Bailed.
20L1	Mar. 17, 1941	18	70	207	----------	Do.
	Jan. 23, 1942	15	145	440	65	Well flowing.
20L2	----do----	15	135	420	----------	Do.
20Q1	Mar. 17, 1941	17	155	424	----------	
20R2	Sept. 22, 1941	14	125	411	----------	
20R3	----do----	14	125	404	----------	Sampled before well was developed.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
		T. 5 S., R. 11 W.—Continued				
5/11-21A1	Mar. 7, 1941	16	155	397		
21A2	do	25	180	543		
21D1	Mar. 11, 1941	47	135	426	64	Bailed.
21D2	do	172	650	1,640	62	15 ft below water surface.
	July 8, 1942	18	165	455	67	Bailed.
21F1	Apr. 3, 1941	17	30	352		
21F2	Mar. 17, 1941	168	390	1,160	62	Do.
	June 28, 1941	191	360	1,360		Do.
	Sept. 18, 1941	313	525	1,840		Do.
	Nov. 8, 1941	320	550	1,850		Do.
	July 8, 1941	138	295	963	67	Do.
21H2	Jan. 14, 1942	14	60	349	68	Well flowing.
	Mar. 20, 1942	18	65	359		
21H3	Mar. 7, 1941	18	165	420		
21L1	Mar. 14, 1941	17	105	363		
	July 8, 1942	14	105	383		
	Oct. 29, 1942	13	105	379		
21M3	Mar. 11, 1941	16	55	309		
21N1	Mar. 20, 1941	18	80	415		
21N2	Mar. 14, 1941	17	80	360		
21P4	do	24	170	435		
21Q1	do	17	35	294		See table 30, p. 229.
21Q3	do	29	130	557		Bailed. See table 30, p. 229.
21R1	Mar. 7, 1941	25	155	442	69	
22B1	do	18	165	417		
22B2	do	28	225	575		
22C1	do	18	165	420		
22D1	do	17	165	417		
22G1	Mar. 6, 1941	27	85	330		
22H2	Mar. 7, 1941	31	195	515		
22J2	Mar. 20, 1942	27	200	556		
22K1	Mar. 6, 1941	28	190	508		
22L2	Mar. 3, 1941	26	195	181		
22L3	Mar. 20, 1942	25	190	521	65	
22L4	Mar. 3, 1941	17	145	382		
22M2	Mar. 5, 1941	21	170	437		
22M3	Nov. 13, 1941	12	40	300		Bailed.
22N2	Mar. 29, 1941	23	175	455		Do.
22N3	Mar. 5, 1941	23	175	457		
	June 28, 1941	22	175	466		
	Sept. 18, 1941	18	145	455		
	Nov. 7, 1941	19	155	463		
	Mar. 20, 1942	19	170	468		
22Q2	Mar. 3, 1941	19	165	413		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 5 S., R. 11 W.—Continued						
5/11-22R2	Mar. 6, 1941	19	175	439		
5/11-23A1	Mar. 24, 1941	19	185	450		See table 30, p. 229.
23A2	Apr. 2, 1941	25	80	275		Bailed.
23B1	Mar. 19, 1942	14	165	421	66	
23P2	Mar. 24, 1941	17	175	434		
23P6	Mar. 6, 1941	16	145	397		
23P9	Mar. 24, 1941	19	170	435		
23P10	do	19	175	444		
23P11	do	15	140	383		
23Q2	do	17	185	435		
23R2	Feb. 25, 1941	16	140	372		
23R3	do	16	165	431		
23R4	do	23	170	448		
23R5	do	153	460	1,030		
23R6	do	15	155	412		
5/11-24D1	Mar. 24, 1941	29	205	503		
24F1	Feb. 27, 1941	17	170	439		
24G1	do	20	170	469		
24J1	May 20, 1941	32	165	521		
24L2	Feb. 27, 1941	17	165	429		
24M1	Mar. 24, 1941	19	185	441		
24N2	Feb. 20, 1941	19	165	427		
24N3	Feb. 25, 1941	19	175	429		
24N4	do	19	180	420		
24R1	Feb. 27, 1941	28	190	526		
24R2	do	21	175	459		
5/11-25A1	Feb. 25, 1941 Oct. 1, 1941	18 15	115 105	338 377		
25C1	Feb. 20, 1941	18	160	420		
25C2	do	18	165	429		
25D1	do	17	150	426		
25D3	do	17	140	389		
25D5	do	16	160	426		
25E1	do	15	145	379		
25F1	Feb. 10, 1941	23	188	457		
25G1	do	24	175	470		
25G2	Feb. 20, 1941	13	55	192	66	Do.
25L1	Feb. 19, 1941	16	155	418		
25L3	Feb. 10, 1941 Feb. 19, 1941	22 19	175 170	461 446		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 5 S., R. 11 W.—Continued						
5/11-25L4	Feb. 19, 1941	17	160	426		
25L6	do	21	205	515	64	
25M3	do	19	155	435		
25M6	Oct. 4, 1941	17	145	436		
25N1	Feb. 19, 1941	27	75	313	66	Do.
25Q1	Feb. 10, 1941	26	200	493		
5/11-26A1	Feb. 25, 1941	19	180	429		
26B1	do	18	165	439		
26B2	do	35	200	571		
26B3	do	21	165	433		
26B4	do	19	165	417		
26B5	do	19	165	415		
26B6	do	21	170	437		
26B8	Mar. 24, 1941	18	175	435		
26C1	do	18	180	402		
26C2	do	19	190	441		
26C3	do	18	175	441		
26C4	do	19	180	444		
26C5	do	20	170	424		
26D1	Mar. 19, 1942	17	145	435		
26E2	Mar. 24, 1941	19	180	472	66	Well flowing.
26G1	Feb. 25, 1941	15	140	379		
26G2	do	17	35	346		
	July 7, 1942	15	35	363		
	Oct. 29, 1942	14	45	374		
26H1	Feb. 20, 1941	15	140	380		See table 30, p. 229.
26H2	do	15	150	395		
26L1	Feb. 19, 1941	19	155	420		
26L2	do	16	85	372		
26L3	Mar. 24, 1941	16	75	369	67	
	Oct. 27, 1943	13	65	373	67	
26L4	Mar. 24, 1941	15	120	377		
26M1	Dec. 10, 1942	44	150	506		15 sec.
		29	130	443		30 sec.
		20	120	409		45 sec.
		15	115	395		1 min.
		12	110	382	67	2 min.
		12	115	381		5 min.
		12	115	384		10 min 15 sec.
				385		15 min.
				383		20 min.
		12	115	384		30 min.
				383	68	50 min.
				385		1 hr 16 min.
		13	115	387	70	1 hr 41 min.
				388		2 hr 3 min.
		13	120	392		2 hr 34 min.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 5 S., R. 11 W.—Continued			
5/11-26M1-con.	Dec. 10, 1942	15	120	405	69	3 hr 52 min.
		17	120	405	69	3 hr 57 min.
	Dec. 29, 1942	175	325	1,000	----------	
	Dec. 31, 1942	196	345	1,090	----------	
	Jan. 2, 1943	208	360	1,130	----------	
	Jan. 4, 1943	205	370	1,120	----------	
	Jan. 11, 1943	243	400	1,270	----------	
	Jan. 20, 1943	208	365	1,160	----------	See table 30, p. 229.
	Feb. 3, 1943	13	120	384	----------	Well flowing.
		16	140	446	65	0 time.
		18	101	390	65	15 sec.
		15	130	392	65	30 sec.
		14	120	388	65	45 sec.
		----------	----------	388	65	1 min.
		----------	----------	389	69	2 min.
		----------	----------	390	70	5 min.
		----------	----------	386	70	6 min 50 sec.
		13	----------	388	70	10 min.
		----------	----------	386	70	15 min.
		----------	----------	386	70	20 min.
		----------	----------	389	70	30 min.
		----------	----------	388	70	40 min.
		----------	----------	388	70	50 min.
		13	115	390	70	1 hr.
		----------	----------	389	70	1 hr 10 min.
		----------	----------	390	----------	1 hr 25 min.
		13	115	394	70	1 hr 35 min.
		13	----------	393	70	1 hr 40 min.
		14	120	395	70	1 hr 45 min.
		----------	----------	396	70	1 hr 50 min.
		----------	----------	397	----------	2 hr.
		----------	----------	400	70	2 hr 10 min.
		16	135	400	70	2 hr 15 min.
		16	135	402	70	2 hr 20 min.
		----------	----------	405	70	2 hr 25 min.
		----------	----------	406	70	2 hr 30 min.
		17	135	407	----------	2 hr 35 min.
		----------	----------	409	----------	2 hr 45 min.
		----------	----------	411	----------	2 hr 55 min.
		----------	----------	414	----------	3 hr.
		18	135	417	----------	3 hr 10 min.
		----------	----------	418	70	3 hr 20 min.
		----------	----------	422	----------	3 hr 30 min.
		21	125	424	----------	3 hr 40 min.
		----------	----------	426	70	3 hr 50 min.
		----------	----------	430	----------	4 hr 5 min.
		----------	----------	436	----------	4 hr 20 min.
		25	135	442	----------	4 hr 35 min.
		26	140	447	----------	4 hr 50 min.
		----------	----------	453	----------	5 hr 5 min.
		----------	----------	452	69	5 hr 20 min.
		29	160	461	----------	5 hr 35 min.
		----------	----------	464	----------	5 hr 50 min.
		----------	----------	467	----------	6 hr 5 min.
		----------	----------	475	----------	6 hr 20 min.
		33	165	478	----------	6 hr 35 min.
		----------	----------	484	69	6 hr 50 min.
		36	155	489	----------	7 hr 5 min.
		----------	----------	493	----------	7 hr 20 min.
		38	160	495	----------	7 hr 35 min.
		----------	----------	502	----------	7 hr 50 min.
		41	175	514	----------	8 hr 5 min.
	June 4, 1943	14	140	434	----------	0 time.
		13	125	434	----------	15 sec.
		14	130	388	----------	30 sec.
		14	120	388	----------	45 sec.
		15	125	393	----------	1 min.
		15	115	389	70	2 min.
		14	120	389	69	3 min.
		16	120	390	69	5 min.
		37	135	479	69	14 min.
		149	230	914	68	30 min.
		183	285	1,050	68	45 min.
		191	285	1,060	67	1 hr.
		----------	----------	1,100	67	1 hr 10 min.
		----------	----------	1,100	67	1 hr 20 min.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 5 S., R. 11 W.—Continued			
5/11-26M1-con.	June 4, 1943	201	270	1,120	67	1 hr 35 min.
		----------	----------	1,120	67	1 hr 45 min.
		----------	----------	1,130	67	2 hr.
		----------	----------	1,130	67	2 hr 15 min.
		----------	----------	1,130	67	2 hr 30 min.
		204	300	1,130	67	2 hr 45 min.
		205	285	1,140	67	3 hr.
		208	300	1,140	67	3 hr 15 min.
		207	270	1,140	67	3 hr 30 min.
		211	270	1,150	67	3 hr 45 min.
		210	285	1,140	67	4 hr 30 min.
		211	300	1,140	67	4 hr 45 min.
		213	285	1,150	67	5 hr.
		213	300	1,100	----------	6 hr.
	June 28, 1941	112	225	782	----------	
26M2------	Jan. 14, 1942	58	190	622	----------	
	Mar. 19, 1942	62	225	608	----------	
	Dec. 4, 1942	126	260	837	----------	See table 30, p. 229.
	Dec. 28, 1942	77	220	668	----------	
	Dec. 30, 1942	75	225	657	----------	
	Jan. 1, 1943	72	235	653	----------	
	Jan. 3, 1943	72	225	652	----------	
	Jan. 18, 1943	59	210	604	----------	
	Oct. 27, 1943	25	155	477	67	
26M3------	Sept. 24, 1943	101	180	751	----------	Well pumped dry, then sampled on recovery.
26M4------	----do-----	16	75	387	----------	15 min.
	Oct. 27, 1943	15	115	437	----------	
26N1-------	Mar. 24, 1941	126	300	813	----------	
	June 28, 1941	78	175	659	----------	
	Sept. 18, 1941	74	190	655	----------	
	Nov. 7, 1941	85	190	682	----------	
	Jan. 14, 1942	57	190	668	----------	
	Mar. 19, 1942	79	255	677	----------	
	Oct. 29, 1942	90	225	685	68	
26N2-------	Sept. 11, 1941	753	415	1,770	72	Bailed.
	Nov. 14, 1941	71	165	558	----------	Do.
	Jan. 22, 1942	213	270	1,240	66	Do.
	Mar. 27, 1942	294	575	1,580	----------	Do.
	Aug. 7, 1942	55	190	574	70	Do.
26N3-------	Sept. 24, 1943	2,070	1,150	7,540	----------	Well pumped dry, then sampled on recovery. Yellowish.
26P3-------	Feb. 19, 1941	17	40	400	----------	
26R1-------	----do-----	20	170	444	----------	
26R2-------	Feb. 25, 1941	19	175	415	----------	
5/11-27A2-------	Jan. 14, 1942	20	145	472	----------	
27A4-------	Mar. 3, 1941	17	165	433	----------	
	Sept. 18, 1941	14	120	423	----------	
27B1-------	Mar. 6, 1941	20	170	424	----------	
	June 28, 1941	20	175	452	----------	
27B2-------	Sept. 11, 1941	29	145	484	74	
	Nov. 14, 1941	64	155	689	----------	
	Jan. 20, 1942	107	160	722	67	
	Mar. 27, 1942	30	95	378	----------	
	July 9, 1942	109	95	663	69	
	May 31, 1943	17	145	478	----------	
27C1-------	Mar. 6, 1941	16	145	403	----------	
27C2-------	----do-----	22	125	366	----------	

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 5 S., R. 11 W.—Continued						
5/11-27C4	Mar. 6, 1941	23	180	463		
	May 31, 1943	17	155	478		
27D1	Mar. 5, 1941	18	65	325		
	June 28, 1941	17	65	341		
	Sept. 18, 1941	19		456		
	Nov. 7, 1941	35	50	330		
	Jan. 14, 1942	14	55	338		
	July 8, 1942	15	75	358	66	Well flowing.
	Oct. 29, 1942	17	50	320		Bailed.
27D2	Mar. 5, 1941	24	175	472		
27F2	Mar. 6, 1941	19	165	431		Well flowing.
27G1	Mar. 18, 1942	17	165	439	66	
27H1	Mar. 24, 1941	25	230	567		
	Oct. 29, 1942	21	235	604		
27K2	Mar. 3, 1941	17	165	429		Bailed; yellowish and turbid.
27L1	do	19	40	370		Well flowing. Yellowish.
	Jan. 14, 1942	16	45	377	67	Do.
27N2	Mar. 3, 1941	16	150	413	66	Bailed.
27N3	Apr. 3, 1941	19	50	377		Well flowing.
	Oct. 29, 1942	19	175	466		
27P1	Mar. 3, 1941	15	85	355		Bailed; turbid.
27P3	Apr. 3, 1941	15	135	395		Sulfide odor.
27Q1	Mar. 3, 1941	23	50	595		Yellowish; sulfide odor.
27Q2	do	17	240	405		
	Oct. 27, 1943	12	130	414		Well flowing.
27R1	Mar. 20, 1941	409	450	1,960	67	
	June 28, 1941	741	925	3,000		
	Sept. 17, 1941	1,170	700	3,730		
	Nov. 7, 1941	740	875	3,010		
	Jan. 14, 1942	1,170	1,200	4,300	67	
	Mar. 19, 1942	1,150	1,200	4,090	66	
	July 8, 1942	1,120	1,250	4,140	68	
	Oct. 29, 1942	951	1,000	3,700	73	
5/11-28A2	Mar. 24, 1941	21	185	461		
	June 28, 1941	23	165	527		
	Sept. 18, 1941	16	125	462		
	Nov. 7, 1941	20	155	465		
	Jan. 14, 1942	18	160	469		
28A3	Mar. 24, 1941	36	35	472		
28C3	Mar. 14, 1941	18	140	379		
	Sept. 17, 1941	16	115	415		
28C5	Mar. 18, 1941	17	150	395		Do.
28D1	Mar. 20, 1941	18	165	417	67	
28D2	do	18	150	402		
28F1	Mar. 18, 1941	16	135	392		Do.
28G1	Mar. 14, 1941	17	145	402	67	Do.
28H2	Mar. 18, 1941	17	115	386	68	Do.
	Jan. 14, 1942	15	110	388	67	Do.
	Mar. 18, 1942	16	40	348	74	
28H4	Aug. 20, 1941	395	235	1,950	73	Bailed.
	Sept. 11, 1941	122	110	1,010		Do.
	Nov. 14, 1941	282	140			Do.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 5 S., R. 11 W.—Continued			
5/11-28H4-con.	Jan. 20, 1942	334	190	1,730	67	Bailed.
	Mar. 27, 1942	123	110	1,010		Do.
	July 9, 1942	253	135	1,470	68	Do.
5/11-28J2	Sept. 11, 1941	15,300	3,900	26,100	68	Do.
	Nov. 14, 1941	9,930	3,400	25,700		Do.
	Jan. 20, 1942	8,690		21,200	66	Do.
	Mar. 27, 1942	9,060	2,750	22,200		Do.
	July 9, 1942	9,080		22,200	65	Do.
28K1	Mar. 14, 1941	19	50	498	72	Well flowing. See table 30, p. 230.
28K2	do	17	165	408	67	Well flowing.
28L1	Mar. 18, 1941	21	115	405	66	Do.
28Q1	Mar. 14, 1941	18	35	329	72	Well flowing. Sulfide odor.
28R4	Apr. 22, 1941	17,350	1,800	41,100	120	Yellowish and turbid.
5/11-29A1	Mar. 20, 1941	18	185	424		
29A2	do	17	160	358		Slightly turbid.
29A3	do	21	175	448		
29A5	do	18	160	420		
29A6	Mar. 17, 1941	18	160	426		
29B1	do	19	140	383		
29B2	do	18	165	429		
29B3	do	22	160	459		
29B4	do	19	155	412		
29B5	do	19	135	391		
29C3	do	23	85	299	62	Bailed.
	Dec. 22, 1941	40	85	397		Do.
				396		15 ft (7¼ ft below static water level).
				395		25 ft.
				395		35 ft.
				398		45 ft.
		40	90	397		46 ft (6.3 ft above bottom of well).
29C4	Mar. 17, 1941	18	85	271	64	Bailed.
	Dec. 22, 1941	16	75	287		Do.
				285		10 ft (7¼ ft below static water level).
				284		20 ft.
				287		30 ft.
				286		40 ft.
				289		50 ft.
				291		60 ft.
				296		70 ft.
		14	80	304		80 ft.
				301		90 ft.
				306		100 ft.
		14	80	311		110 ft.
				289		120 ft.
				301		130 ft.
				302		140 ft.
		14	80	305		147 ft (13 ft above bottom of well).
29D1	Mar. 17, 1941	17	95	313		
29E1	July 25, 1941	12,900	2,600	32,500		0 time.
		13,400	2,700	32,500		5 min.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 5 S., R. 11 W.—Continued			
5/11-29E1-con.	July 25, 1941	12,800	2,600	32,500		15 min.
		16,120	3,100	38,300		90 min.
		13,100	2,550	32,500		110 min.
		13,900	2,600	31,500		2 hr.
		13,300	2,750	33,500		2 hr 10 min.
		13,100	2,550	32,500		2 hr 20 min.
29E2	do	15,100	5,500	35,700		
		13,600	5,650	31,500		10 min.
		14,900	6,150	33,500		20 min.
		16,500	7,000	37,000		35 min.
		16,100	6,500	36,300		50 min.
		16,400	7,000	35,700		2 hr 5 min.
		16,500	7,000	35,700		2 hr 25 min.
29P1	Mar. 18, 1941	2,050	550	6,670	78	Well flowing. Yellowish. See table 30, p. 230.
5/11-30B1	do	532	500	2,230	64	
5/11-33A1	Sept. 11, 1941	10,600	5,000	27,100	74	Bailed.
	Nov. 14, 1941	10,400	5,000	26,300		
	Jan. 20, 1942	11,600		27,800	67	Do.
	Mar. 27, 1942	10,800	6,250	25,600		Do.
	July 9, 1942	10,600		25,600	66	Do.
33G1	Sept. 11, 1941	10,400	5,250	29,000	74	Do.
	Nov. 14, 1941	11,900	5,750	29,600		Do.
	Jan. 20, 1942	12,900		29,400	67	Do.
	July 9, 1942	12,400		28,600	67	Do.
33H1	June 7, 1941	16	35	320		
33L1	Aug. 21, 1941	18,100	7,500	38,800	79	Do.
	Sept. 11, 1941	15,800	6,750	38,000	74	Do.
	Nov. 14, 1941	18,000	7,250	39,200		Do.
	Jan. 20, 1942	16,800		37,000	68	Do.
	Mar. 27, 1942	16,900	8,000	37,000		Do.
	July 9, 1942	18,400		40,000	67	Do.
33M1	Aug. 21, 1941	24,800	10,500	47,500	77	Do.
	Sept. 11, 1941	25,500	9,500	53,200		
	Jan. 20, 1942	22,400		47,500	66	Do.
	Mar. 27, 1942	25,400		52,500		Do.
	July 9, 1942	25,100		50,000	66	Do.
33N1	Aug. 21, 1941	11,500	5,950	27,500	69	Do.
	Sept. 11, 1941	11,400	4,250	28,800		Do.
	Nov. 14, 1941	12,000	5,000	29,200		Do.
	Jan. 20, 1942	11,800		27,800	67	Do.
	Mar. 27, 1942	12,500	4,900	28,600		Do.
	July 9, 1942	8,400		20,400	68	Do.
5/11-34G2	Feb. 28, 1941	233	445	6,850		Do.
35A1	Feb. 18, 1941	15	75	368	67	
35A3	Feb. 10, 1941	23	190	465		
35B2	Feb. 18, 1941	17	35	388		
35C1	do	19	175	446		
35C2	Feb. 19, 1941	16	45	352		
35D2	Sept. 11, 1941	533	650	2,300	74	Do.
	Jan. 22, 1942	715		3,250	68	Do.
	Mar. 27, 1942	383	525	1,630		Do.
	Aug. 7, 1942	366	475	1,790	70	Do.
35F1	Feb. 19, 1941	30	185	505		
	Oct. 27, 1943	22	150	483		
35F2	May 31, 1943	14	55	335	67	
35H1	Feb. 18, 1941	23	190	467		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 5 S., R. 11 W.—Continued			
5/11-35L1	Feb. 19, 1941	476	540	1,980		
	Mar. 19, 1942	207	285	1,120		
	Apr. 9, 1942	315	475	1,550		See table 30, p. 230.
	July 8, 1942	251	450	1,370		
35M1	Feb. 19, 1941	392	460	1,450		
	June 28, 1941	227	375	1,270		
	Sept. 18, 1941	275	275	1,340		
	Nov. 7, 1941	283	290	1,350		
	Jan. 14, 1942	231	350	1,290		
	July 8, 1942	241	425	1,340	69.5	
	Oct. 29, 1942	285	390	1,470	68.5	
35P1	Feb. 28, 1941	77	75	559		See table 30, p. 230.
	Sept. 12, 1941	92	75	646		
5/11-36B2	Feb. 10, 1941	23	175	481		
36D2	do	25	150	410		
36E1	Feb. 18, 1941	21	180	461		
36F1	Feb. 10, 1941	21	150	433		
36F2	do	22	195	457		
36F3	do	21	175	448	66	
36G2	Jan. 6, 1941	31	45	302	68	Bailed.
36J3	do	17	50	231	64	Do.
36K2	Aug. 3, 1942	20	190	481	69	5 min.
36K3	Jan. 6, 1941	19	60	311	65	Bailed.
36L1	Feb. 10, 1941	20	180	442		
36M4	Feb. 18, 1941	20	175	441	67	
36M6	do	19	170	442		
36N2	do	40	175	513		
36P1	Feb. 19, 1941	20	175	450		
36Q1	Jan. 6, 1941	20	100	328	66	Do.
36R1	do	24	185	478		
			T. 5 S., R. 12 W.			
5/12-1A1	Apr. 8, 1941	17	75	364		
1D1	Sept. 8, 1941	209	725	1,290	72	Bailed.
	Nov. 15, 1941	283	275	1,260		Do.
	Jan. 21, 1942	211	165	910	67	Do.
	Mar. 27, 1942	288	200	1,170		Do.
	Aug. 5, 1942	85	100	485	71	Do.
	Dec. 22, 1942	49	125	366	70	Do.
5/12-2A1	Sept. 8, 1941	5,030	5,000	13,300	72	Do.
	Nov. 15, 1941	1,350	1,400	4,120		Do.
	Jan. 22, 1942	619	675	2,230	68	Do.
	Mar. 27, 1942	476	350	1,620		Do.
	Aug. 5, 1942	269	195	952	71	Do.
	Dec. 22, 1942	176	125	659	69	Do.
2B1	Apr. 10, 1941	17	90	394		Well flowing.
2B2	do	17	85	398		Do.
	Jan. 10, 1942	15	85	392	74	Do.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 5 S., R. 12 W.—Continued						
5/12-2B3	do	17	105	430	73	Do.
2C2	Apr. 10, 1941	19	35	323		
2C3	Sept. 22, 1941	50	285	1,040	67	
2C4	Sept. 30, 1941	18	25	347		
2D1	Apr. 10, 1941	18	45	338		Yellowish.
2D2	do	18	55	452		Do.
2G2	do	17	105	402		
2H1	do	18	120	403		
2H3	Sept. 8, 1941	623	600	2,870	72	Bailed.
	Nov. 15, 1941	190	200	948		Do.
	Jan. 22, 1942	71	110	635	66	Do.
	Mar. 27, 1942	69	125	665		Do.
	Aug. 5, 1942	47	115	524	71	Do.
	Dec. 22, 1942	28	185	433	68	
2J2	Apr. 10, 1941	17	30	329		Yellowish; sulfide odor. See table 30, p. 230.
2J3	June 3, 1941	57	105	573		Sampled while drilling.
	Apr. 3, 1942	14	100	385		
	July 14, 1942	15	70	366		
2K1	Sept. 8, 1941	11,000	9,250	26,800	72	Bailed.
	Nov. 15, 1941	9,670	2,250	23,700		Do.
	Jan. 22, 1942	6,960		17,900	67	Do.
	Mar. 27, 1942	8,170		18,900		Do.
	Aug. 5, 1942	8,750		19,100	73	Do.
2P1	Apr. 9, 1941	17	40	365		Yellowish.
2P2	do	17	35	366		Sulfide odor.
2P3	do	17	60	370		Do.
2P4	Sept. 8, 1941	19,900	6,500	46,600	72	Bailed.
	Nov. 15, 1941	18,800	5,750	42,300		Do.
	Jan. 22, 1942	15,200		33,300	66	Do.
	Mar. 27, 1942	17,800		38,500		Do.
	Aug. 5, 1942	19,300		41,600	72	Do.
5/12-3A1	Apr. 10, 1941	17	120	452		
5/12-10A1	Sept. 9, 1941			1,280		21 ft (2 ft below static water level).
		335	140			30 ft.
		353	135	1,230		40 ft.
		384	155	1,410		50 ft.
		395	170	1,440		60 ft.
		395	165	1,480		70 ft.
		391	170	1,470		80 ft.
		384	165	1,440		90 ft.
		378	160	1,450		100 ft.
		376	165	1,440		110 ft.
		392	155	1,430		120 ft.
		390	165	1,450		130 ft.
		1,450	575	4,440		140 ft.
		1,710	625	5,140		160 ft.
		1,690	625	5,060		180 ft.
		1,710	650	5,120		200 ft (100.4 ft above bottom of well).
10H1	Sept. 8, 1941	25,300	8,150	52,900	77	Bailed.
	Nov. 15, 1941	26,000	8,500	51,500		Do.
	Jan. 22, 1942	22,200		45,500	68	Do.
	Mar. 27, 1942	25,000		50,000		Do.
	Aug. 5, 1942	26,100		50,000	74	Do.
10H2	Sept. 8, 1941	35,200	16,000	66,600		Do.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
		T. 5 S., R. 12 W.—Continued				
5/12-10H2-con.	Nov. 15, 1941	34,600	15,000	66,300		Bailed.
	Jan. 22, 1942	29,500		58,800	68	Do.
	Mar. 27, 1942	33,300		62,500		Do.
	Aug. 5, 1942	33,900		66,700	74	Do.
10K1	Sept. 8, 1941	10,300	3,150	26,800		Do.
	Nov. 15, 1941	8,720	1,900	23,800		Do.
	Jan. 22, 1942	7,630		19,400	67	Do.
	Mar. 27, 1942	9,900		24,400		Do.
	Aug. 5, 1942	9,440		22,900	69	Do.
10P1	Sept. 8, 1941	5,060	2,200	14,300	76	Do.
	Nov. 15, 1941	6,090	2,000	16,700		Do.
	Jan. 22, 1942	6,110		16,500	66	Do.
	Mar. 27, 1942	7,110		18,600		Do.
	Aug. 5, 1942	7,900		19,200	77	Do.
5/12-11A1	Apr. 10, 1941	20	25	629		Bailed; yellowish.
	July 14, 1942	45	45	762	72	Do.
	Oct. 30, 1942	21	30	684		Bailed.
11D1	Sept. 8, 1941	16,900	5,900	38,300	79	Do.
	Nov. 15, 1941	5,780	1,000	15,800		Do.
	Mar. 27, 1942	4,130		11,700		Do.
	Aug. 5, 1942	4,060		11,100	75	Do.
11G1	Apr. 9, 1941	33	55	357		Sulfide odor; yellowish.
	Sept. 17, 1941	27	45	368		Do.
	Nov. 12, 1941	27	65	381		Do.
	Jan. 14, 1942	27	60	385		Do.
	Oct. 30, 1942	29	65	417		
	May 10, 1943	36	70	427		4 hr.
	May 15, 1943	37	70	425		5 hr.
	May 20, 1943	36	65	426		5 hr.
	May 22, 1943	37	65	424		5 hr.
11H1	June 28, 1942	6,900	2,250	17,900		Bailed.
		7,000	2,000	18,000		20 ft below water surface.
	Nov. 9, 1943	2,080	390	6,370		About 1 min.
5/12-12A1	Apr. 8, 1941	17	140	410	67	
12C1	do	16	40	310		Well flowing.
12F1	do	22	50	444	68	Bailed; yellowish.
12L1	do	16	30	322		Sulfide odor.
12P1	do	341	280	1,430		
	June 25, 1941	203	205	1,050		
	Sept. 18, 1941	102	135	690	70	0 time.
		94	145	673	70	15 sec.
		98	125	690	70	30 sec.
		100	125	685	70	45 sec.
		95	115	655	70	1 min 45 sec.
		113	135	737	70	3 min.
		123		756	70	8 min.
		138	150	819	70	33 min.
		143	150	828	70	42 min.
		152	155	853	70	92 min.
		155	155	854	70	3 hr 7 min.
		156	155	862	70	4 hr 12 min.
		154	145	862	70	5 hr 37 min.
	Nov. 12, 1941	182	160	966		
	Jan. 14, 1942	170	155	924		
	Mar. 20, 1942	184	190	976	69	
	Apr. 9, 1942	129	190	776	66	See table 30, p. 230.
	Sept. 11, 1942	67	120	487	70	0 time.
		32	110	418	70	15 sec.
		32	120	420	70	30 sec.
		32	120	418	70	45 sec.
		30	115	420	70	1 min.
		33	125	431	70	2 min. 15 sec.
		258	250	1,320	70	2 min 45 sec.
		320	250	1,380	70	3 min 15 sec.
		329	265	1,400	70	4 min.
		344	290	1,470	70	6 min.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 5 S., R. 12 W.—Continued			
5/12-12P1-con.	Sept. 11, 1942	346	290	1,500	70	16 min.
		315	275	1,380	70	50 min.
		303	265	1,340	70	61 min.
		260	265	1,200	70	2 hr 21 min.
		224	215	1,090	70	5 hr 12 min
		211	215	1,030	70	8 hr 11 min.
		211	225	1,030	70	8 hr 21 min.
12P4	Apr. 8, 1941	47	80	518		Slightly yellowish.
	Sept. 17, 1941	38	65	496	66	Do.
	Nov. 12, 1941	45	75	501		Do.
	Nov. 13, 1941	28	65	476		Do.
	Jan. 14, 1942	25	60	471		Do.
	July 14, 1942	13	55	476	77	Do.
	Oct. 27, 1943	20	50	425		Yellowish.
12P6	Mar. 17, 1942	15	80	356		1 min.
		15	70	354		3 min.
		14	70	351		5 min.
		14	65	348		7 min.
		14	55	343		10 min.
		14	45	381		15 min.
		15	45	413		27 min.
		15	45	427		33 min.
		16	50	433		36 min.
		15	50	437		41 min.
		15	50	448		53 min.
		16	50	448		60 min.
		15	50	451		64 min.
	Mar. 18, 1942	16	55	482		Yellowish. About 5½ hr intermittent pumping.
		28	60	493		Yellowish. About 7 hr intermittent pumping.
	July 14, 1942	14	55	481		Yellowish.
	Oct. 27, 1943	13	40	398		Do.
5/12-13D1	Jan. 29, 1942	5,180	3,250			7 min.
		13,300	6,650			16 min.
		16,400	6,500	35,700		30 min.
		17,400	7,250	38,500		78 min.
		17,300	7,000	37,000		103 min.
		17,800	7,400	38,500		110 min.
		18,100	6,750	38,500		2 hr 13 min.
		18,400	6,900	40,000		3 hr 1 min.
	Jan. 30, 1942	18,800	7,500	40,000		0 time.
		18,800	7,000	40,000		25 min.
		19,100	7,500	40,000		75 min.
		18,800	7,400	41,700		89 min.
	Apr. 25, 1942	9,670	550	23,300		Bailed. See table 30, p. 230.
13D2	Jan. 29, 1942	1,890	2,000			0 time.
		12,600	5,150	29,400		10 min.
		13,000	5,250	30,300		18 min.
		13,000	5,650	30,300		33 min.
		13,200	5,900	30,300		40 min.
5/12-24H1	Sept. 9, 1941	9,340	3,500	24,000	73	Bailed.
	Nov. 15, 1941	12,100	4,250	29,100		Do.
	Jan. 21, 1942	11,200		26,400	67	Do.
	Mar. 27, 1942	12,700	4,250	29,400		Do.
	Aug. 5, 1942	13,300		30,400	72	Do.
			T. 5 S., R. 13 W.			
5/13-3D1	Jan. 8, 1941	3,980	1,750	11,500		See table 30, p. 230.
	Jan. 10, 1942	4,740	2,300	13,400		
	Mar. 25, 1942	5,170	2,500	13,700		
	Nov. 3, 1942	5,330	3,190	15,400	70	
3K2	Jan. 8, 1941	2,040	615	6,100	68	
5/13-18J1	do	585	160	3,660	64	Bailed; yellowish.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 6 S., R. 10 W.						
6/10-1E1	Dec. 13, 1940	17	190	370		
1E2	Apr. 16, 1942	18	20	371		Yellowish. See table 30, p. 231.
1E3	Dec. 13, 1940	26	240	491		
1E4	Dec. 14, 1940	358	1,450	3,190		
	July 8, 1941	333	1,150	3,260		
	Sept. 18, 1941	330	2,400	3,210		
	Nov. 5, 1941	326	1,100	3,400		
	Jan. 12, 1942	325	1,050	3,260		
	Mar. 17, 1942	326	1,300	3,270		
	July 3, 1942	301	1,250	3,380		
1F1	Dec. 13, 1940	25	290	540		
1F2	do	22	290	557		
1L1	do	47	375	883		
	July 8, 1941	39	260	814		
1L2	Dec. 13, 1940	174	1,400	2,490	67	Bailed; yellowish.
	Mar. 17, 1942	371	1,300	3,300		Do.
1L3	Dec. 13, 1940	46	260	593	67	Bailed; turbid.
6/10-2B1	Dec. 14, 1940	18	225	461		
2B2	do	165	700	1,430	67	Bailed.
2B3	do	18	155	416		
2C1	Dec. 17, 1940	21	150	415		
2E1	do	65	560	1,250	68	Do.
2F1	Dec. 16, 1940	21	145	474		
2F2	Dec. 17, 1940	29	80	321		
2G1	Dec. 13, 1940	17	190	759	72	
2G2	do	205	800	1,470		
2G4	do	31	500	349	66	Do.
2G5	do	138	450	1,170	66	Do.
2H1	do	321	1,600	2,640		
	May 9, 1941	437	1,550	3,450		
	Apr. 9, 1942	380	1,500	3,300		See table 30, p. 231.
2J1	Dec. 13, 1940	238	1,000	2,560		
	July 8, 1941	263	1,200	2,840		
	Sept. 19, 1941	279	1,150	2,740		
	Nov. 6, 1941	301	1,300	3,070		
	Jan. 12, 1942	312	1,350	3,110		
	Mar. 17, 1942	323	1,350	3,200		
	Oct. 27, 1942	341	1,500	3,440		
2J2	Dec. 13, 1940	21	170	458		Sulfide odor.
2J3	Dec. 16, 1940	17	50	361		
2K1	do	20	185	483		
	June 25, 1942	19	195	553		
2L1	Dec. 16, 1940	21	135	424		
6/10-3E1	Dec. 17, 1940	18	140	426		
3F1	do	17	165	457		
3H1	do	20	60	398	63	Do.
3H2	do	17	60	385		
	July 8, 1941	18	40	376		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 6 S., R. 10 W.—Continued			
6/10-3H3	Dec. 18, 1940	20	160	442		
3J1	Dec. 17, 1940	57	355	943		
3K2	do	16	160	452		
3L1	do	16	125	391		
3M1	do	19	155	441		
3M2	do	32	135	439		
3M3	do	16	165	467		
3N2	do	18	150	435		
3N3	Dec. 18, 1940	85	115	629		
	July 8, 1941	81	100	630		
	Sept. 19, 1941	76	85	608		
	Nov. 6, 1941	76	100	623		
	Jan. 12, 1942	75	75	617		
	Mar. 17, 1942		85	622		
	Oct. 27, 1942	68	65	502		
3P1	Dec. 18, 1940	19	150	439		
3Q1	Aug. 14, 1941	34	35	459		
6/10-4C1	Dec. 18, 1940	15	50	366		
4D1	do	15	85	340		
6/10-5B1	Dec. 19, 1940	160	235	1,040	67	Bailed.
5C1	do	23	190	493	66	
	June 2, 1941	18	155	442	67	2 hr.
5C2	Dec. 19, 1940	24	190	500		
5N1	do	20	170	413		
5R2	Dec. 18, 1940	238	60	1,330		Yellowish.
	July 8, 1941	234	35	1,290		Do.
5R3	do	93	30	754		Do.
	Sept. 18, 1941	80	30	679		Do.
	Sept. 22, 1941	79	30	672		Do.
	Nov. 6, 1941	84	35	697		Do.
	Jan. 12, 1942	98	35	762		Do.
	July 3, 1942	84	50	894		Do.
	Oct. 27, 1942	99	40	777		Do.
6/10-6A2	Dec. 19, 1940	15	130	403	65	Bailed.
6B1	do	17	110	338	64	See table 30, p. 231.
6D1	Dec. 20, 1940	14	30	197	66	Bailed; yellowish.
	Jan. 14, 1942	18	145	456	65	Well flowing.
6F1	Mar. 18, 1942	16	155	431	67	
6K1	Dec. 19, 1940	17	110	338		
6L2	do	55	380	885		
	July 8, 1941	20	150	430		
	Sept. 18, 1941	14	105	421		
	Nov. 7, 1941	18	150	426		
	Jan. 13, 1942	17	130	433		
	Mar. 18, 1942	17	155	427		
	July 6, 1942	15	155	432		
	Oct. 28, 1942	16	160	437		
6P1	Dec. 9, 1940	20	90	350	66	Bailed.
6P2	Apr. 3, 1941	17	155	457		Do.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 6 S., R. 10 W.—Continued			
6/10-7B1	Dec. 3, 1940	24	135	441	68	Bailed; turbid.
7C1	Dec. 20, 1940	17	120	345	66	Bailed.
7C3	Mar. 18, 1942	16	135	424	67	
7D1	Dec. 3, 1940	17	130	382	67	
	Mar. 18, 1942	16	150	421	67	
7D2	Dec. 20, 1940	17	75	300		Do.
7F1	do	19	55	446		
7G1	do	16	150	346		
7K1	Dec. 5, 1940	21	30	408	68	Yellowish.
7K5	do	16	150	427	66	See table 30, p. 231.
7L1	Dec. 3, 1940	17	150	429	66	
7L3	Dec. 20, 1940	16	155	418		
7L4	Sept. 11, 1941	149	415	1,670	73	Bailed.
	Nov. 13, 1941	95	215	1,520		Do.
	Jan. 20, 1942	78	365	1,000	67	Do.
	Mar. 27, 1942	85	270	1,720		Do.
	Apr. 16, 1942	150	350	1,960		Do.
	Aug. 7, 1942	79	235	1,730	68	Do.
7N1	Dec. 3, 1940	16	451	409		
	Oct. 27, 1942	14	145	409		
	Oct. 26, 1943	12	130	410		
7P1	Sept. 11, 1941	255	825	1,800	70	Do.
	Nov. 13, 1941	144	500	1,370		Do.
	Jan. 20, 1942	80	170	1,502	67	Do.
	Mar. 27, 1942	78	305	991		Do.
	Aug. 6, 1942	107	665	1,480	69	Do.
6/10-8A1	Dec. 18, 1940	111	30	797	72	Do.
8B1	do	89	125	541	66	Bailed; sulfide odor.
	Mar. 18, 1942	374	700	2,780	68	Bailed.
8B2	Jan. 27, 1941	111	165	850		While drilling; cased 80 ft.
	Jan. 29, 1941	113	175	896		While drilling; cased 100 ft.
	do	103	175	835		While drilling; cased 115 ft.
	do	92	125	822		While drilling; cased 180 ft.
	Apr. 9, 1942	88	125	681		
	July 23, 1942	97	135	743		
8D2	Dec. 19, 1940	20	150	420		
	Dec. 20, 1940	16	140		68	See table 31, p. 231.
	July 8, 1941	20	125	443		
	Sept. 18, 1941	18	130	432		
	Nov. 6, 1941	18	130	435		
	Jan. 12, 1942	19	130	438	69	
	Oct. 27, 1942	19	155	454	70	
8D5	Mar. 18, 1942	21	155	469	69	See table 31, p. 232.
8D6	Jan. 22, 1941	234	415	2,070		While drilling; cased 86 ft.
	do	272	490	2,340		While drilling; cased 100 ft.
	do	120	235	1,240		While drilling; cased 110 ft.
	July 8, 1941	21	140	454		
	Oct. 27, 1943	19	120	459	69	
8G2	Dec. 3, 1940	86	35	637	77	
	Apr. 16, 1943	73	35	644		
8M1	Jan. 4, 1941	29	45	500	66	Bailed.
6/10-10A1	Dec. 18, 1940	22	25	383		
10D1	do	33	95	435		

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 6 S., R. 10 W.—Continued			
6/10-10D2	Dec. 18, 1940	24	55	375		Yellowish.
10H1	Mar. 31, 1943	18	45	361		Do.
6/10-11B1	Oct. 4, 1941	20	25	387		Do.
	Oct. 5, 1941	25	25	436		Yellowish. See table 30, p. 232.
	Mar. 17, 1942	15	65	346		Yellowish.
	Sept. 19, 1942	17	65	355	80	Do.
	Dec. 1, 1942	15	60	350	78	
	Feb. 1, 1943	17	60	353	78	½ hr.
	Mar. 31, 1943	18	55	375	75	
	June 1, 1943	18	55	357	79	1½ hr.
	June 30, 1943	16	55	357	79	3 hr 15 min.
	July 31, 1943	17	55	360	79	3½ hr.
	Sept. 30, 1943	17	55	353	79	3 hr.
	Nov. 30, 1943	17	55	352	79	4 hr.
11B2	Oct. 12, 1941	19	40	359		See table 30, p. 232.
	Oct. 14, 1941	16	35	370		43 hr (at 800 gpm).
	Mar. 17, 1942	18	50	362		
	Sept. 19, 1942	17	30	366	84	
	Dec. 1, 1942	15	35	367	83	
	Feb. 1, 1943	16	30	377	85	
	Mar. 31, 1943	20	70	400	77	
	June 1, 1943	16	30	368	83	1 hr. 45 min
	June 30, 1943	17	25	369	84	3 hr.
	July 31, 1943	16	30	375	84	
	Oct. 7, 1943	14	55	356		4 hr.
	Nov. 30, 1943	15	25	360	84	4 hr.
	Feb. 29, 1944	15	20	362	83	16 min.
11G1	June 1, 1943	19	25	419	85	1 hr 45 min; yellowish.
	June 30, 1943	19	25	413	85	3 hr. 10 min; yellowish.
	July 31, 1943	20	30	419	85	3½ hr; yellowish.
	Sept. 30, 1943	20	25	415	85	3 hr; yellowish.
	Nov. 30, 1943	20	25	408	85	4 hr; yellowish.
11G2	Mar. 31, 1943	17	40	374	84	3½ hr; yellowish.
	July 31, 1943	16	30	378	84	4 hr; yellowish.
	Sept. 30, 1943	16	25	370	85	3 hr; yellowish.
6/10-17C1	Apr. 16, 1943	168	35	956	77	Yellowish. See table 30, p. 233.
		165	35	955		10 min; yellowish.
		163	35	955		20 min; yellowish.
		161	35	953		½ hr; yellowish.
17L1	Dec. 4, 1940	335	265	1,490		4 ft below water surface.
	Mar. 17, 1942	260	300	1,510		Bailed.
17L3	Oct. 4, 1944	1,270	325	5,360		15 min.
	Oct. 5, 1944	1,120	275	5,000		2½ hr.
	Nov. 20, 1944	577	175	2,550		30 days.
17L4	Nov. 17, 1944	192	30	1,050		30 min.
17L5	Dec. 18, 1944	243	45	1,250		Several hours.
6/10-18B3	Dec. 3, 1940	17	120	407	66	
	Jan. 14, 1942	17	95	397		
	Jan. 20, 1943	18	115	411	68	24 hr a day for two weeks.
18B4	Dec. 4, 1940	15	145	411	66	
	June 28, 1941	18	135	414		
	Oct. 27, 1942	15	140	409		
18B5	Oct. 26, 1943	627	600	2,250		
	Feb. 1943	366	400	1,460		
	Oct. 31, 1944	923	725	3,080	66	
18B6	Feb. 1, 1945	16	120	421	66	About a week.
18C1	Dec. 4, 1940	22	150	444		See table 30 p. 233.
	June 28, 1941	21	120	421		
	Sept. 18, 1941	19	130	420		
	Nov. 13, 1941	18	130	425		
	Jan. 12, 1942	17	130	420	67	

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 6 S., R. 10 W.—Continued			
6/10-18C1-con.	July 3, 1942	20	150	448	66	
	Oct. 27, 1942	22	150	437	67	
	Oct. 26, 1943	19	140	433	66	
	Dec. 31, 1943	20	110	439	----------	6 hr.
	Feb. 1944	24	130	440	----------	
18C2	Dec. 4, 1940	200	350	974	67	
	Dec. 20, 1940	199	335	----------	----------	See table 30, p. 233.
	July 8, 1941	217	315	1,010	----------	
	Sept. 18, 1941	255	275	1,090	----------	
	Nov. 13, 1941	204	275	9,560	----------	
	Jan. 12, 1942	260	335	1,140	71	
	Mar. 17, 1942	304	420	1,260	----------	
	July 3, 1942	292	375	1,230	66	
	Aug. 26, 1942	311	465	1,260	66	5 sec.
		298	475	1,250	66	15 sec.
		294	465	1,240	66	30 sec.
		269	450	1,170	66	1 min.
		301	450	1,250	66	1½ min.
		302	450	1,260	66	2 min.
		303	425	1,250	66	4 min.
		303	425	1,260	66	2 hr 12 min.
		303	425	1,260	66	3 hr 32 min.
		302	425	1,260	66	4 hr 27 min.
	Oct. 27, 1942	366	525	1,470	67	
	Oct. 26, 1943	360	325	1,460	66	Sulfide odor.
	Dec. 31, 1943	308	300	1,280	----------	2½ hr.
	Feb. 1, 1945	91	170	626	----------	About a week.
18C3	Oct. 1943	367	245	1,360	----------	½hr.
	Dec. 31, 1943	761	440	2,750	----------	2 weeks intermittently; sulfide odor.
18C4	Sept. 19, 1941	184	250	811	----------	20 ft (2½ ft below static water level). See table 30, p. 233.
		204	255	913	----------	30 ft.
		190	265	835	----------	40 ft.
		186	255	854	----------	50 ft.
		187	265	872	----------	60 ft.
		187	260	846	----------	70 ft.
		184	260	867	----------	80 ft.
		185	260	851	----------	90 ft.
		186	280	877	----------	100 ft.
		189	270	869	----------	110 ft.
		176	275	855	----------	120 ft.
		180	270	850	----------	130 ft.
		184	265	836	----------	140 ft.
		174	265	827	----------	150 ft.
		190	270	860	----------	160 ft.
		180	270	849	----------	170 ft.
		305	365	1,240	----------	180 ft.
		187	260	877	----------	190 ft (sampler may have tripped prematurely).
18C5	Aug. 18, 1941	827	1,250	4,050	----------	Bailed.
	Sept. 11, 1941	1,020	1,000	4,340	----------	Do.
	Nov. 13, 1941	1,090	----------	4,320	----------	Do.
	Aug. 7, 1940	1,200	700	4,680	70	Do.
18E1	Dec. 26, 1940	3,840	2,600	10,600	----------	
	July 8, 1941	4,530	----------	13,000	----------	
	Mar. 18, 1942	942	500	3,040	----------	Do.
18E3	Nov. 28, 1942	2,820	2,100	8,320	74	
18F1	Jan. 20, 1943	1,060	1,150	3,590	68	
	Oct. 26, 1943	1,540	1,200	4,980	----------	
18F2	Aug. 18, 1941	2,180	2,250	9,180	74	Do.
	Sept. 9, 1941	2,500	2,500	10,500	----------	Do.
	Nov. 13, 1941	2,350	1,450	9,250	----------	Do.
	Jan. 20, 1942	2,770	1,900	11,000	66	Do.
	Mar. 27, 1942	2,870	1,800	10,900	----------	Do.
	Aug. 6, 1942	3,020	----------	10,900	68	Do.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hard-ness	Sp cond	Temp	Remarks
			T. 6 S., R. 10 W.—Continued			
6/10-18G4	Dec. 5, 1940	184	250	820	66	Bailed.
18G6	do	76	130	664	67	Do.
	Aug. 28, 1942	123	145	887		50 ft.
		134	135	888		200 ft.
18J1	Dec. 20, 1940	638	450	2,120		See table 30, p. 233.
	Aug. 31, 1944	887	500	3,170		
	July 11, 1945			25,100		0 time.
				25,300		15 sec.
				25,400	66	30 sec.
				25,400	66	45 sec.
				25,200	66	1 min.
				25,200		3 min.
				25,400	66	5 min.
				25,400	66	15 min.
				25,600	66	30 min.
		8,680	3,500	25,900	66	1 hr.
				25,000	66	5 min (pump off about 1 hr).
				25,000	66	25 min.
				25,300	66	1 hr 7 min.
				24,900	66	1 hr 35 min.
				24,900	66	1 hr 55 min.
		8,700	3,400	24,500	66	2 hr 17 min.
18J2	June 28, 1941	614	335	2,350		
	Sept. 18, 1941	520	225	1,930		
	Jan. 14, 1942	357	165	1,640	65	
	Apr. 9, 1942	492	350	1,920	68	See table 30, p. 233.
	July 3, 1942	652	315	2,450	68	
	Aug. 27, 1942	658	300	2,410	68	0 time.
		669	315	2,410	68	15 sec.
		664	300	2,340	68	30 sec.
		584	290	2,140	68	45 sec.
		521	250	1,920	68	1 min.
		476	240	1,750	68	2 min.
		511	240	1,930	68	3 min.
		642	300	2,250	68	5 min.
		656	300	2,310	68	8 min.
		658	340	2,410	68	38 min.
		659	325	2,410	68	56 min.
		656	325	2,410	68	2 hr 18 min.
		653	325	2,410	68	3 hr 57 min.
	Oct. 26, 1943	744	315	2,770	69	Yellowish.
	June 19, 1944	652	300	2,540		Do.
	Aug. 31, 1944	707	375	2,670		Do.
	Sept. 29, 1944	673	275	2,590	68	
	May 1, 1945			2,240		0 time.
				2,300	66	15 sec.
				2,280	66	30 sec.
				2,260	66	45 sec.
				2,280		1 min.
				2,250	67	2 min.
				3,210	68	5 min.
				2,640	68	10 min.
				2,370	68	15 min.
				2,290	69	30 min.
	May 5, 1945			2,270		0 time.
				2,190	67	15 sec.
				2,610	67	30 sec.
				2,580	67	45 sec.
				2,480	67	1 min.
				2,160	68	2 min.
				1,960	67	5 min.
				1,800	67	10 min.
				1,780	67	15 min.
				1,780	67	30 min.
				1,650	67	1 hr.
				1,560	67	1 hr 35 min.
				1,600	67	2 hr.
				1,630	67	2 hr 30 min.
				1,570	67	3 hr.
				1,600	67	3 hr 30 min.
				1,510	67	4 hr.
				1,520	67	4 hr 24 min.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 6 S., R. 10 W.—Continued			
6/10-18J2-con.	May 5, 1945	----------	----------	1,630	67	5 hr.
		----------	----------	1,520	67	5 hr 30 min.
		----------	----------	1,550	67	5 hr 51 min.
	June 20, 1945	795	325	2,400	----------	3¼ hr.
	June 29, 1945	846	380	3,060	----------	
	July 11, 1945	858	410	3,060	----------	
18J3	June 28, 1941	276	105	1,300	----------	See table 30, p. 235.
	Sept. 18, 1941	353	155	1,450	----------	
	Mar. 17, 1942	366	150	1,520	67	
	July 3, 1942	244	105	1,210	68	
	Oct. 27, 1942	363	190	1,550	68	Yellowish.
	Aug. 31, 1944	246	80	1,230	----------	Do.
	June 20, 1945	412	165	1,710	----------	5 min.
	June 20, 1945	412	225	1,710	----------	20 min.
18J4	Dec. 20, 1940	401	155	1,630	68	Bailed.
18J5	do	147	65	1,330	----------	Do.
	Apr. 9, 1942	143	60	1,400	----------	Do.
		143	55	1,400	----------	Bailed, after lowering water level 5 ft.
18K6	Dec. 1942	1,520	1,200	4,970	69	
18L1	Aug. 19, 1941	1,580	1,550	5,980	----------	Bailed.
	Sept. 9, 1941	1,050	1,200	4,730	----------	Do.
	Nov. 13, 1941	1,150	1,000	5,060	----------	Do.
	Jan. 20, 1942	1,090	----------	4,680	65	Do.
	Mar. 27, 1942	837	1,350	4,470	----------	Do.
	Apr. 22, 1942	1,010	1,750	4,670	66	Bailed. See table 30, p. 235.
	Aug. 7, 1942	804	1,600	4,490	70	Bailed.
18P1	Sept. 9, 1941	2,015	915	6,410	----------	
	June 16, 1943	2,550	1,450	792	----------	Daily for 4 days.
18P2	Aug. 19, 1941	4,030	2,500	12,500	72	Bailed.
	Sept. 9, 1941	4,030	1,550	12,300	----------	Do.
	Nov. 13, 1941	4,590	1,800	13,300	----------	Do.
	Jan. 20, 1942	4,280	1,900	11,900	66	Do.
	Mar. 27, 1942	4,230	1,850	12,100	----------	Do.
	Aug. 6, 1942	4,450	----------	12,200	68	Do.
6/10-19B1	Dec. 26, 1940	152	110	610	----------	Do.
19B3	do	157	205	773	----------	Do.
	June 28, 1941	599	400	2,210	----------	Do.
	Aug. 19, 1941	1,520	835	4,780	----------	
	July 6, 1942	2,690	1,550	7,970	66	
19C1	Aug. 19, 1941	8,190	4,500	20,900	72	Do.
	Sept. 9, 1941	8,380	4,750	22,000	----------	Do.
	Nov. 13, 1941	7,930	3,250	20,500	----------	Do.
	Jan. 20, 1942	7,500	----------	18,900	66	Do.
	Mar. 27, 1942	7,310	2,900	17,900	----------	Do.
	Aug. 6, 1942	7,560	----------	18,300	69	Do.
19C2	Aug. 19, 1941	12,600	5,900	29,900	68	Do.
	Sept. 9, 1941	13,400	7,750	33,100	----------	Do.
	Nov. 14, 1941	14,200	6,000	34,800	----------	Do.
	Jan. 20, 1942	10,800	----------	28,100	68	Do.
	Mar. 27, 1942	12,200	5,500	28,600	----------	Do.
	Aug. 6, 1942	17,300	8,000	37,000	66	Do.
19F2	Aug. 18, 1941	13,100	6,500	31,900	78	Do.
	Sept. 9, 1941	11,000	5,750	29,500	----------	Do.
	Nov. 13, 1941	8,700	3,400	24,700	----------	Do.
	Jan. 20, 1942	11,300	----------	27,000	----------	Do.
	Mar. 27, 1942	21,000	10,000	43,500	----------	Do.
	Aug. 6, 1942	20,000	12,000	43,500	74	Do.
19F3	Apr. 15, 1942	5,350	----------	12,300	----------	
19L1	Aug. 18, 1941	18	130	338	68	Do.
	Sept. 9, 1941	27	145	423	----------	Do.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
T. 6 S., R. 10 W.—Continued						
6/10-19L1-con.	Nov. 13, 1941	56	225	773	----------	Do.
	Jan. 20, 1942	33	135	451	67	Do.
	Mar. 27, 1942	34	154	421	65	Do.
	Aug. 7, 1942	97	265	885	70	Do.
19R1	Jan. 4, 1941	203	75	794	68	Do.
6/10-20D2	Sept. 1944	2,473	1,500	773	----------	
T. 6 S., R. 11 W.						
6/11-1A2	Sept. 5, 1941	24	165	483	----------	
1C1	Jan. 2, 1941	19	175	442	----------	See table 30, p. 235.
1E1	----do-----	18	180	427	----------	
1J2	----do-----	16	190	397	----------	Do.
1N1	----do-----	17	60	493	----------	Do.
1Q1	Dec. 9, 1940	21	160	432	65	Bailed.
	Mar. 18, 1942	20	125	441	67	Do.
6/11-2A2	Jan. 3, 1941	14	45	355	----------	
2A3	----do-----	53	210	544	----------	
	Oct. 27, 1943	64	125	555	----------	5 min.
2B2	Mar. 3, 1941	87	75	588	----------	Yellowish.
	Sept. 18, 1941	76	75	558	72	Do.
	Apr. 22, 1942	64	80	561	70	Do.
	Oct. 29, 1942	111	245	794	----------	Bailed; yellowish.
2D1	Jan. 3, 1941	820	675	2,780	72	Bailed. See table 30, p. 235.
	Nov. 7, 1941	384	375	2,140	----------	Bailed.
	Mar. 19, 1942	655	375	2,340	----------	Do.
	Oct. 29, 1942	774	490	2,710	----------	Do.
2F1	Jan. 3, 1941	1,530	1,050	5,010	----------	Do.
2G1	Dec. 9, 1940	127	160	555	----------	Bailed. See table 30, p. 235.
	Mar. 26, 1941	18	65	148	----------	60 ft (3½ ft below static water level).
		24	60	154	----------	70 ft.
		23	65	156	----------	80 ft.
		24	60	154	----------	90 ft.
		130	95	500	----------	100 ft.
		2,890	675	7,780	----------	110 ft.
		3,170	700	9,010	----------	120 ft.
		3,400	850	9,830	----------	130 ft.
		3,570	900	9,860	----------	140 ft.
		3,550	800	9,860	----------	150 ft.
		3,510	850	9,800	----------	160 ft.
		3,580	850	9,800	----------	170 ft.
		3,550	850	9,860	----------	180 ft.
		3,600	850	9,860	----------	190 ft.
		3,640	850	9,950	----------	200 ft (5.8 ft above bottom of well).
2G2	Dec. 9, 1940	457	475	1,710	----------	Bailed. See table 30, p. 235.
	Mar. 26, 1941	178	140	804	----------	60 ft (2½ ft below static water level).
		180	125	802	----------	70 ft.
		363	250	1,270	----------	80 ft.
		1,610	950	5,180	----------	90 ft.
		2,330	1,200	7,200	----------	100 ft.
		3,260	1,350	9,680	----------	110 ft.
		3,530	1,250	10,500	----------	120 ft (3.9 ft above bottom of well).
2G3	Dec. 9, 1940	88	120	417	----------	Bailed.
	Mar. 26, 1941	30	100	287	----------	Do.
		26	105	257	----------	100 ft (44 ft below water surface).

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 6 S., R. 11 W.—Continued			
6/11-2G4	Dec. 9, 1940	2,180	1,200	3,980	68	
	May 20, 1941	1,580	1,100	4,830	70	0 time.
		1,830	1,250	5,620	69	1 min.
		1,860	1,300	5,650	69	2 min.
		1,860	1,400	5,860	69	3 min.
		1,860	1,450	5,710	69	4 min.
		1,870	1,350	5,430	69	5 min.
		1,850	1,500	----------	69	7 min. See table 30, p. 235.
		1,890	1,300	5,520	69	10 min.
		1,860	1,350	5,710	69	20 min.
		1,850	1,300	5,650	69	30 min.
		1,820	1,350	5,560	69	40 min.
		1,800	1,050	5,360	69	55 min.
		1,780	1,250	5,610	69	85 min.
		1,780	1,100	5,360	69	1 hr 55 min.
		1,790	1,150	5,290	69	2 hr 25 min.
		1,800	1,200	5,320	69	2 hr 32 min.
2J2	July 8, 1941	22	155	438	----------	Bailed.
	Mar. 19, 1942	19	150	433	64	Do.
2M2	Jan. 6, 1941	42	55	536	----------	Yellowish.
	July 8, 1941	41	55	538	----------	Do.
	Sept. 18, 1941	31	50	532	----------	Do.
	Nov. 7, 1941	39	55	530	----------	Do.
	Jan. 14, 1942	37	55	533	71	Do.
	July 6, 1942	38	95	534	----------	Do.
	Oct. 29, 1942	37	65	536	65	
	Oct. 27, 1943	37	60	523	----------	
2R3	Jan. 3, 1941	47	125	426	68	Bailed.
	July 8, 1941	35	180	438	----------	
	Sept. 18, 1941	36	165	489	----------	
	Nov. 7, 1941	36	175	505	----------	
	Jan. 14, 1942	36	160	497	----------	
	Oct. 29, 1942	36	185	512	----------	
6/11-11A2	Apr. 22, 1941	14,370	985	35,000	120	Turbid.
11G1	Oct. 27, 1943	931	1,150	3,420	----------	After pumping 20 gal.
11J4	Apr. 15, 1942	3,390	2,950	9,550	66	
	Oct. 28, 1942	578	575	1,930	67	
11Q1	July 6, 1942	245	240	1,150	----------	Bailed.
6/11-12A1	Dec. 31, 1940	17	170	431	----------	
	Mar. 18, 1942	17	155	444	68	
12C1	----do-----	15	130	429	67	
12E1	Dec. 31, 1940	15	150	394	----------	See table 30, p. 235.
12F3	Mar. 18, 1942	14	100	404	66	
12J1	----do-----	14	135	409	67	
12J2	Dec. 31, 1940	19	110	341	65	Bailed.
6/11-13A1	Dec. 26, 1940	14	140	376	----------	
	July 8, 1941	16	120	385	----------	
	Aug. 26, 1942	14	135	400	----------	
	Oct. 27, 1942	14	130	391	----------	
	Sept. 29, 1944	14	105	391	----------	
13B1	Dec. 26, 1940	15	155	394	----------	
	Mar. 17, 1942	14	135	401	----------	
	Oct. 27, 1942	20	150	435	----------	
13C2	Dec. 31, 1940	65	185	476	----------	Do.
	Aug. 14, 1941	810	875	2,690	67	
	Sept. 12, 1941	485	590	1,810	66	0 time.
		303	415	1,300	66	15 sec.
		316	400	1,330	66	30 sec.
		317	400	1,340	66	45 sec.
		319	400	1,330	66	1 min.

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hardness	Sp cond	Temp	Remarks
			T. 6 S., R. 11 W.—Continued			
6/11-13C2-con.	Sept. 12, 1941	323	415	1,350	66	2 min.
		482	540	1,810	66	3½ min.
		736	825	2,530	66	8 min.
		850	925	2,850	66	45 min.
		852	990	2,880	66	90 min.
		860	1,000	3,010	66	3 hr 15 min.
	July 6, 1942	39	155	473	----------	Bailed.
	Feb. 8, 1944	895	925	----------	----------	2 hr.
		885	900	----------	----------	3 hr.
	Sept. 29, 1944	1,230	1,200	4,260	65	½ hr.
13D1	Dec. 31, 1940	201	255	885	65	Bailed.
	Apr. 15, 1942	247	315	1,070	----------	Do.
13F2	Dec. 26, 1940	93	160	551	----------	
	Aug. 14, 1941	304	200	1,220	----------	
	May 11, 1944	13	110	384	----------	8 hr. Well not pumped heavily since mid-1942.
13F3	Apr. 15, 1942	136	150	839	----------	Bailed.
13G1	Aug. 14, 1941	30	125	396	----------	
	Sept. 29, 1944	91	175	640	66	2½ hr.
13G3	Dec. 26, 1940	----------	2,850	12,700	64	Bailed.
13J1	Apr. 16, 1942	125	200	756	65	See table 30, p. 236.
	July 6, 1942	1,380	775	4,520	----------	Several hours.
	Aug. 25, 1942	38	155	474	66	1 min.
		70	165	578	66	1 min 15 sec.
		133	195	781	66	1 min 25 sec.
		191	215	960	66	1 min 45 sec.
		409	325	1,670	66	4 min 30 sec.
		498	365	1,900	66	5 min 15 sec.
		557	390	2,080	66	6 min 30 sec.
		625	390	2,290	66	8 min.
		740	465	2,640	66	11 min.
		895	550	3,050	66	16 min.
		1,050	640	3,470	66	24 min.
		1,240	800	4,070	66	49 min.
		1,390	825	4,460	66	84 min.
		1,440	875	4,550	66	94 min.
		1,440	925	4,600	66	1 hr 59 min.
		1,530	925	4,810	66	3 hr 4 min.
		1,560	925	4,940	66	4 hr 49 min.
		1,580	850	4,990	66	5 hr 51 min.
	Sept. 18, 1942	1,590	925	5,170	66	8½ hr.
	Oct. 27, 1942	779	465	281	----------	
13K2	Dec. 26, 1940	964	850	3,170	----------	
	July 8, 1941	922	700	3,200	----------	
		909	625	3,120	----------	
	Mar. 18, 1942	1,000	700	3,420	67	
	Apr. 15, 1942	1,120	790	3,700	67	
	Apr. 15, 1942	1,110	900	3,660	67	See table 30, p. 236.
	July 6, 1942	1,050	700	3,590	----------	
	Oct. 27, 1942	1,100	825	3,780	----------	
	Aug. 31, 1944	18,800	----------	50,130	----------	
	Sept. 29, 1944	17,700	----------	45,700	----------	Do.
	Mar. 1, 1945	----------	----------	48,900	----------	
13M1	Dec. 31, 1940	4,980	4,250	13,100	----------	
	Feb. 18, 1941	4,260	4,150	----------	----------	10 ft (about 2 ft below static water level).
		4,770	4,250	----------	----------	30 ft.
		4,510	4,250	----------	----------	50 ft.
		4,550	4,400	----------	----------	70 ft.
		4,000	3,625	----------	----------	90 ft.
		3,580	3,375	----------	----------	110 ft.
		3,650	3,250	----------	----------	130 ft.
		6,980	6,250	----------	----------	150 ft.
		7,130	6,250	----------	----------	170 ft.
		7,060	6,250	----------	----------	190 ft.
		7,100	5,750	----------	----------	200 ft (164.1 ft above bottom of well).

TABLE 31.—*Partial chemical analyses of waters from wells*—Continued

Well	Date	Cl	Hard-ness	Sp cond	Temp	Remarks
T. 6 S., R. 11 W.—Continued						
6/11-13M3	Mar. 27, 1941	5,860	3,950	17,500		Bailed.
	June 16, 1941	2,890	2,000	10,900		Do.
13M4	Feb. 1, 1945	19,100		49,600		
13Q1	Apr. 15, 1942	4,860	800	12,700		Do.
	do	4,840	800	12,600		Do.
	Apr. 21, 1942	4,820	675	12,300		See table 30 p. 236.
Irvine tract						
I-6A1	June 6, 1941	25	40	258		
6D1	July 2, 1941	165		1,060		
6E1	July 3, 1942	85	25	638		Yellowish.
	Oct. 27, 1942	82	25	615	86	Do.
6E3	June 6, 1941	25	15	391		Sulfide odor; yellowish.
I-51R1	do	119	30	676		

TABLE 32.—*Partial chemical analyses of waters from streams in the coastal zone, 1941–45*

Source	Number	Date	Chloride (Cl) (ppm)	Soap hardness as $CaCO_3$ (ppm)	Specific conductance ($K \times 10^6$ at 25°C)	Temperature (°F)
Compton Creek at at Olive St.	3/13-27B	Feb. 12, 1942	69	325	954	----------
		Aug. 7, 1942	66	365	1,040	92
		Jan. 6, 1943	62	290	995	62
Compton Creek at Del Amo St.	4/13-2Q	Feb. 13, 1942	132	330	1,270	----------
		Aug. 6, 1942	73	350	1,0 0	78
		Jan. 6, 1943	84	325	1,060	52
Coyote Creek, west branch, at Artesia St.	3/11-33A	Jan. 22, 1942	112	390	1,230	----------
Coyote Creek, east branch, at Artesia St.	3/11-34B	----do----	136	75	1,610	----------
Coyote Creek at Orangethorpe Ave.	3/11-33N	----do----	121	375	1,300	----------
		Jan. 6, 1943	92	285	1,020	50
Coyote Creek at Carson St.	4/11-17D	Jan. 22, 1942	142	415	1,430	----------
		Aug. 7, 1942	140	300	1,330	78
Coyote Creek at Los Alamitos Blvd.	4/11-19C	June 18, 1941	402	575	2,980	----------
		Feb. 12, 1942	145	400	1,490	----------
		Aug. 7, 1942	225	----------	2,020	74
		Jan. 6, 1943	103	325	1,080	49
Dominguez Channel at Main St.	4/13-6G	Feb. 12, 1942	1,030	200	3,600	----------
		Aug. 7, 1942	10,000	2,150	24,400	92
		Jan. 6, 1943	145	225	1,200	47
Dominguez Channel at Wilmington Ave.	4/13-16J	Feb. 12, 1942	4,810	800	13,400	----------
		Aug. 7, 1942	5,410	700	15,300	82
		Jan. 6, 1943	4,010	600	13,600	52
Dominguez Channel at Willow St.	4/13-22Q	----do----	2,450	400	9,260	52
Los Angeles River at Firestone Blvd.	2/12-31J	June 18, 1941	97	340	1,120	----------
		Feb. 12, 1942	80	315	992	----------
		Aug. 7, 1942	156	375	1,250	91
		Jan. 6, 1943	68	305	3,450	58
Los Angeles River at Rosecrans Ave.	3/12-19D	June 18, 1941	91	360	1,100	----------
Los Angeles River at Olive St.	3/12-30D	----do----	95	365	1,130	----------
		Feb. 12, 1942	122	385	1,200	----------
		Aug. 7, 1942	163	335	1,270	89
		Jan. 6, 1943	72	305	900	58
Los Angeles River at Artesia St.	3/13-36A	June 18, 1941	99	350	1,110	----------
Los Angeles River at Long Beach Blvd.	3/13-36P	----do----	102	335	1,100	----------
		Feb. 12, 1942	108	375	1,170	----------
		Aug. 6, 1942	151	340	1,220	84
		Jan. 6, 1943	87	290	964	53
Los Angeles River at Del Amo St.	4/13-12D	June 18, 1941	101	365	1,110	----------
Los Angeles River at Dominguez St.	4/13-11H	----do----	130	340	1,220	----------
Los Angeles River at 223d St.	4/13-14J	----do----	126	325	1,230	----------
		Feb. 12, 1942	117	355	1,190	----------
		Aug. 6, 1942	187	340	1,460	93
		Jan. 6, 1943	85	300	950	47
Los Angeles River at Wardlow Road.	4/13-23A	June 18, 1941	125	345	1,230	----------
Los Angeles River at Spring St., extended.	4/13-23J	----do----	1,790	590	6,080	----------
		Feb. 12, 1942	1,410	565	4,820	----------
		Aug. 6, 1942	2,810	800	8,030	92
		Jan. 6, 1943	1,160	490	4,240	48

TABLE 32.—*Chemical analyses of waters from streams*—Continued

Source	Number	Date	Cl	Hardness	Sp cond	Temp
Los Angeles River at Willow St.	4/13-26A	May 9, 1941	756	400	2,880	----------
		June 18, 1941	972	375	3,740	----------
		Feb. 12, 1942	1,480	588	5,100	----------
		June 6, 1943	1,050	465	3,990	48
Los Angeles River at State St.	4/13-35A	May 9, 1941	528	325	2,280	----------
		June 18, 1941	1,210	450	4,370	----------
Los Angeles River at Anaheim St.	4/13-35H	....do....	1,100	450	4,120	----------
		Feb. 12, 1942	1,490	575	5,700	----------
		Aug. 6, 1942	2,560	650	7,840	92
		Jan. 6, 1943	1,070	475	3,980	46
Rio Hondo at Firestone Blvd.	2/12-32P	June 18, 1941	36	235	566	----------
		Feb. 12, 1942	68	260	906	----------
		Aug. 7, 1942	49	220	629	90
Rio Hondo, culvert discharging into, at Firestone Blvd., near east end of highway bridge.	2/12-32P	Jan. 6, 1943	27	205	519	57
San Gabriel River at Firestone Blvd.	3/12-11F	Feb. 12, 1942	19	225	556	----------
San Gabriel River at Center St.	3/12-26C	June 18, 1941	17	190	461	----------
		Feb. 12, 1942	19	240	564	----------
San Gabriel River at Artesia Ave.	3/12-35B	June 18, 1941	17	200	456	----------
San Gabriel River, 0.5 mile south of Artesia Ave.	3/12-35K	Aug. 7, 1942	19	240	574	----------
San Gabriel River, 0.5 mile south of Artesia Ave., from hole excavated 6 ft below river bed.	3/12-35K	....do....	19	240	577	81
San Gabriel River at Orangethorpe Ave.	4/12-2A	June 18, 1941	15	195	446	----------
		Feb. 12, 1942	19	240	576	----------
San Gabriel River at Carson St.	4/12-13C	June 18, 1941	15	215	456	----------
		Feb. 12, 1942	12	205	564	----------
San Gabriel River at Spring St.	4/12-24F	June 18, 1941	17	145	362	----------
San Gabriel River, below Coyo teCreek, 0.75 mile north of 7th St.	4/12-36E	....do....	57	240	715	----------
San Gabriel River at 7th St.	5/12-2A	....do....	262	375	2,120	----------
		Feb. 12, 1942	29	245	642	----------
		Dec. 31, 1942	155	265	1,280	62
		Jan. 6, 1943	111	325	1,140	62
San Gabriel River, 1 mile south of 7th St.	5/12-11A	June 18, 1941	283	420	2,080	----------
Santa Ana River at Harbor Blvd., 250 ft north of highway bridge, slight flow.	5/10-28A	Feb. 12, 1942	94	345	1,020	----------
Santa Ana River at Talbert Ave., 2 ft below channel bottom. No Strem flow.	5/10-33C	June 19, 1941	43	300	754	----------
Santa Ana River at Garfield Ave., 2 ft below channel bottom. No stream flow.	6/10-5A	....do....	83	360	1,050	----------
Santa Ana River at Adams Ave., 1.5 ft below channel bottom. No stream flow.	6/10-8C	....do....	105	340	1,180	----------
Santiago Creek at North Main St., Santa Ana.	5/9-6E	Feb. 12, 1942	74	250	732	----------

TABLE 33.—*Partial chemical analyses of waters from ponds, sumps, and other miscellaneous sources in the coastal zone, 1941–45*

Source	Number	Date	Chloride (Cl) (ppm)	Soap hardness as $CaCO_3$ (ppm)	Specific conductance ($K \times 10^6$ at 25°C)	Temperature (°F)
T. 4 S., R. 12 W.						
Bouton Lake, south side of Carson St. at culvert 0.5 mile west of Lakewood Blvd.; 0.5 ft depth.	4/12-17A	Feb. 12, 1942	20	125	478	----------
		Aug. 6, 1942	48	80	603	81
		Dec. 31, 1942	21	130	532	65
Sump, 875 ft north of Stearns St. and 270 ft east of Newport Ave.	4/12-28E	Mar. 4, 1942	16,300	2,500	38,000	----------
		Dec. 31, 1942	15,800	2,400	39,000	93
T. 4 S., R. 13 W.						
Pond, 150 ft west of Main St., 0.83 mile north of Carson St., at south end; 0.5 ft below surface.	4/13-7B	Feb. 2, 1942	143	215	2,140	----------
		Aug. 7, 1942	150	240	2,040	82
		Jan. 6, 1943	89	200	1,340	46
Sump, Oil Operators, Inc., at discharge to Los Angeles River on east bank, 0.26 mile south of 223d St.	4/13-14R	Jan. 1941	15,700	5,000	37,000	----------
		May 17, 1941	15,300	2,600	----------	----------
		Feb. 12, 1942	16,000	2,750	----------	----------
		Aug. 6, 1942	16,300	3,450	38,000	97
		Jan. 6, 1943	16,200	3,400	39,000	68
Bixby Slough, north of Anaheim St., 0.22 mile west of Figueroa St.; 1 ft below surface.	4/13-31L	Feb. 12, 1942	212	105	1,240	----------
		Aug. 7, 1942	420	195	2,060	80
		Jan. 6, 1943	552	185	2,700	49
Bixby Slough, south side of Anaheim St., 0.23 mile west of Figueroa St.; 1 ft below surface.	4/13-31L	Feb. 12, 1942	18,200	6,600	41,000	----------
Pipeline discharge into Bixby Slough, south side of Anaheim St., 0.22 mile west of Figueroa St.	4/13-31L	----do----	18,300	6,900	40,000	----------
T. 5 S., R. 11 W.						
Sump in depression east of well 5/11-28D1, 700 ft south of Wintersburg Ave. and 850 ft east of Bolsa Chica Ave.; 0.5 ft below surface.	5/11-28D	Feb. 13, 1942	132	1,350	7,260	----------
		Dec. 31, 1942	----------	1,200	5,130	78
Sump, 0.4 mile south of Slater Ave., 0.7 mile west of Edwards St., at centrifugal pump used for filling ponds; 0.5 ft below surface.	5/11-28R	Feb. 13, 1942	1,970	825	6,410	----------
		Aug. 6, 1942	1,950	900	6,090	74
Sump, 0.35 mile south of Slater Ave., 0.6 mile west of Edwards St.; from discharge pipe leading to sump from largest of three tanks.	5/11-28R	Dec. 31, 1942	17,300	2,250	43,000	108
Stream, north edge of Ellis Ave., 0.27 mile west of Golden West Ave. Flow about 0.75 gpm.	5/11-34G	Aug. 6, 1942	9,860	1,450	23,800	91
		Nov. 19, 1942	14,300	1,650	36,700	64
		Dec. 31, 1942	14,500	1,950	37,000	70

TABLE 33.—*Chemical analyses of waters from ponds, sumps, and other miscellaneous sources*—Continued

Source	Number	Date	Cl	Hardness	Sp cond	Temp
T. 5 S., R. 11 W.—Continued						
Sump, 30 ft north of Ellis Ave., 0.37 mile west of Golden West Ave.; 0.5 ft below surface.	5/11-34G	Aug. 6, 1942	15,200	4,000	35,500	91
		Dec. 31, 1942	14,600	1,750	37,000	71
Sump, 425 ft south of Ellis Ave., 0.44 mile west of Golden West Ave.; from discharge pipe.	5/11-34K	Aug. 6, 1942	13,900	1,750	33,000	89
Pond, larger of two, 150 ft south of Talbert Ave., 300 ft east of Golden West Ave., southwest of well 5/11-35D2; 1.0 ft below surface.	5/11-35D	Aug. 6, 1942	19,200	3,250	43,000	81
		Dec. 31, 1942	20,000	4,450	45,000	57
Pond, smaller of two, 150 ft south of Talbert Ave., 300 ft east of Golden West Ave., east of larger pond; 0.3 ft below surface.	5/11-35D	----do----	17,300	4,750	44,500	63
Stream, 0.34 mile north of Garfield Ave., 65 ft west of Southern Pacific Railroad, at west edge of Gothard St. Flow about 5 gpm.	5/11-35L	Dec. 4, 1942	9,900	1,250	23,800	65
		Dec. 31, 1942	8,280	870	22,700	64
Stream, 0.33 mile north of Garfield Ave., 400 ft east of Golden West Ave. Flow 1¼ gpm.	5/11-35M	Aug. 6, 1942	526	185	2,000	88
		Nov. 19, 1942	1,360	340	4,510	64
		Dec. 31, 1942	1,120	365	3,930	64
Stream, south side of Ellis Ave., 1,000 ft east of Golden West Ave. Flow about 10 gpm.	5/11-35M	Dec. 4, 1942	13,600	1,900	32,500	84
		Dec. 31, 1942	12,100	1,250	33,000	83
Sump, 50 ft north of Garfield Ave., 200 ft east of Main St.	5/11-35Q	----do----	14,500	425	37,000	88
T. 6 S., R. 11 W.						
Pond, 350 ft north and 60 ft east of intersection of Delaware Ave. and Clay St.; 0.5 ft below surface.	6/11-2A	Jan. 3, 1941	178	70	752	----------
Pond, 300 ft south of Clay St., 200 ft east of Huntington Ave.; 0.5 ft below surface.	6/11-2G	Jan. 3, 1941	1,750	270	5,210	----------
		Feb. 13, 1942	7,030	900	16,200	----------
		Apr. 22, 1942	8,560	1,250	18,600	----------
		Aug. 6, 1942	36,500	4,500	66,800	-----
		Dec. 31, 1942	22,400	3,150	53,000	56
Pipe discharge from tank into pond, 250 ft south of Clay St., 50 ft east of Huntington Ave. Flow about 1 gpm.	6/11-2G	Apr. 22, 1942	17,000	2,100	40,000	----------
		Aug. 6, 1942	17,100	2,400	39,000	80
		Dec. 31, 1942	16,700	2,250	41,000	63
Pond, 50 ft north and 100 ft west of intersection of Yorktown St. and 17th St.; 3 ft below surface.	6/11-2G	Jan. 3, 1941	429	150	1,750	----------
Pond, 60 ft south of intersection of Clay St. and Florida Ave.; 1 ft below surface.	6/11-2H	----do----	20	90	223	----------

TABLE 33.—*Chemical analyses of waters from ponds, sumps, and other miscellaneous sources*—Continued

Source	Number	Date	Cl	Hardness	Sp cond	Temp
T. 6 S., R. 11 W.—*Continued*						
Pond, 300 ft north of Utica St., 100 ft west of Delaware Ave.; 1.5 ft below surface.	6/11-2K	Jan. 13, 1941 Feb. 13, 1942 Aug. 6, 1942 Dec. 31, 1942	2,650 9,080 16,300 17,900	300 550 1,050 1,100	7,660 20,000 38,000 45,000	---------- ---------- 83 58
Pond, 10 ft north of Adams Ave. and 200 ft west of Huntington Ave., 500 ft east of Southern Pacific Railway; 0.5 ft below surface.	6/11-2Q	Jan. 6, 1941	1,180	390	3,500	----------
Pond, 500 ft north and 1,500 ft west of turning circle at west end of Clay St.; 0.8 ft below surface.	6/11-3B	Jan. 3, 1941 Dec. 31, 1942	6,200 15,000	710 2,150	17,000 37,000	---------- 64
Pond, 10 ft north of Clay St. (extended) and 800 ft east of Edwards St.; 1 ft below surface.	6/11-3B	Jan. 6, 1941 Dec. 31, 1942	29 73	60 90	259 1,050	---------- 54
Pond, 0.35 mile northeast of U. S. Highway 101 and 0.5 mile northwest of 23d St.; 1 ft below surface.	6/11-3M	Jan. 6, 1941 Dec. 31, 1942	27 15,500	50 2,250	195 40,000	---------- 57
Pond, 0.4 mile northeast of U. S. Highway 101, 0.95 mile northwest of 23d St.; 0.5 ft below surface.	6/11-4H	Jan. 6, 1941	9	30	96	----------
Pond, 135 ft north and 175 ft east of the intersection of Alabama Ave. and Nashville St.; 2 ft below surface.	6/11-11B	----do---- Aug. 6, 1942 Dec. 31, 1942	2,650 99,900 51,000	715 23,500 12,000	7,720 148,000 93,000	---------- 102 63
Ocean water, from breakwater near San Pedro; from surface.		May 18, 1941	18,700	6,000	45,000	65

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