TEXAS WATER COMMISSION

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BULLETIN 6303

PUMPAGE OF GROUND WATER AND CHANGES IN WATER LEVELS IN GALVESTON COUNTY, TEXAS, 1958-62

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in cooperation with the
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TABLE OF CONTENTS

TABLES

TABLE OF CONTENTS (Cont'd.)

PUMPAGE OF GROUND WATER AND CHANGES IN WATER LEVELS IN GALVESTON COUNTY, TEXAS, 1958-62

ABSTRACT

The quantity of water used in Galveston County during the period 1958-62 was nearly constant, ranging from 86 mgd (million gallons per day) in 1960 to 88 mgd in 1961. Of the 1961 total, 21 mgd was ground water and 67 mgd was water from the Brazos River.

Ground-water withdrawal in Galveston County has declined slightly since 1957, ranging from 27.8 mgd in 1959 to 21.5 mgd in 1961. In 1961, 15.7 mgd was used for public supply, 5.3 for industry, and 0.5 for irrigation. Between 1958 and 1962, industrial pumpage ranged from 6.3 mgd in 1959 to 5.3 mgd in 1961; withdrawal for public supply ranged from 15.6 mgd in 1958 to 16.7 mgd in 1960. Pumpage for irrigation in Galveston County ranged from 0.5 mgd in 1960-61 to 1.5 mgd in 1958.

Water levels in wells in Galveston County changed very little in some areas and declined slowly in others during the period 1958-62. In the city of Galveston's well fields near Alta Loma, near the center of pumping, they have remained about the same, but in outlying areas they have declined somewhat, especially near the Harris County line, where the maximum decline was 25 feet between 1957 and 1962. Levels in Texas City and vicinity have remained nearly stable.

Land-surface subsidence continued during the period, ranging from 0.1 to 0.5 foot. The greatest subsidence was 0.5 foot at League City.

No major changes were noted in the chemical quality of water from wells. The average quality of water from the city of Galveston's "old" well field has improved slightly. The chloride content of water from one well in the "new" well field continued to increase slowly.

PUMPAGE OF GROUND WATER AND CHANGES IN WATER LEVELS IN GALVESTON COUNTY, TEXAS, 1958-62

INTRODUCTION

Galveston County, on the upper Gulf Coast of Texas, has an area of 710 square miles, of which 430 square miles is land. Lying about 25 miles southeast of Houston (Figure 1), it is bounded on the north by Harris and Chambers Counties, on the west by Brazoria County, and on the south and east by the Gulf of Mexico (Plate 1).

This report is one of a series (see "Selected References") containing information on the ground-water resources of Galveston County. It presents data on pumpage, changes in water levels, changes in chemical quality of the water, and related information compiled during the period 1958-62 by the U. S. Geological Survey in cooperation with the city of Galveston and the Texas Water Commission. A similar report by Wood (1958b) presents data for the period 1952-57, and a report by Petitt and Winslow (1957) supplies still earlier data and contains a tabulation of well records and a summary of the geology, geography, and climate of Galveston County. Well numbers in this report are the same as those used originally by Petitt and Winslow (1957).

PUMPAGE

Practically all the ground water used in Galveston County is from sands in the Beaumont Clay (Petitt and Winslow, 1957, p. 9-15). Most of the water is pumped from a sand at or near the base of the Beaumont Clay, known locally as the "Alta Loma sand" (Rose, 1943, p. 3) because of its occurrence in the vicinity of Alta Loma and the early production of relatively large quantities of water from it. Sands in the upper part of the Beaumont Clay are thinner and less persistent than those in the "Alta Loma" and hence constitute a less productive aquifer; however, they are a major source of water and in some places yield water of better quality than that from the "Alta Loma sand."

Pumpage data are obtained each spring for the preceding calendar year for all industries, municipalities, and water districts pumping more than 5,000 gpd (gallons per day). About 80 percent of the water pumped is metered; the rest is estimated from data supplied by the well owners. Figures of pumpage for irrigation are based on the estimated number of acres irrigated, rainfall during the pumping season, and the duty of water per acre.

Figure 1

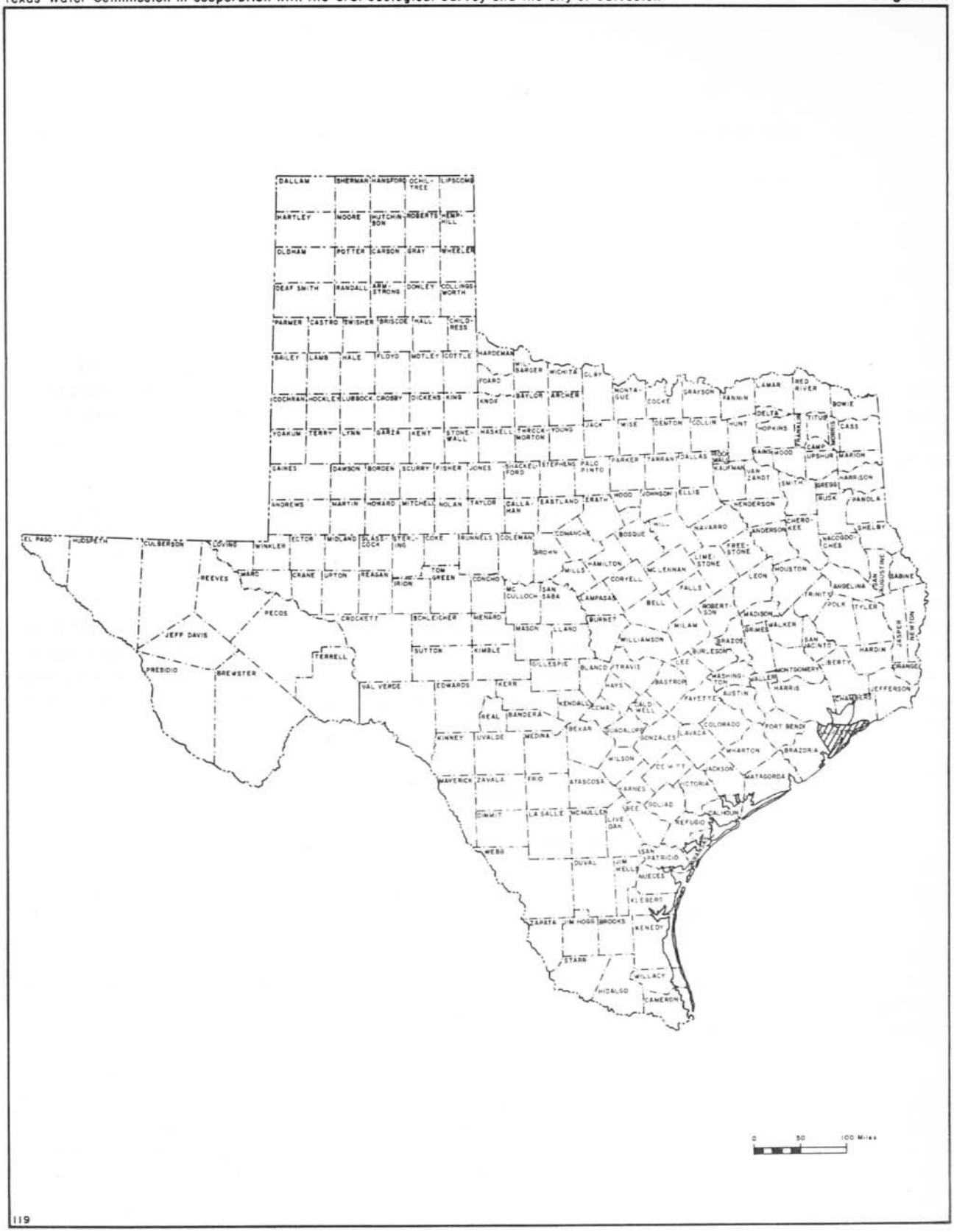


FIGURE 1. - Map of Texas showing location of Galveston County

In 1961 all water used for public and domestic supplies in Galveston County was from wells. Prior to July 1948, all industrial water also was derived from wells; however, since that time industrial supplies in the Texas City area have been supplemented with surface water, so that the ground-water pumpage could be reduced to help check salt-water intrusion and land-surface subsidence.

The total pumpage of ground water for the period 1951-61 is shown in Table 1. As may be seen, the pumpage has decreased from a high of 27.3 mgd (million gallons per day) in 1954 to 21.5 mgd in 1961, chiefly because of a decrease in the industrial use of ground water.

Ground-water withdrawals for public supply and industrial use have remained relatively constant since 1951, ranging from 26.1 mgd in 1951 to 21.0 mgd in 1961 (Table 1). During the 11-year period 1951 through 1961, ground-water withdrawals for public supply increased 2.4 mgd, whereas withdrawals for industrial use decreased 7.5 mgd, as a result of the increased use of surface water.

Prior to about 1930, fruit orchards, truck gardens, and a few rice farms in Galveston County were irrigated primarily with water from flowing wells. By 1930 most wells no longer flowed, and the remaining wells generally had such small flows that it was necessary to increase the yield by pumping; in addition, some nonflowing wells were abandoned. Although accurate records are not available to show early withdrawals, it is probably safe to assume that as flows decreased, the amount of water used for irrigation also decreased. Irrigation of truck farms and orchards with ground water continued through 1961, but the amount of water used was small, averaging 500,000 gpd during the period 1951-61.

Rice was irrigated with ground water in Galveston County possibly before 1900, and irrigation was continued sporadically during the period 1900-1953. A few hundred acres of rice was irrigated in 1954, the peak year for which records are available (Table 1). The withdrawal for rice irrigation has decreased since 1954, and in 1960 and 1961 no ground water was used for this purpose.

Rice has been a major crop only since 1942, when canals were first used to bring irrigation water from the Brazos River into the county. The number of acres of rice irrigated by surface water rose from less than 9,000 in 1942 to more than 20,000 in 1951. In 1952, 17,000 acres of rice was irrigated, and in 1953 and 1954, 16,000 acres was irrigated (Table 2). The decrease after 1954 resulted from acreage limitations instituted under the price-support program of the U. S. Department of Agriculture, begun in 1955. The use of surface water for rice irrigation during the period 1951-61 ranged from 45 mgd in 1951 to 20 mgd in 1957.

The use of surface water for industry increased steadily during the period 1951-60, largely as the result of industrial expansion but also because the use of surface water has replaced the use of ground water to some extent. In 1951, 16.7 mgd was used, and in 1960 a peak of 42.2 mgd.

The total annual use of water in Galveston County has remained fairly constant during the period 1951-61 (Table 3). The use of surface water has increased slightly, and the use of ground water has decreased almost correspondingly. The average daily use of ground and surface water was estimated to range from 95 mgd in 1954 to 82 mgd in 1957.

Table 1.--Withdrawal of ground water in Galveston County, in million gallons per day, 1951-61

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
Public supplies:											
Galveston	10.7	10.7	10.5	11.3	11.4	12.2	11.3	11.4	11.6	11.9	10.6
Texas City	1.5	1.6	1.7	1.9	1.9	2.2	2.4	2.3	2.4	2.5	2.8
Other cities	0	0	0	0	0	0	0	0	.9	1.5	1.4
Water districts	1.1	1.7	2.0	2.0	1.7	1.7	1.6	1.9	1.3	.8	.9
Subtotal	13.3	14.0	14.2	15.2	15.0	16.1	15.3	15.6	16.2	16.7	15.7
Industrial supplies:											
Oil refineries	7.0	6.6	5.4	4.9	4.4	4.4	4.3	5.0	5.0	4.9	4.0
Chemical plants	2.7	1.3	1.2	1.1	.5	.9	.8	.7	1.0	.7	.6
Miscellaneous industries	3.1	3.0	3.5	3.6	1.3	1.7	.9	.2	.3	.6	.7
Subtotal	12.8	10.9	10.1	9.6	6.2	7.0	6.0	5.9	6.3	6.2	5.3
Total public and industrial supplies	26.1	24.9	24.3	24.8	21.2	23.1	21.3	21.5	22.5	22.9	21.0
Irrigation:											
Rice	--	--	--	2.0	1.7	1.5	1.5	1.0	.8	0	0
Other crops	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5
Subtotal	0.5	0.5	0.5	2.5	2.2	2.0	2.0	1.5	1.3	0.5	0.5
TOTAL*	26.6	25.4	24.8	27.3	23.4	25.1	23.3	23.0	23.8	23.4	21.5

* Figures are approximate because some of the pumpage rates are estimated.

Table 2.--Estimated use of surface water in Galveston County, 1951-61

Year	Industrial		Rice irrigation			Total	
	Million gallons per day	Acre-feet per year	Acres	Million gallons per day	Acre-feet per year	Million gallons per day	Acre-feet per year
1951	16.7	18,700	20,000	45	50,000	62	68,700
1952	23.7	26,500	17,000	38	42,500	62	69,000
1953	27.6	30,900	16,000	36	40,000	64	70,900
1954	31.8	35,600	16,000	36	40,000	68	75,600
1955	38.4	43,000	11,000	25	27,500	63	70,500
1956	38.5	43,100	10,000	22	25,000	61	68,100
1957	38.6	43,200	9,000	20	22,500	59	65,700
1958	39.4	44,100	11,000	25	27,500	64	71,600
1959	37.8	42,300	11,000	25	27,500	63	69,800
1960	42.2	47,300	10,000	21	24,000	63	71,300
1961	42.0	47,000	11,000	25	27,500	67	74,500

Table 3.--Average use of water in Galveston County, in million gallons per day, 1951-61

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
Ground water:											
"Alta Loma sand"	18.7	18.9	17.8	19.1	17.3	18.8	17.5	16.7	16.9	16.3	14.3
Upper part of Beaumont Clay	7.9	6.5	7.0	8.2	6.1	6.3	5.8	6.3	6.9	7.1	7.2
Subtotal	26.6	25.4	24.8	27.3	23.4	25.1	23.3	23.0	23.8	23.4	21.5
Surface water	62	62	64	68	63	61	59	64	63	63	67
TOTAL	89	87	89	95	86	86	82	87	87	86	88

"Alta Loma Sand" of the Beaumont Clay

Most of the ground water pumped in Galveston County is from the "Alta Loma sand" of the Beaumont Clay of Pleistocene age. Somewhat larger amounts are pumped from the "Alta Loma" in the Baytown-La Porte and Houston ship-channel areas north and east of Deer Park in Harris County (Figure 6).

The Galveston municipal well field near Alta Loma and the industrial area of Texas City are the centers of the largest withdrawal from the "Alta Loma sand" (Figure 2). The total pumpage in the two areas has fluctuated during the 1951-61 period but has generally decreased; in 1951 it was 16 mgd, and in 1961 it was 14 mgd, the decrease being due to a reduction of pumpage in the Texas City area.

Pumpage by the city of Galveston in the Alta Loma area was fairly constant during the period 1945-61, ranging from 10.5 to 12.2 mgd. In the Texas City area, pumpage from the "Alta Loma sand" reached a peak of 18 mgd in 1944 and then decreased slowly to 14.5 mgd in 1948, when surface water became available. By 1950 the withdrawal in the Texas City area had decreased to 5.6 mgd; it thereafter continued to decrease slowly to 3.6 mgd in 1957. From 1958 to 1961, withdrawal in the Texas City area ranged from 4.2 mgd to 3.2 mgd.

Pumpage from the "Alta Loma sand" in the rest of Galveston County has never been large, reaching a maximum of 3.7 mgd in 1954; of this quantity 2 mgd was used for cooling on Galveston Island and most of the remainder was used for irrigation in northern Galveston County. Since 1954, pumpage in the same areas has been less than 3 mgd, primarily because withdrawal on Galveston Island was reduced in 1955 and finally was stopped altogether by 1958. Probably less than 500,000 gpd was used outside the Texas City and Alta Loma areas in 1960 and 1961, the reduction being caused chiefly by the lack of rice irrigation with ground water.

Upper Part of the Beaumont Clay

More wells in Galveston County are screened in sands in the upper part of the Beaumont Clay than in the "Alta Loma sand." However, most of the wells are of small capacity, furnishing water for domestic and livestock use. The large wells that draw from sands in the upper part of the Beaumont are mostly in the Texas City area, where they supply water to industries and the cities of Texas City and La Marque. In the Texas City area, the upper part of the Beaumont Clay yields water that is of better chemical quality and hence is more desirable for municipal and industrial use than the water from the "Alta Loma sand." Coastward from Texas City, the sands in the upper part of the Beaumont Clay of Pleistocene age are the only source of moderate to relatively large amounts of potable water.

Ground-water withdrawal from the upper part of the Beaumont Clay in the Texas City area increased substantially during the war years and more slowly thereafter, reaching a peak of 7.3 mgd in 1951 (Figure 3). Since then withdrawal has been variable, ranging from 6.9 mgd in 1954 to 4.5 in 1958, after which it increased to 5.7 in 1961. Withdrawal for industry decreased from 5.5 mgd in 1951 to 1.8 mgd in 1958, subsequently rising to 2.5 mgd in 1960 and then declining to 2.3 mgd in 1961.

Most of the rest of the pumpage from the upper part of the Beaumont Clay was from public-supply and irrigation wells. Pumpage from these wells was small during the period 1951-61, ranging from 0.5 to less than 2 mgd. The pumpage from domestic, livestock, oil-well drilling-supply wells, and other small wells in the county probably is less than 1 mgd.

CHANGES IN WATER LEVELS IN WELLS

Before 1930, many wells in Galveston County flowed. According to Petitt and Winslow (1957, p. 35), the artesian pressure was as much as 32 feet above the land surface in a well in the "Alta Loma sand" near Dickinson in 1900. Similar pressures were reported in other wells that penetrated both the "Alta Loma sand" and the Beaumont Clay in the years just before and after 1900. Only small amounts of ground water were withdrawn in Galveston County before 1900, and the water levels generally were about the same as those before development. After 1900, levels in both aquifers slowly declined in response to increased withdrawal until about 1930, when in many wells levels were at or slightly below land surface. The rate of decline increased during the 1930's, and by 1940 levels were 40 to 70 feet below land surface. During the latter part of the 1930's and early 1940's, pumping rates increased rapidly, causing large declines in water levels. The declines were different in the two principal aquifers because of differences in aquifer characteristics and pumping rates.

"Alta Loma Sand" of the Beaumont Clay

Between 1940 and 1945, water levels in wells in the "Alta Loma sand" declined rapidly in and near the Galveston municipal well fields (wells D-14, E-79, L-63, L-68, and L-25, Figure 4) because of steadily increasing pumping rates. From 1945 until 1962, water was withdrawn at a nearly constant rate in and near the well fields, and, although levels fluctuated somewhat, the overall decline was very slow. Levels declined slightly faster in the vicinity of the "new" well field (wells D-14, E-79, Figure 4) north of Alta Loma than in the "old" well field (wells L-63, L-68, and L-25, Figure 4), where levels were nearly stable. Declines, which averaged 2.5 feet per year during the period 1952-62, in part of the "new" well field were caused chiefly by small increases in pumpage in the city of Galveston well fields.

In the Texas City area, levels in wells screened in the "Alta Loma sand" declined rapidly from 1940 to 1945, then more slowly until 1948 (wells F-34 and F-50, Figure 5). After the introduction of surface water into the Texas City area in July 1948, ground-water withdrawal decreased sharply, and levels rose rapidly until 1950. During the period 1950-62, levels remained about the same, or were only slightly lower in 1962 than in 1950.

In areas distant from the main centers of pumping in Galveston and Harris Counties, water levels declined steadily between 1940 and 1962 (wells D-7, D-14, and L-25, Figure 4, and wells L-33, A-7, B-40, and B-10, Figure 5), although declines during the 1940's were greater than those during the 1950's. The decline between 1952 and 1962 generally was about 3 feet per year.

Texas Water Commission in cooperation with the U.S. Geological Survey and the city of Galveston

Figure 2

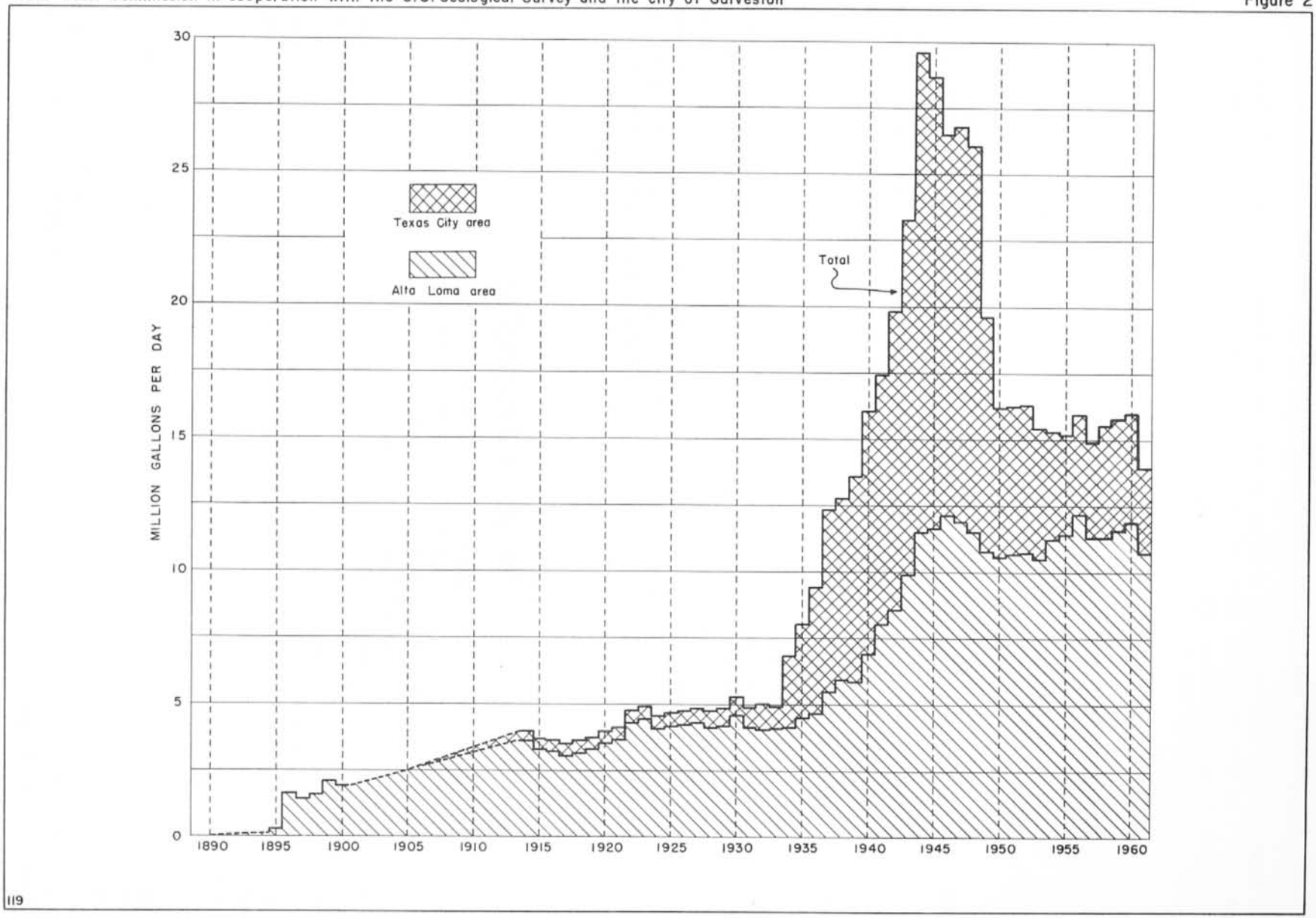


FIGURE 2.- Average daily pumpage from the "Alta Loma sand" in the Alta Loma and Texas City areas, 1890-1961

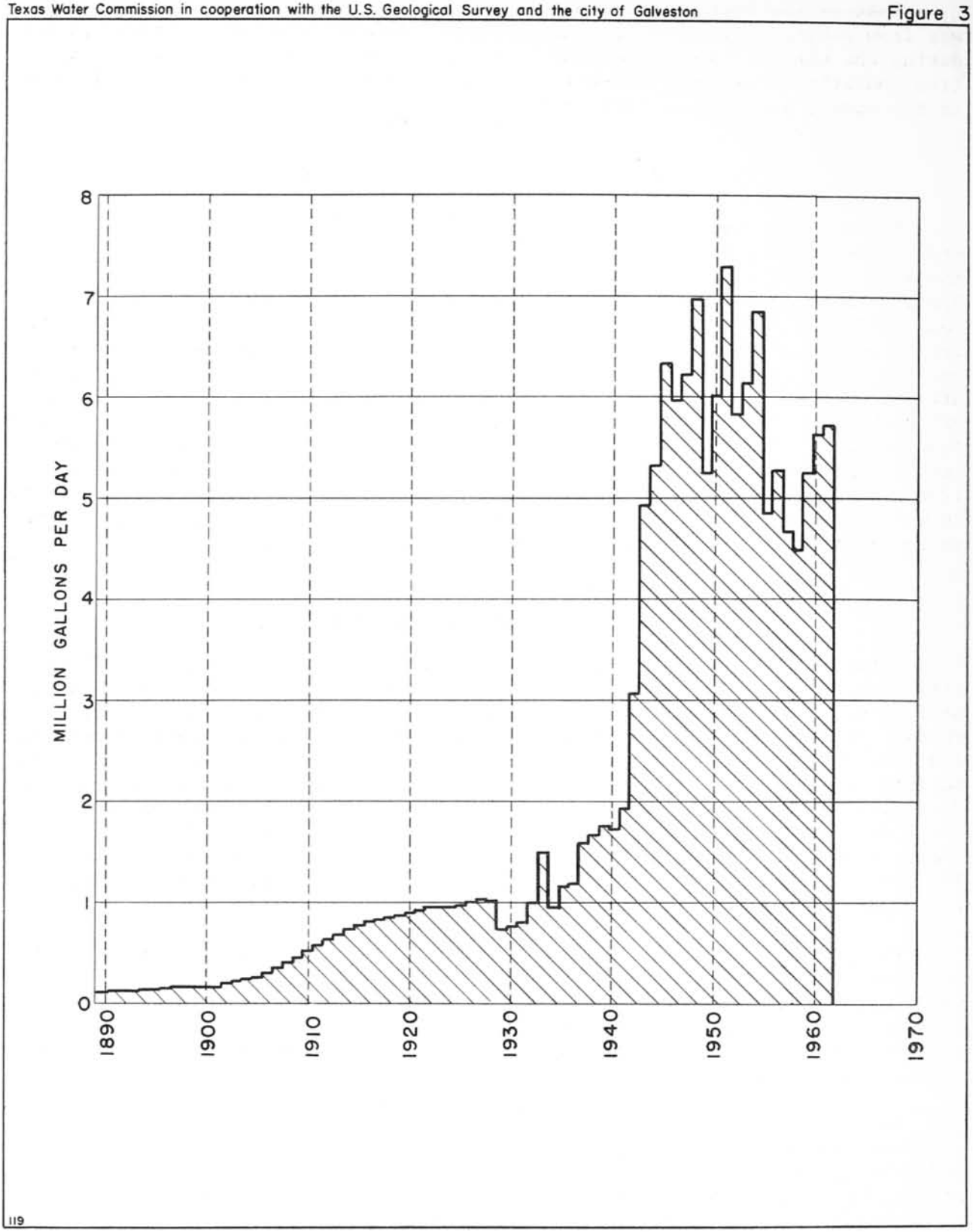
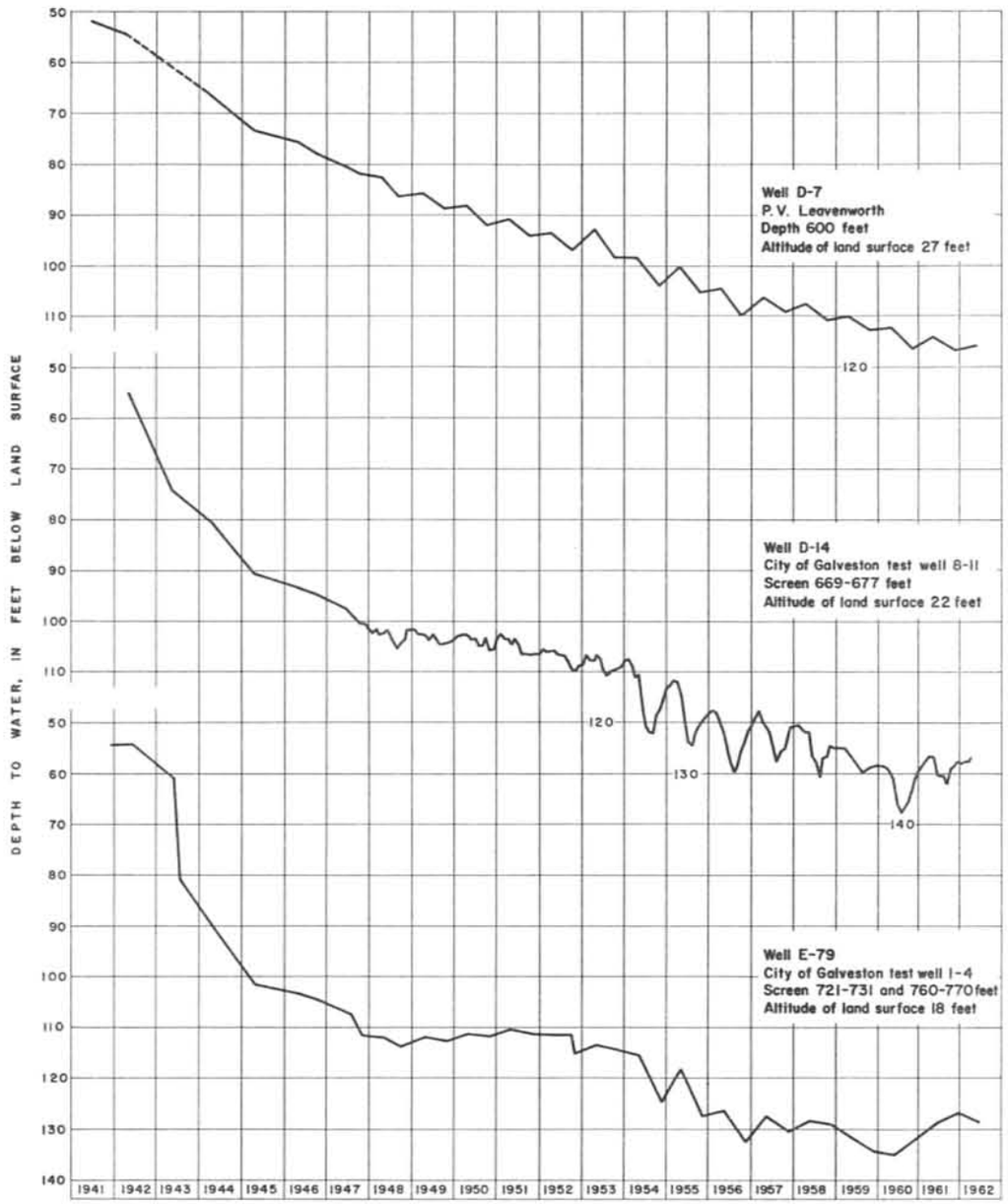


FIGURE 3. – Average daily pumpage from the upper part of the Beaumont Clay in the Texas City area, 1890-1961



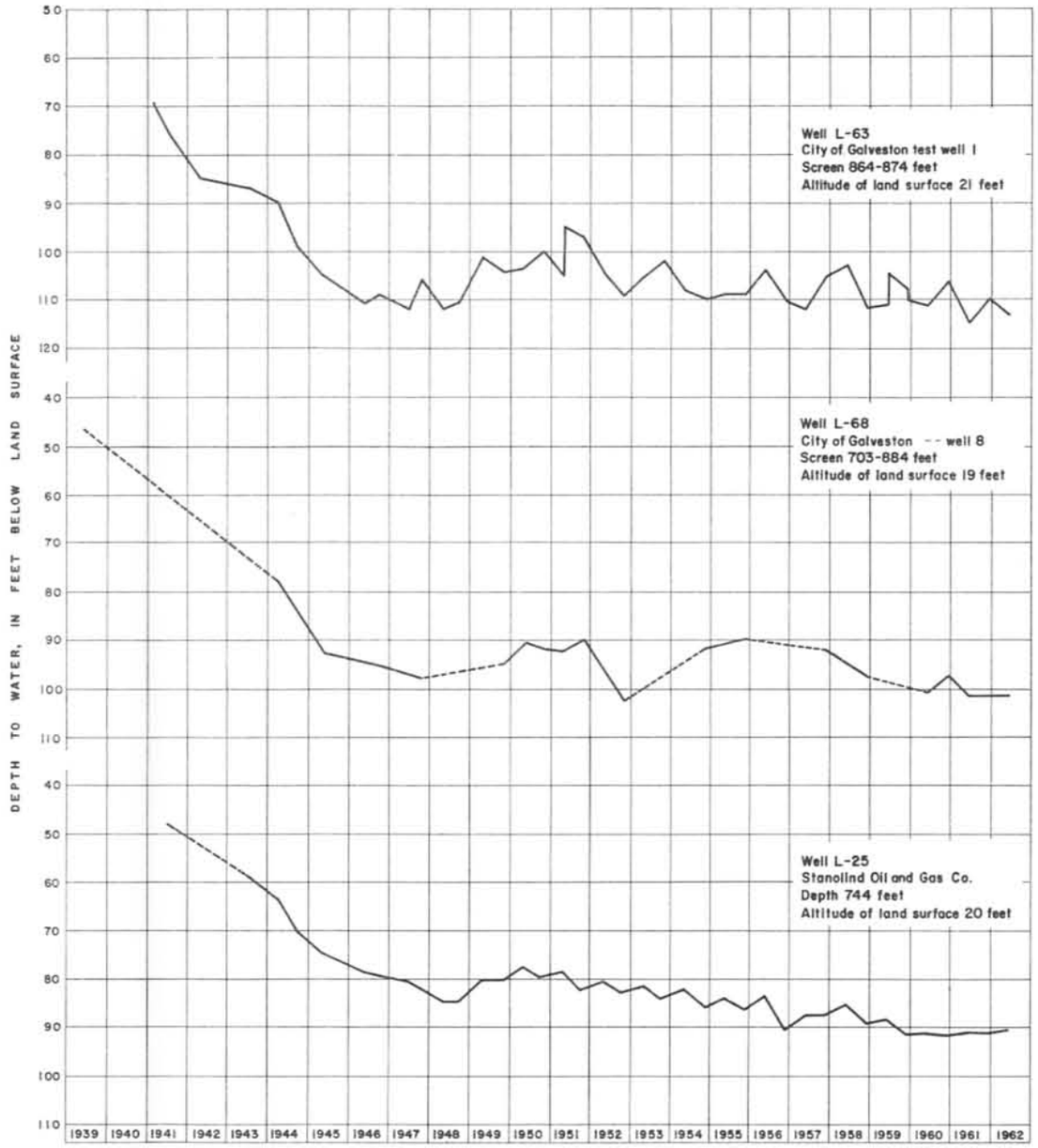


FIGURE 4 – Changes in water levels in wells in the "Alta Loma sand," Galveston County

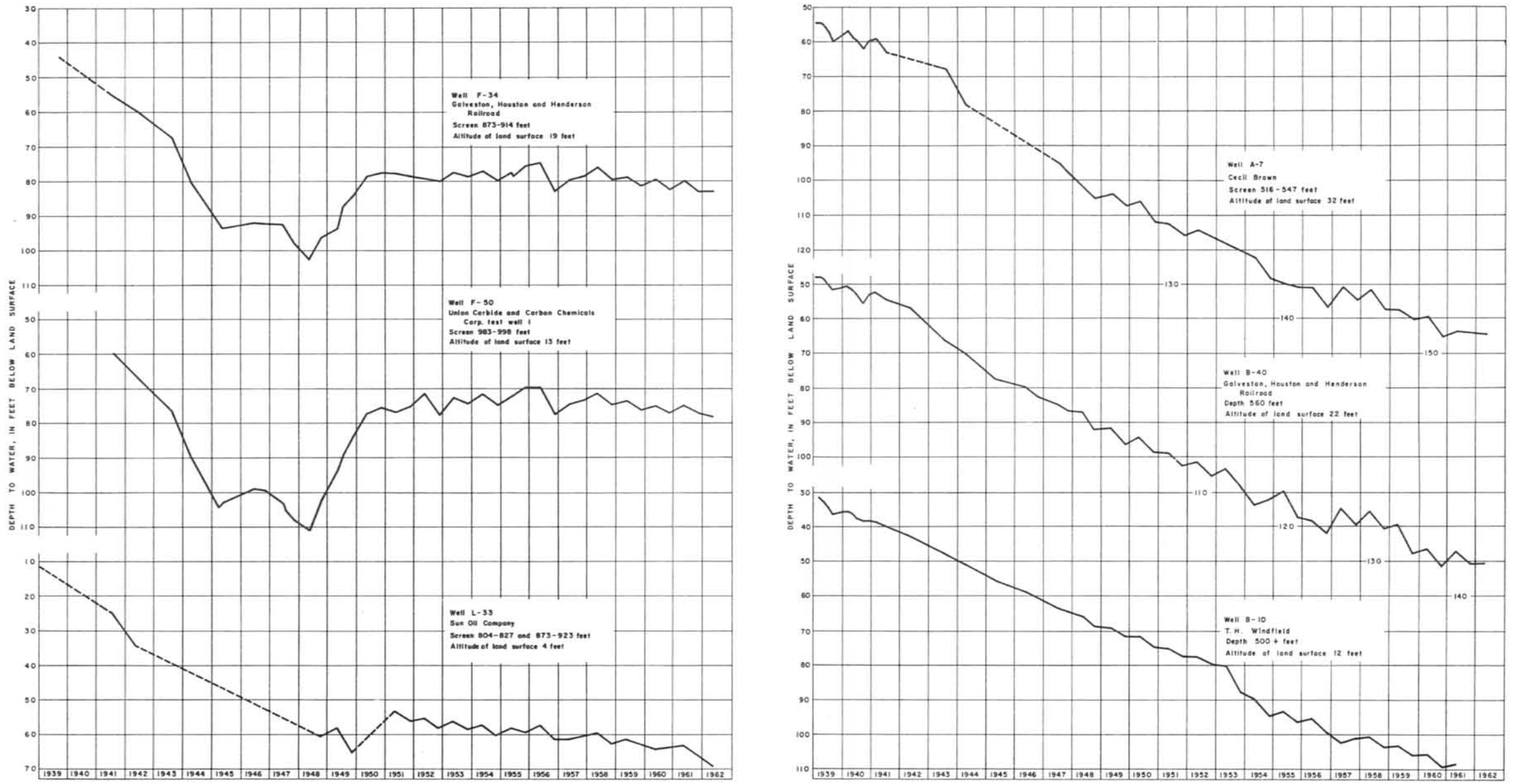


FIGURE 5.– Changes in water levels in wells in the "Alta Loma sand," Galveston County

Although very little ground water has been pumped in the vicinity of well L-33 (Figure 5) in the southern part of Galveston County, the water level in the well has declined more or less steadily between 1939 and 1962, primarily as a result of pumping in the rather distant Texas City and Alta Loma areas. The continued decline of level in well L-33 even after the reduction in pumpage from the "Alta Loma sand" in 1954 (Table 3) indicates that levels have not yet reached equilibrium, even at relatively great distances from centers of pumping, and that they will continue to decline slowly for several years if pumping rates remain unchanged.

Figure 6, a map showing the approximate altitude of water levels in wells screened in the "Alta Loma sand" in May 1962 in Galveston County and parts of Harris, Brazoria, and Chambers Counties, also shows the effect of the heavy withdrawal in the Alta Loma, Houston ship-channel, and Baytown-La Porte areas. A comparison with the equivalent map for May 1957 (Wood, 1958b, Fig. 6, p. 11) shows that levels in the city of Galveston's "new" well field in the Alta Loma area and in the centers of pumping in the Houston ship-channel area and Baytown-La Porte area declined 3, 23, and 20 feet, respectively. These declines are appreciably less than those given by Wood (1958b, p. 8) for the period 1952-57 for the same areas.

Electric logs of wells north and west of the Houston ship channel, west of the Deer Park area, and in an area a few miles west of the northern part of Galveston County indicate that the "Alta Loma sand" breaks up into thin layers of sand interbedded with relatively massive clays, and the sand is not recognizable as a stratigraphic unit in these areas. In some wells the "Alta Loma" equivalent consists of 60 to 80 percent clay. Because of the resulting lower transmissibility in these areas, the hydraulic gradient as shown in Figure 6 is much steeper north of the ship channel and west of Deer Park. The positions of the contours in the Pasadena area are based on water levels north and southwest of Deer Park and, to some extent, on stratigraphic control from electric logs.

Profiles of water levels in wells from a point north of Deer Park in Harris County to a point south of Alta Loma are shown for the years 1941, 1948, 1952, 1957, and 1962 in A-A', Figure 7. Profiles from a point northwest of Alta Loma to Texas City for the same years are shown in B-B', Figure 7. Profile B-B'--which passes through Galveston's "new" well field, where the water levels are the lowest in the county--shows that levels have declined very little at the center of pumping between 1957 and 1962. However, levels in the northern part of Galveston County were 5 to more than 25 feet lower in 1962 than in 1957, indicating that they have not yet reached equilibrium and will continue to decline slowly--reflecting chiefly the pumping in Harris County.

Data from wells drilled near Alta Loma show that the "Alta Loma sand" is divided into two sand bodies by a clay of variable thickness. According to the electric log of well E-93 (Plate 1), the main body of sand is separated from the underlying sand by clay between 800 and 850 feet. Changes in water levels in well E-92, screened between 661 and 775 feet in the main sand body, and nearby well E-93, screened between 850 and 870 feet in the underlying sand, are shown in Figure 8. For comparison, the average daily pumpage from Galveston wells for each month from October 1946 to 1962 is shown also. The similarity in the hydrographs of the two wells (Figure 8) is good evidence that the two sands are hydraulically connected, as practically no water is pumped from the

deeper sand in the immediate area. The increased seasonal fluctuation in levels since 1953 is due partly to a somewhat greater seasonal range in rate of withdrawal from Galveston's municipal wells and partly to seasonal withdrawal for irrigation from wells to the north.

Upper Part of the Beaumont Clay

Most of the water pumped from sands in the upper part of the Beaumont Clay in Galveston County is from wells in the Texas City area. Although some of these sands are nearly as permeable as the "Alta Loma sand," they transmit water much less readily because they are generally considerably thinner and more lenticular. Prior to the extensive development of ground water in Galveston County, the artesian heads in sands in the upper part of the Beaumont Clay and in the "Alta Loma sand" were at approximately the same altitude. As withdrawal increased, water levels in both aquifers declined at somewhat different rates because of differences in aquifer characteristics, thickness, and rates of discharge. In relation to the amount of water withdrawn, levels in the upper part of the Beaumont have declined at a much greater rate than those in the "Alta Loma sand."

Water levels in wells in the upper part of the Beaumont Clay declined rapidly during World War II in and near the Texas City area largely as a result of an increase in industrial pumping (wells F-42 and M-15, Figure 9). During the period 1945-48, the decline of water levels slowed appreciably as a result of a reduction in industrial pumping. After industrial supplies were supplemented with surface water in 1948, levels rose rapidly. Since that time, levels in the Texas City area have remained fairly stable or have declined very slowly.

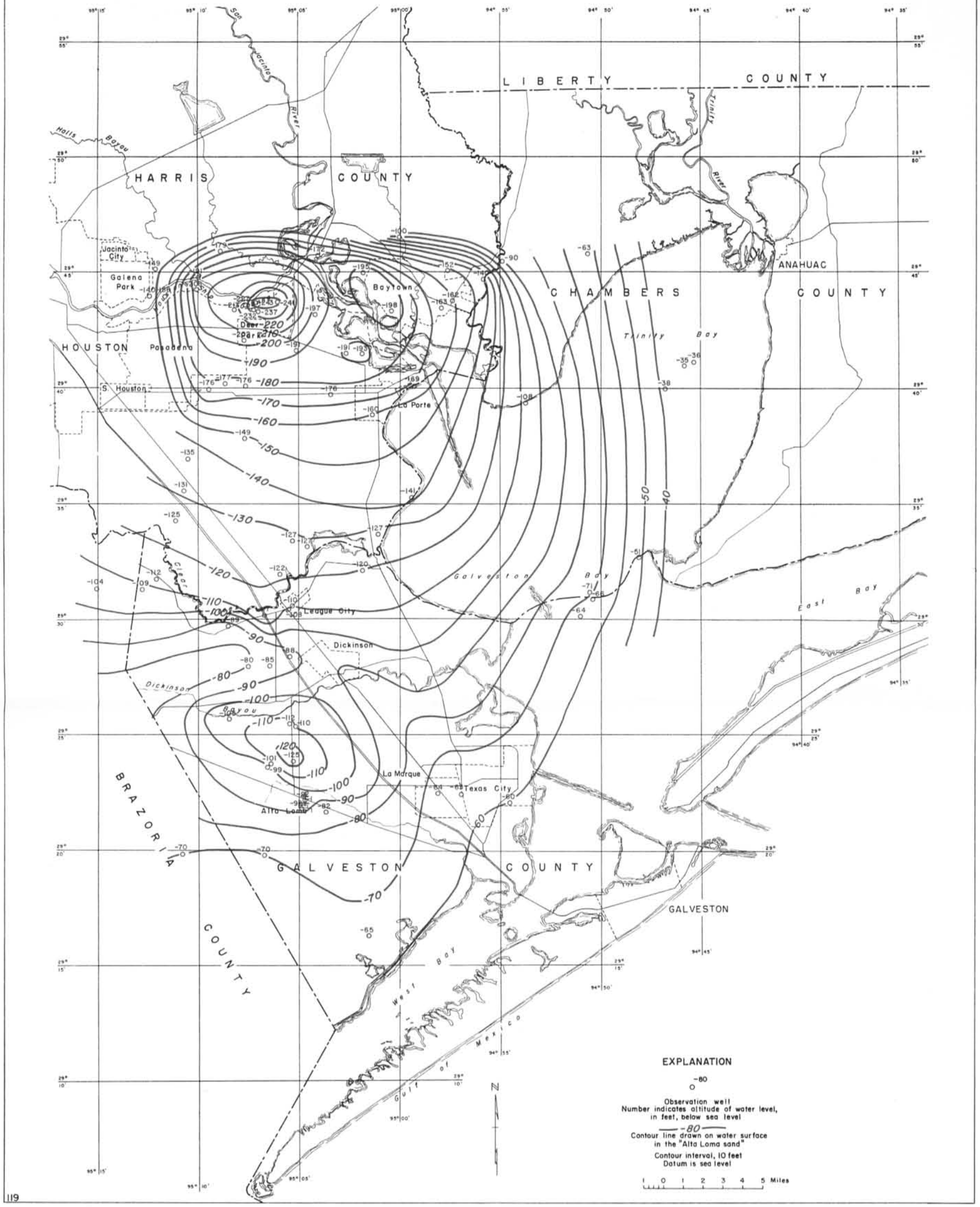
SUBSIDENCE OF THE LAND SURFACE

Land-surface subsidence in Galveston County is caused by a reduction of artesian pressure in the water-bearing sands resulting from pumping ground water. The reduction in pressure creates a hydraulic gradient from the clays to the adjoining water-producing sands, which results in water slowly leaving the clays. As the water leaves the clays, the clay particles are squeezed more closely together and the land surface subsides. Although some subsidence has resulted from withdrawal of water from the "Alta Loma sand," it is probably less than that resulting from withdrawal from the upper part of the Beaumont Clay. The land surface has subsided somewhat throughout Galveston County; however, only in the Texas City area has it been great enough to cause appreciable concern.

The method by which subsidence was determined in Galveston County is discussed by Wood (1958b, p. 16), who states, "The extent of the subsidence in Galveston County has been determined by releveling of previously established level lines in the county. U. S. Coast and Geodetic Surveys level line number 111, which passes through Texas City, was established in 1936 and was releveled in part in 1951 and in its entirety in 1953-54. Supplementary level lines were established in the Texas City area by private firms during the period 1940-45, and many of the lines have been releveled semiannually since 1951." Between 1936 and 1954, the land surface subsided nearly 5 feet in a small area a short distance from one of the U. S. Coast and Geodetic Survey level lines in Texas

Texas Water Commission in cooperation with the U.S. Geological Survey and the city of Galveston

Figure 6



119

FIGURE 6.– Approximate altitudes of water levels, in feet, in wells screened in the "Alta Loma sand," Galveston, Harris, Brazoria, and Chambers Counties, May 1962

Texas Water Commission in cooperation with the U.S. Geological Survey and the city of Galveston

Figure 7

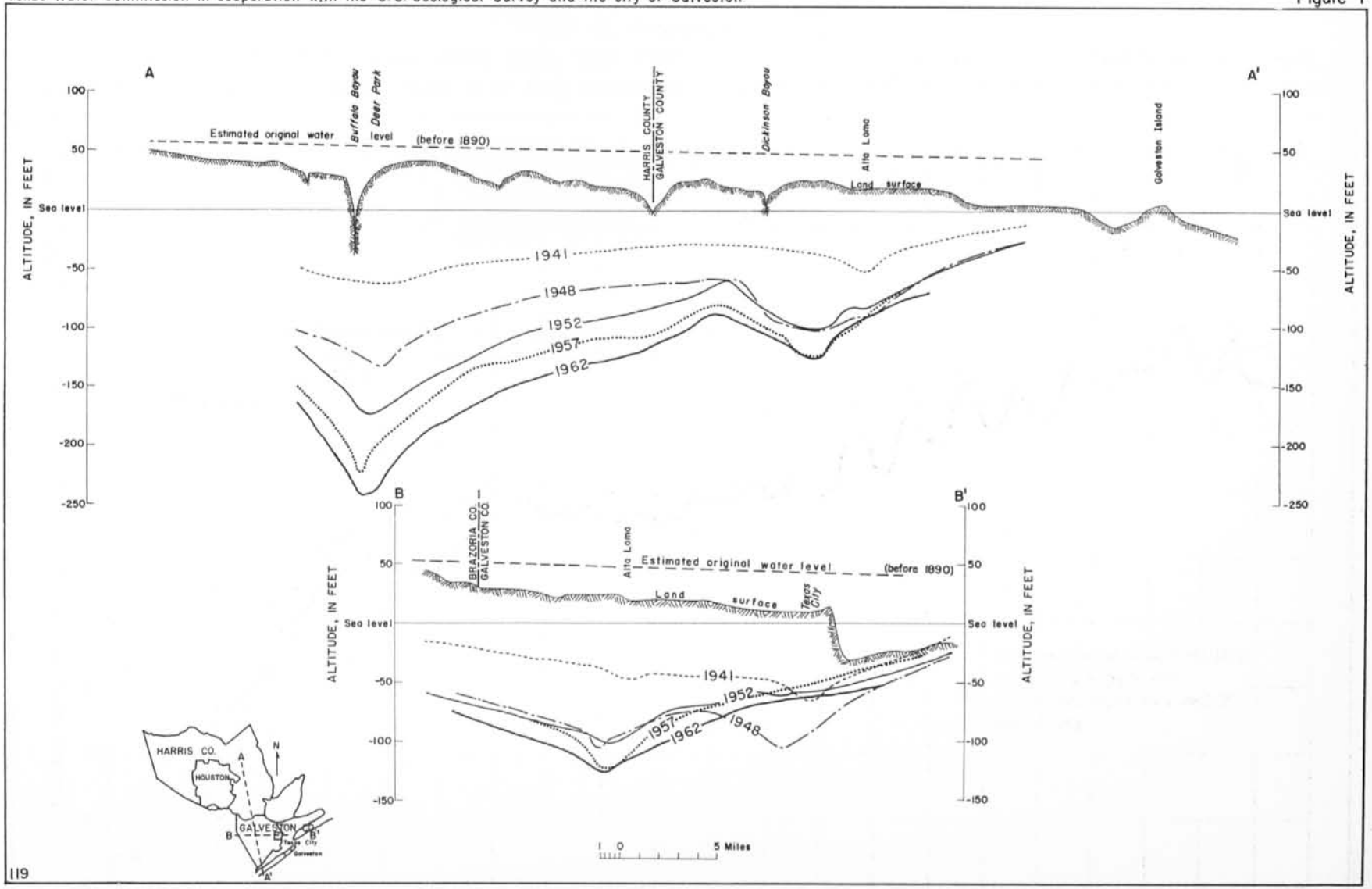


FIGURE 7.- Profiles of water levels in wells in the "Alta Loma sand"

Texas Water Commission in cooperation with the U. S. Geological Survey and the city of Galveston

Figure 8

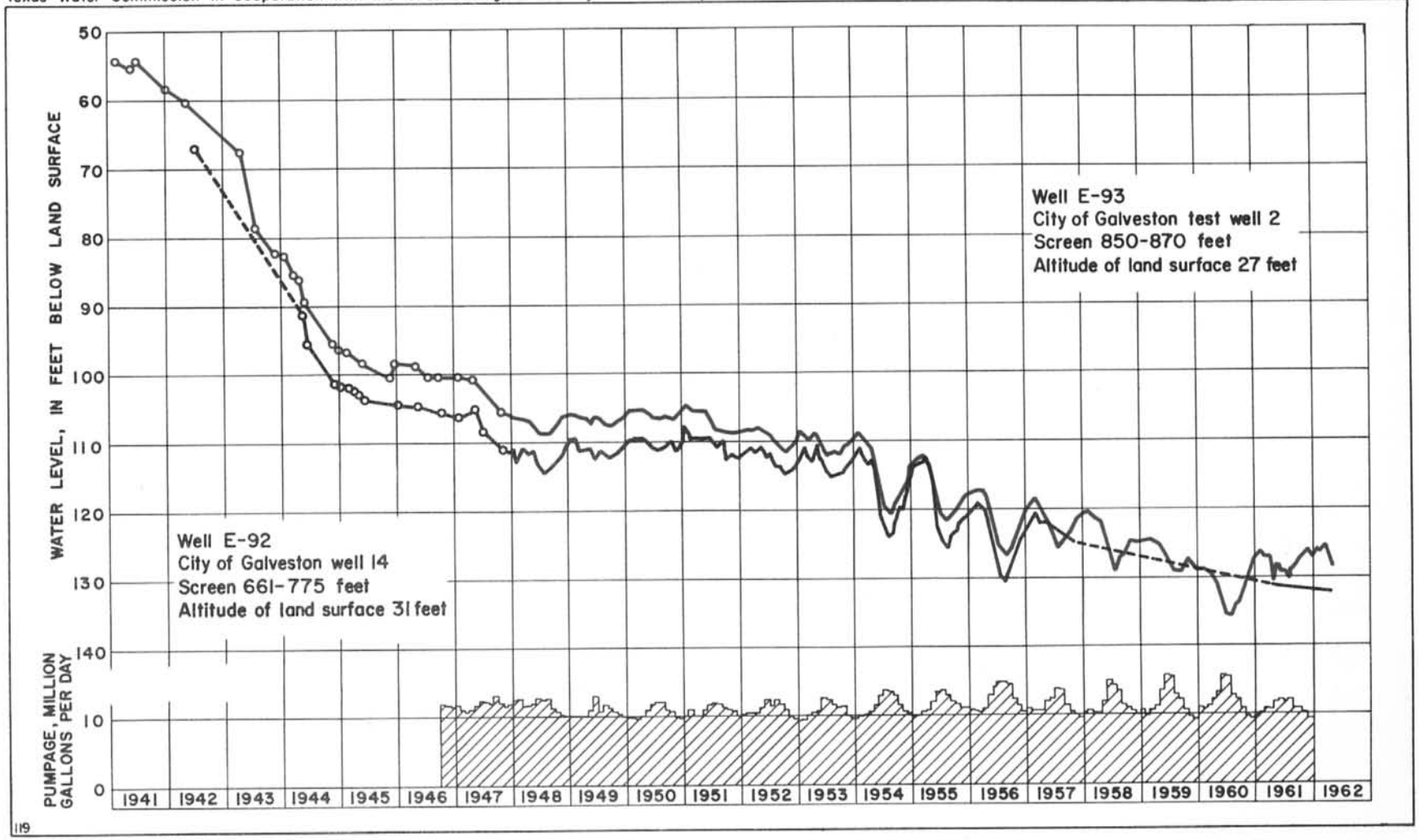


FIGURE 8.–Changes in water level in a well screened in the main body of the "Alta Loma sand" and in a well screened in the underlying sand near Alta Loma compared with average daily pumpage from the city of Galveston's wells

Texas Water Commission in cooperation with the U.S. Geological Survey and the city of Galveston

Figure 9

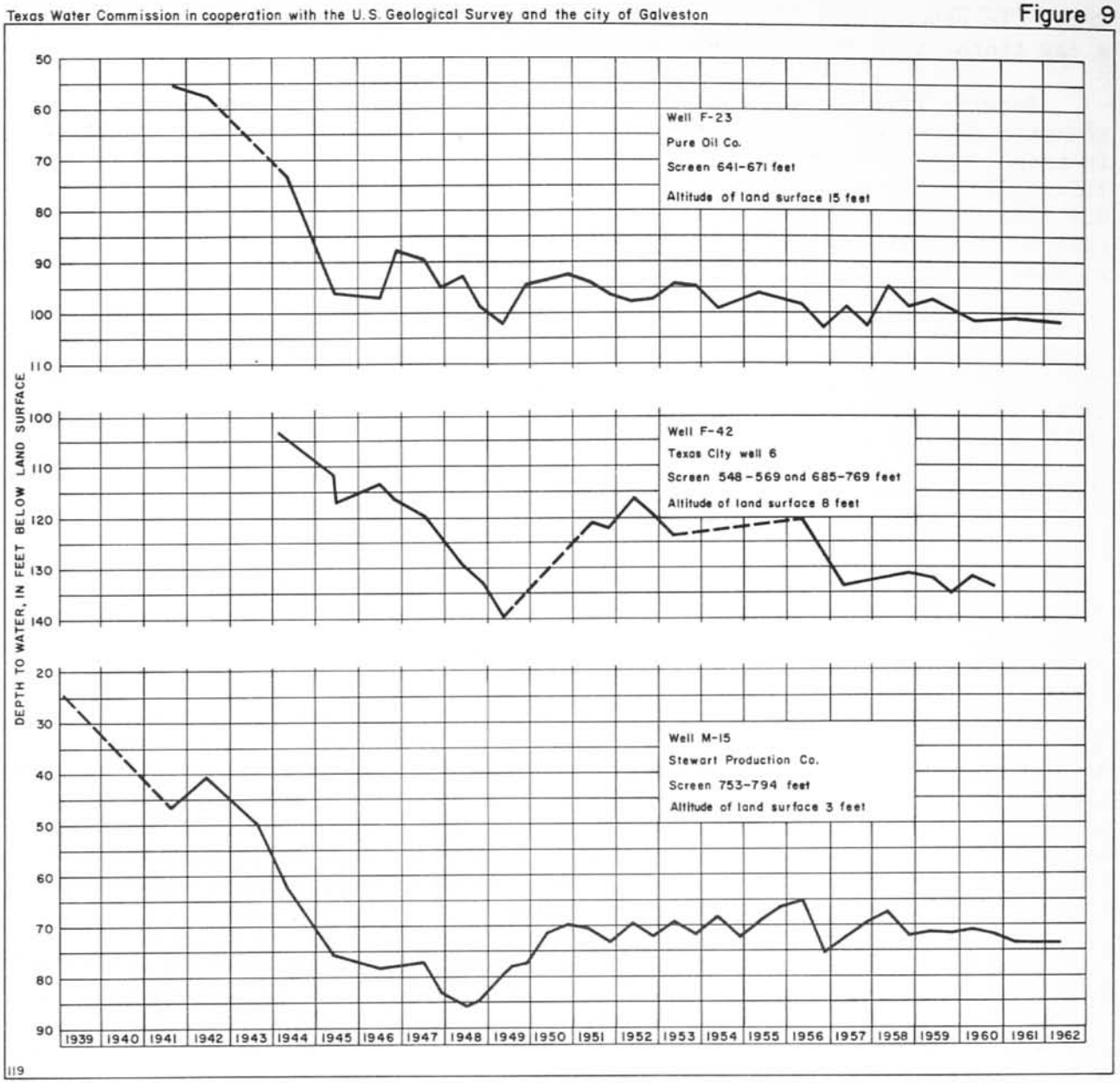


FIGURE 9. - Changes in water levels in wells in the upper part of the Beaumont Clay, Galveston County

City. In other parts of Galveston County, the observed subsidence ranged from a few tenths of a foot to about a foot.

Between 1954 and the releveling by the Coast and Geodetic Survey in 1958-59, the rate of subsidence apparently decreased in the Texas City area, undoubtedly in response to lower pumping rates and near stabilization of water levels since 1954. The maximum subsidence in the Texas City area between 1954 and 1959 was 0.4 foot, and the maximum in the county was 0.5 foot, near League City. In the rest of the county the subsidence was considerably less, as little as 0.1 foot in many places.

Although large quantities of water have been pumped from the "Alta Loma sand" in the Alta Loma area, the observed subsidence has been only about a foot. The relatively small amount of subsidence at Alta Loma, as compared with that at Texas City, possibly substantiates the hypothesis that most of the subsidence in the Texas City area is taking place in the upper part of the Beaumont Clay. On the other hand, most of the subsidence at Alta Loma may have taken place before the earliest leveling in the area.

CHANGES IN CHEMICAL QUALITY OF GROUND WATER

"Alta Loma Sand" of the Beaumont Clay

Large quantities of water of good chemical quality are available from the "Alta Loma sand" in the northwestern two-thirds of Galveston County. On the mainland in the rest of the county, the water generally is slightly saline containing 1,000 to 3,000 ppm (parts per million) of dissolved solids, becoming progressively more highly mineralized downdip toward the coast. On Galveston Island, electric logs of wells and analyses of water from wells N-5a and N-9 indicate that water in the "Alta Loma sand" is moderately saline, containing from 3,000 to 10,000 ppm of dissolved solids.

The movement of salt water into sands containing fresh water in Galveston County was recognized and discussed by Barnes (1941c, p. 6-9), and by Petitt and Winslow (1957, p. 31-33). A detailed discussion of the changes in quality of water from wells in both the "new" and the "old" well fields of the city of Galveston is given by Wood (1958b, p. 16-18).

The chemical quality of water from the "Alta Loma sand" has deteriorated considerably in the "old" well field (Figure 10). The figure shows, by means of graphs of changes in chloride concentrations (chlorographs), that the rate of salt-water encroachment has not been constant. The relatively wide fluctuations in chloride content of the water from most wells in the "old" well field can be accounted for primarily by changes in pumpage patterns, and by the presence or absence of a discontinuous clay bed which separates the main body of the "Alta Loma sand" from an underlying sand containing slightly saline water. Well E-93, which was drilled in 1941 and completed in the lower sand, yielded water containing 990 ppm of chloride, whereas well E-92, which was drilled in 1942 but not pumped until 1957, yielded water containing only 360 ppm of chloride in March 1958. The electric logs of other production and test wells in the Alta Loma area also indicate that water from the lower sand is of much poorer quality.

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Figure 10

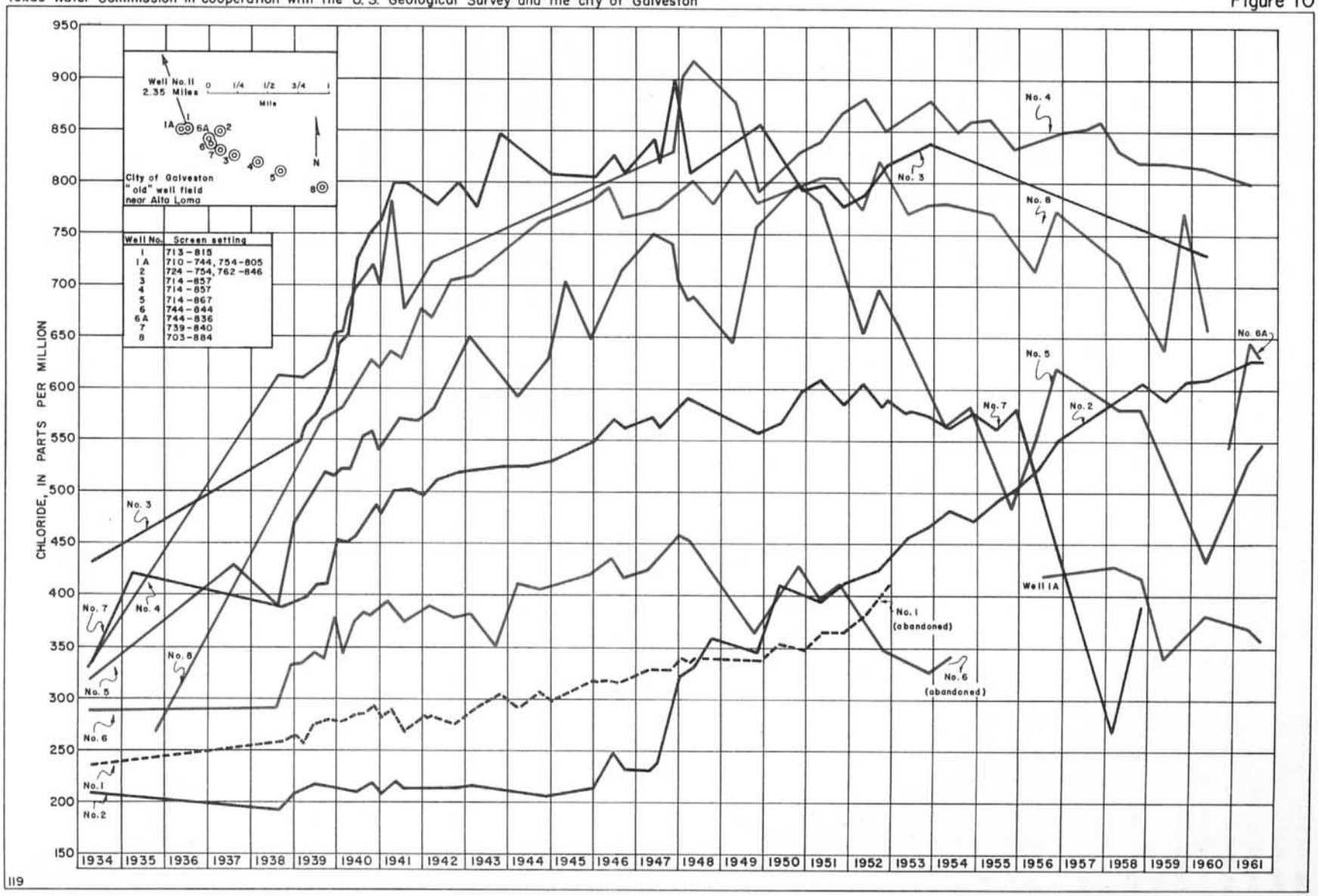

FIGURE 10.- Changes in chloride content of water from wells in the city of Galveston's "old" well field in the vicinity of Alta Loma, Galveston County, 1934-61

The discontinuity of the clay allows the slightly saline water to move up into the main sand body in response to a lowering of the pressure head in the upper sand caused by pumping. The resultant movement of the slightly saline water around the clay and into the main sand body, as well as lateral movement in the main sand body itself, has caused the increase in chloride content of water from the "old" well field. The distribution of the areas where the clay is absent, the quality of the water in the lower sand bed, the quality of water adjacent to the well field in the "Alta Loma sand," and the distribution of pumpage in both time and space are the chief factors controlling variations in the quality of water produced from the city of Galveston's well fields in 1962.

Electric logs and analyses of water from wells L-11, L-25, and L-33 generally south of the "old" well field indicate the presence of fresh water in the upper part of the "Alta Loma sand" south and southeast of Alta Loma. However, electric logs in the same area indicate that the water in the lower part of the "Alta Loma sand" is somewhat more highly mineralized. According to Barnes (1943, p. 22), analyses of water samples from the upper and lower parts of the "Alta Loma sand" in each of four test wells indicated that water nearer the bottom had a higher chloride content. After examining the data from the test wells and electric logs, Petitt and Winslow (1957, p. 49) concluded that the salt water in the "Alta Loma sand" occurs in the form of a wedge in the lower part of the sand and that the wedge thickens downdip. They also stated that salt water probably was encroaching updip in the "Alta Loma sand" and from underlying sands in areas where separating clay beds were not present (Petitt and Winslow, p. 48-55).

The chlorographs of wells 1A, 3, 4, 5, 7, and 8 (Figure 10) indicate a definite but erratic reduction in chloride content of water from the wells since about 1952. The reductions apparently are related to changes in pumpage patterns, chiefly a reduction of pumpage in the "old" well field.

Chlorographs of wells in the "new" well field (Figure 11) show only minor changes in the chloride content of the water since 1945 except in the water from well 10 (E-78), which increased in chloride content from 150 ppm in 1942 to 280 ppm in 1961. As indicated by Wood (1958b, p. 18) and further substantiated by analyses of water from well 14 (E-92), the chloride content of water in the "Alta Loma sand" becomes progressively higher west of wells 12 (E-83) and 13 (E-81), at least as far west as well 14 (E-92) and E-86, beyond which data are not available. Well 10 (E-78) is on the northwest side of the cone of depression caused by the pumping at Alta Loma (Figure 6). The movement of water of poorer quality from the northwest and west is probably at least partly responsible for the increase in chloride in water yielded by well 10.

Upper Part of the Beaumont Clay

The chemical quality of the water from sands in the upper part of the Beaumont Clay varies to some extent from place to place, partly because of the lenticularity and small areal extent of the sands. In general, the sands of the upper part of the Beaumont yield water of better quality than the "Alta Loma sand." Locally, however, one or more sands in the upper part of the Beaumont contain water that is more highly mineralized than that in the underlying "Alta Loma sand."

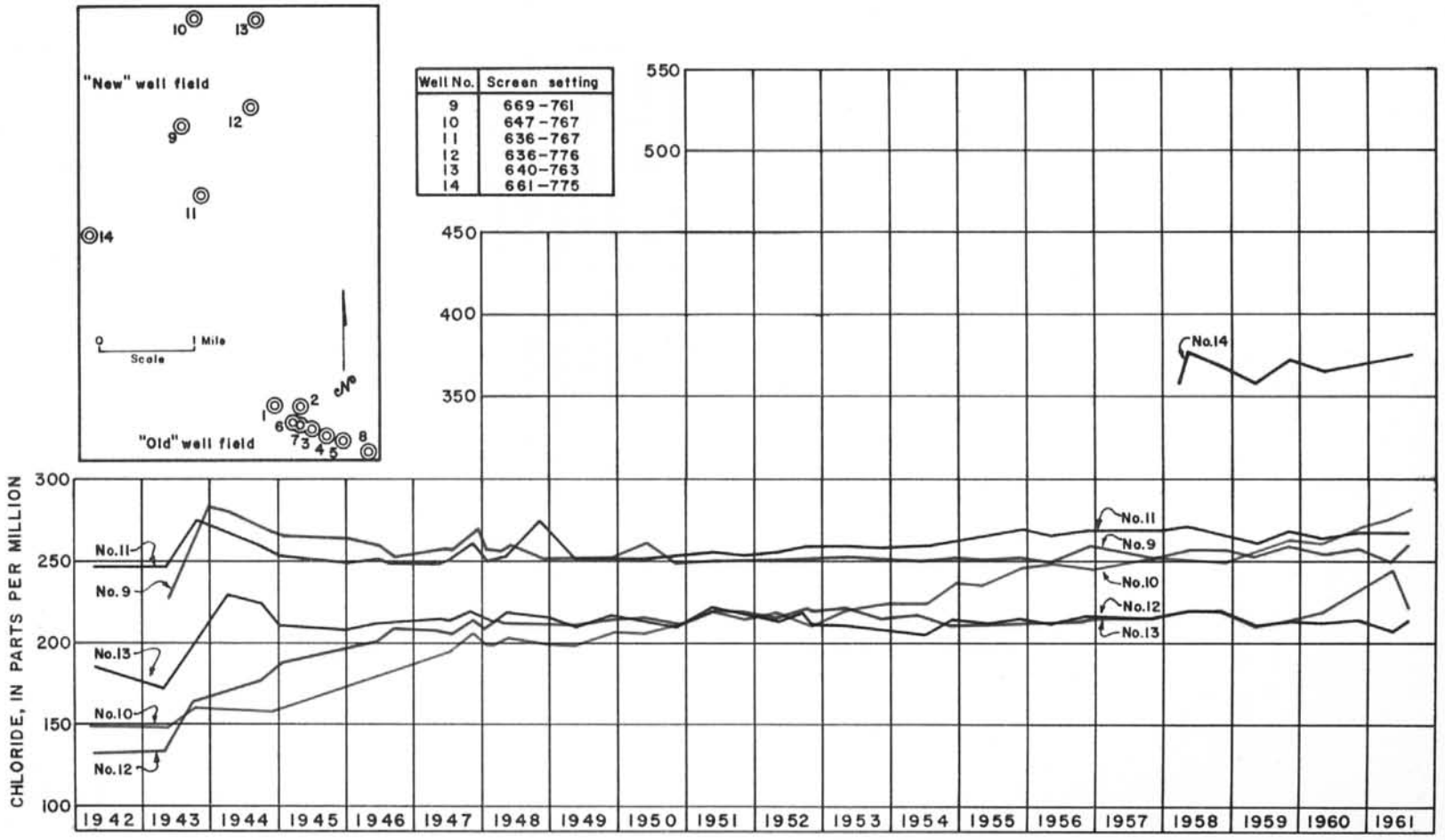

FIGURE 11.- Changes in chloride content of water from wells in the city of Galveston's "new" well field north of Alta Loma, Galveston County, 1942-61

Most of the water produced from the upper part of the Beaumont in Galveston County comes from wells in the Texas City area. Chlorographs of wells F-41, F-45, and F-59 (Figure 12), which are screened in the upper sands of the Beaumont, indicate that the quality of water in the Texas City area has not changed markedly. However, the chlorograph of well F-45 shows a slow, steady increase in chloride of about 30 ppm between 1946 and 1960. The increase in chloride content of water from a well screened in sands in the upper part of the Beaumont Clay in the Texas City area does not necessarily mean that salt water is encroaching updip from the southeast, although such encroachment is possible. The contamination may come from a local source, such as a nearby well which contains more highly mineralized water (Wood, 1958b, p. 22) and is screened also in the "Alta Loma sand."

Several industrial and municipal wells draw water from both the "Alta Loma sand" and sands in the upper part of the Beaumont Clay. The chlorograph of well M-2 (Figure 12), which is completed in both aquifers, shows a generally increasing chloride content since the well went into production in 1951. The rapid increase in 1961 suggests that a larger proportion of its water is coming directly from the "Alta Loma sand," or indirectly from water that has moved up the well bore from the "Alta Loma" and into sands in the upper part of the Beaumont Clay. Only relatively small amounts of water from the "Alta Loma sand," containing 800 to 1,400 ppm of chloride, need be mixed with water from sands in the upper part of the Beaumont Clay, which generally have less than 250 ppm of chloride, to raise appreciably the chloride content of the water produced.

SUMMARY

Withdrawal of ground water in Galveston County remained nearly constant during the period 1958-61, ranging from 23.8 mgd in 1959 to 21.5 mgd in 1961. The use of water for public supply was 15.6 mgd in 1958 and reached a peak of 16.7 mgd in 1960. In 1961 the public-supply use was 15.7 mgd. The use of water for industry likewise was nearly constant during the period, ranging from 6.3 mgd in 1959 to 5.3 mgd in 1961. The use of water for irrigation was 1.5 mgd in 1958 and 0.5 mgd in both 1960 and 1961; no ground water was used for rice irrigation during those 2 years.

The use of surface water in Galveston County during the period 1958-62 was nearly constant, ranging from 64 mgd in 1958 to 67 mgd in 1961. The small increase in use represents increased industrial consumption. Industry used 39.4 mgd of surface water in 1958 and 42.0 mgd in 1961. The only other use of surface water in Galveston County was for rice irrigation.

Water levels in wells in Galveston County changed only slowly during the period 1958-62 because of the nearly uniform rate of ground-water withdrawal. Small water-level declines in most of the county indicate that equilibrium conditions have not quite been reached. Small declines in the northern part of the county may have been caused by increases in ground-water withdrawal in the heavily industralized Houston area north of Galveston County.

The subsidence of the land surface in Galveston County resulting from the withdrawal of ground water continued during the period 1954-59, the maximum being 0.5 foot at League City. Elsewhere the subsidence ranged from 0.1 to 0.4 foot.

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Figure 12

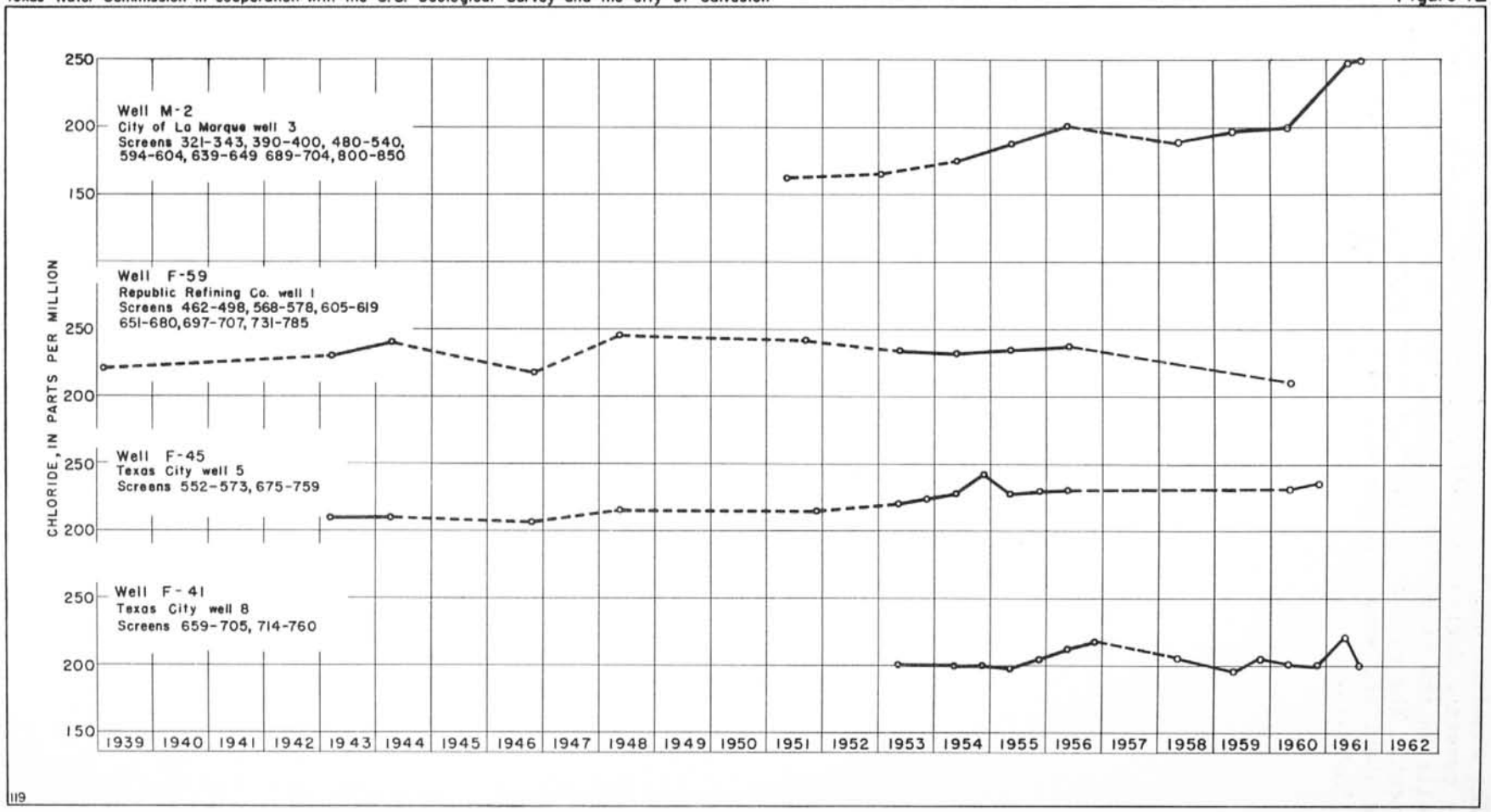

FIGURE 12.- Changes in chloride content of water from wells screened in the upper part of the Beaumont Clay in the Texas City area, Galveston County

The chemical quality of water from wells in Galveston County remained nearly constant during the period 1958-62. The quality of water from some of the wells in the city of Galveston's "old" well field actually showed some improvement. The chloride content of water produced in the "new" well field remained about the same with the exception of water from well 10, which showed a small increase.

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Year	Water-Supply Paper No.	Year	Water-Supply Paper No.	Year	Water-Supply Paper No.
1935	777	1943	989	1950	1168
1937	840	1944	1019	1951	1194
1938	845	1945	1026	1952	1224
1939	886	1946	1074	1953	1268
1940	909	1947	1099	1954	1324
1941	939	1948	1129	1955	1407
1942	947	1949	1159		

* Name of agency changed to Texas Water Commission January 30, 1962.

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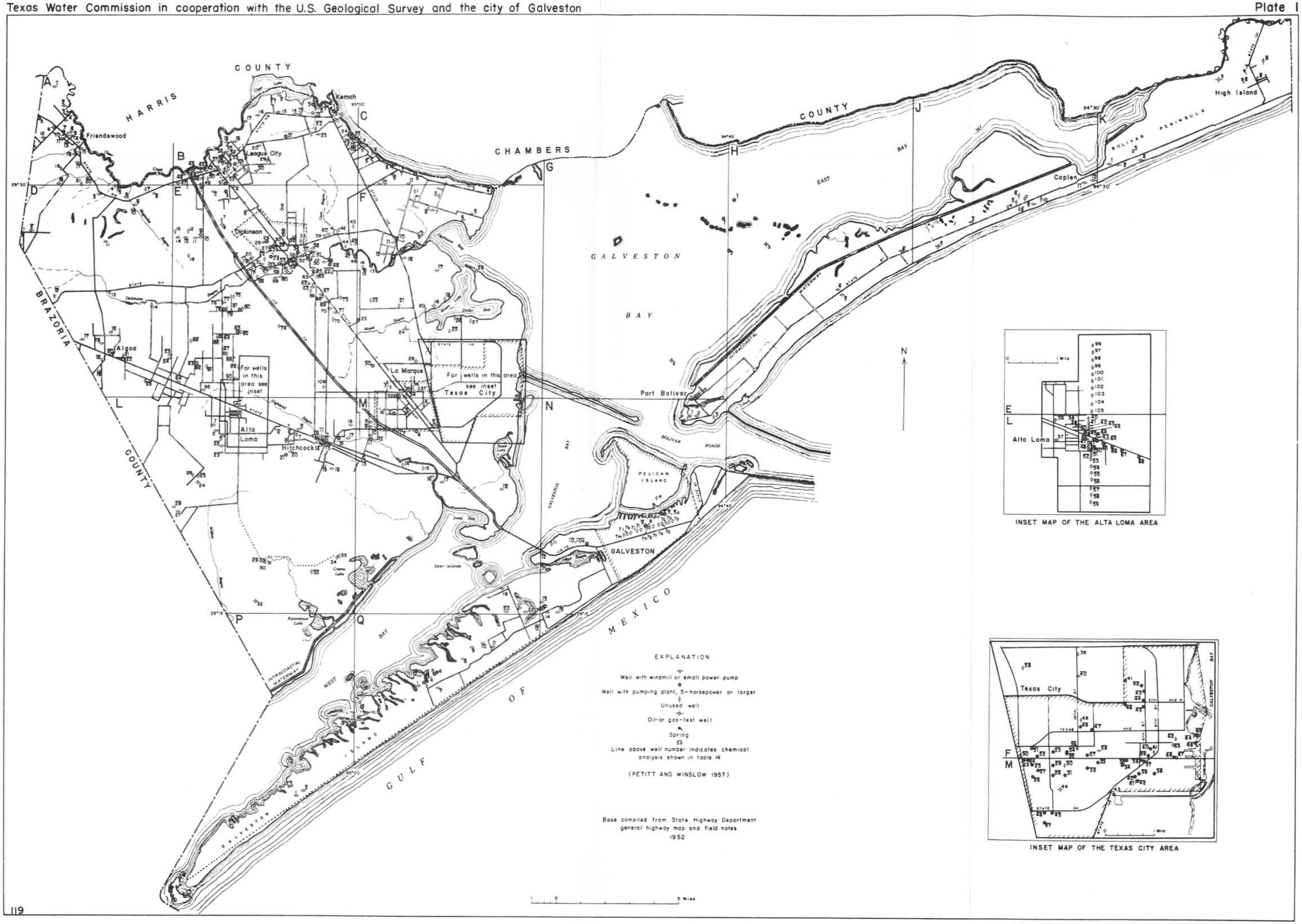
Plate I



EXPLANATION

Well with windmill or small power pump

Well with pumping plant, 5-horsepower or larger

Unused well

Oil-or gas-test well

Spring

53

Line above well number indicates chemical analysis shown in table 14

(PETITT AND WINSLOW 1957)

Base compiled from State Highway Department general highway map and field notes 1952

INSET MAP OF THE ALTA LOMA AREA

INSET MAP OF THE TEXAS CITY AREA

119

MAP OF GALVESTON COUNTY SHOWING LOCATION OF WELLS