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PUMPAGE OF GROUND WATER AND CHANGES IN WATER LEVELS IN GALVESTON COUNTY, TEX., 1952-57

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ABSTRACT

No important changes in the total rate of withdrawal from wells in Galveston County took place from 1952 to 1957. The average rate was about 25 mgd (million gallons per day). However, the amount of water pumped for public supply increased from about 13.3 mgd in 1951 to about 15.3 mgd in 1957 and the amount of water pumped for irrigation increased from about 500,000 gpd in 1951 to an estimated 2 mgd in 1957. During the same period the amount of water pumped for industrial supply decreased from 12.8 mgd to about 6 mgd.

Use in Galveston County of surface water from the Brazos River also remained about the same from 1952 to 1957--about 70,000 acre-feet per year. Industrial use of surface water increased from 18,700 acre-feet in 1951 to 43,200 acre-feet in 1957. Irrigational use of surface water for growing rice declined from about 50,000 acre-feet in 1951 to about 22,500 acre-feet in 1957.

Water levels in wells in Galveston County changed very little or declined slowly in the period 1952-57. Water levels in wells in the vicinity of the city of Galveston's well field near Alta Loma have declined very slowly since 1945, but have shown more seasonal fluctuation since 1954 because of seasonal pumping-rate changes. Water levels in the Texas City area changed very little between 1952 and 1957, but the water levels in wells in the shallower sands of the Beaumont clay in northern Galveston County continued to decline at an average rate of 2.5 to 3.5 feet per year from 1952 to 1957.

The land surface continued to subside in the period 1952-57, although in the Texas City area, where most of the subsidence has taken place, the rate of subsidence lessened.

The chemical quality of the water from wells was about the same in the period 1952-57 as in 1951, except in a few wells in the Alta Loma and Texas City areas. Most of the wells in the city of Galveston's "old" well field near Alta Loma yielded water of about the same chloride content in 1952-57 as in 1951, except the water from well 2, which increased in chloride content at about the same rate as from 1946 to 1951. However, the chloride content of water from well 2 was less in 1957 than that from wells 3, 4, and 8, which was between 750 and 900 parts per million from 1952 to 1957. The chloride content of water from wells in the city of Galveston's "new" well field near Alta Loma changed very little from 1952 to 1957, although the chloride content of water from well 10 increased to about the same as that in well 9 in 1957. In the Texas City area a few of the wells in the upper sands of the Beaumont clay yielded water that had a higher chloride content than in 1951, but the increase was small and may or may not be indicative of future changes.

INTRODUCTION

This is one of a series of reports* on the ground-water resources of Galveston County prepared by the United States Geological Survey in cooperation with the Texas Board of Water Engineers and the city of Galveston. The report presents data on pumpage, changes in water levels, changes in chemical quality, and related information compiled during the period 1952-57. Similar data and tabulations of well records through 1951 were prepared by Petitt and Winslow (1955). They summarized the geology, geography, and climate of Galveston County; therefore, these topics will not be discussed in this report. Well numbers used in this report are the same as those used by Petitt and Winslow.

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

The field work and preparation of the report were under the administrative direction of A. N. Sayre, chief of the Ground Water Branch, U. S. Geological Survey, and under the direct supervision of R. W. Sundstrom, district engineer in charge of ground-water investigations in Texas.

PUMPAGE

In 1957 all water for domestic and public supplies in Galveston County was obtained from wells. Before July 1948 all industrial water also was obtained from wells, but thereafter the industrial supplies in the Texas City area were supplemented with surface water to help counteract problems of salt-water intrusion and subsidence of the land surface. Because of continued industrial expansion, the use of surface water for industrial purposes has increased from 16.7 mgd in 1951 to 38.6 mgd in 1957 (table 1).

Truck gardens, fruit orchards, and some rice farms were irrigated from flowing wells from shortly before 1900 until about 1930, when the flow stopped in most wells owing to a decline in artesian pressure. As the natural flow from a well became small, the yield commonly was increased by pumping. Irrigation of truck gardens by wells equipped with pumps continued through 1957, but the amount of water used was comparatively small (estimated at 500,000 gpd) during the period 1952-57. Some rice was irrigated with ground water in Galveston County in many of the years during the period 1900-57. In 1951 about 80 acres of rice was irrigated with ground water near Friendswood and in the period 1954-57 a few hundred acres of rice was irrigated from wells near Dickinson. However, rice has been a major crop only since 1942, when surface water from the Brazos River was made available in Galveston County (table 1).

Table 1.- Estimated use of surface water in Galveston County, Tex., 1951-57

	Industrial		Rice Irrigation		Total
Year	Million gallons per day	Acre-feet per year	Acres	Acre-feet per year	Acre-feet per year
1951	16.7	18,700	20,000	50,000	68,700
1952	23.6	26,500	17,000	42,500	69,000
1953	27.6	30,900	16,000	40,000	70,900
1954	31.8	35,600	16,000	40,000	75,600
1955	38.4	43,000	11,000	27,500	70,500
1956	38.4	43,100	10,000	25,000	68,100
1957	38.6	43,200	9,000	22,500	65,700

* See selected bibliography, p. 23

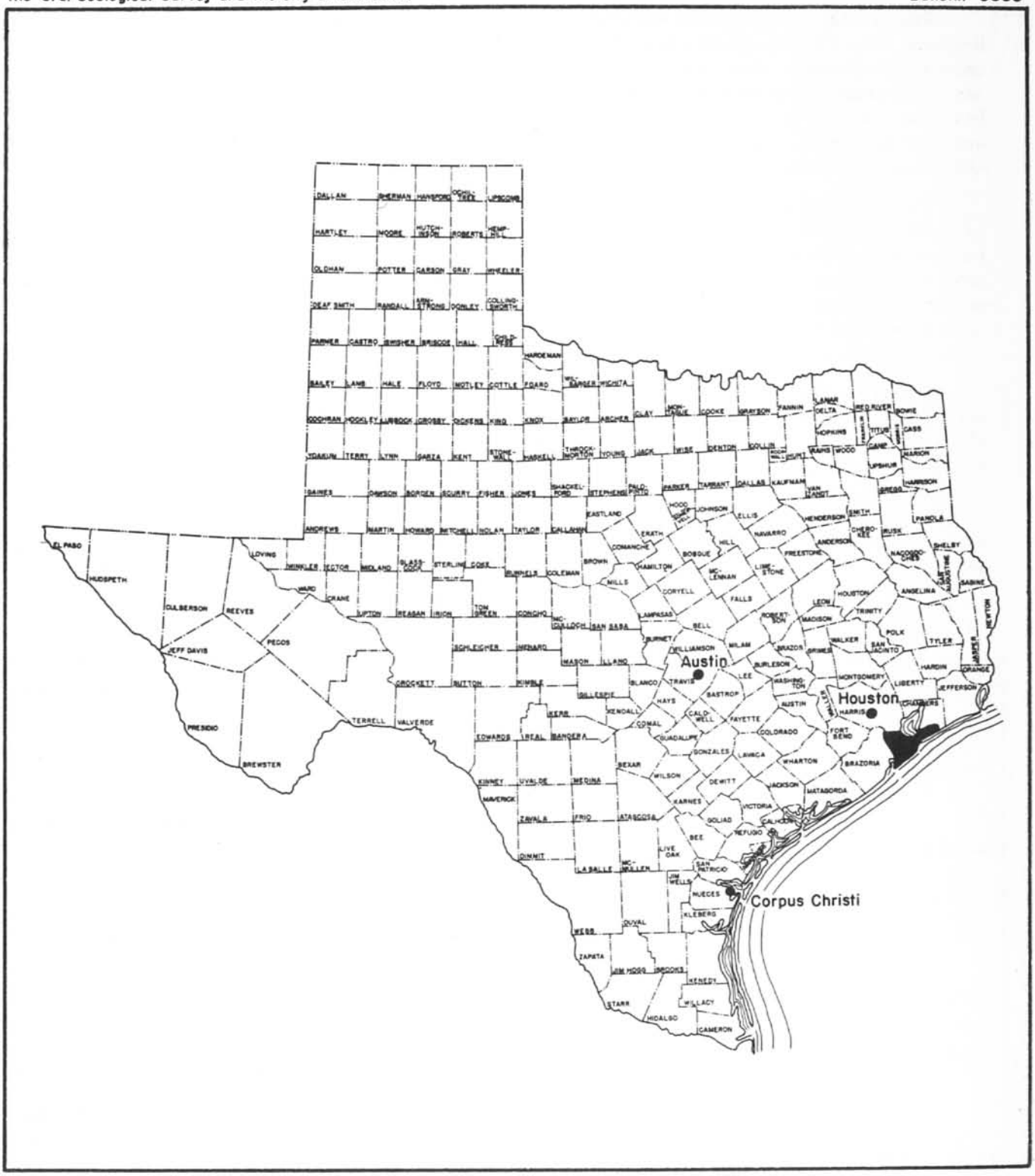


FIGURE 1.- Map of Texas showing location of Galveston County.

Practically all the water withdrawn from wells in Galveston County comes from sands in the Beaumont clay (Petitt and Winslow, 1955, p. 15-21). The principal aquifer is the basal sand unit of the Beaumont clay, locally known as the Alta Loma sand because of its occurrence, and the development of water from it, in the vicinity of Alta Loma. Sands in the upper part of the Beaumont clay constitute a less productive aquifer, the sands being thinner, less persistent, and less permeable. However, they are an important source of water for public supply because the water is of better quality than that in the Alta Loma sand.

A pumpage inventory covering the preceding calendar year has been made in Galveston County each spring. Pumpage data were obtained from all industries, municipalities, and water districts pumping more than 5,000 gallons of water per day. Although some of the smaller industries and municipalities do not meter the water pumped from wells, nearly all the larger water systems are metered. The remainder was estimated from data supplied by the owners. Pumpage figures for irrigation from wells are based on the acreage irrigated, the duty of water per acre, and the total rainfall during the pumping season.

The rate of withdrawal of ground water in Galveston County changed very little during the period 1951-57 (table 2). Ground-water withdrawals for public supplies have increased from 13.3 mgd in 1951 to 15.3 mgd in 1957. During the same period withdrawals for industrial supplies decreased from 12.8 mgd in 1951 to 6 mgd in 1957. About 500,000 gpd was withdrawn for irrigation supplies during the period 1951-53; in 1954 the withdrawal was about 2.5 mgd, in 1955 it was about 2.2 mgd, and in 1956 and 1957 about 2 mgd. The rate of withdrawal for irrigation (principally for rice) is more than twice as large during the irrigation season than the average rate for the year shown in table 2.

Table 2.- Withdrawals of ground water in Galveston County, Tex., in million gallons per day, 1951-57

	1951	1952	1953	1954	1955	1956	1957
Public supplies:							
Galveston	10.7	10.7	10.5	11.3	11.4	12.2	11.3
Texas City	1.5	1.6	1.7	1.9	1.9	2.2	2.4
Water districts	1.1	1.7	2.0	2.0	1.7	1.7	1.6
Subtotal	13.3	14.0	14.2	15.2	15.0	16.1	15.3
Industrial supplies:							
Oil refineries	7.0	6.6	5.4	4.9	4.4	4.4	4.3
Chemical plants	2.7	1.3	1.2	1.1	.5	.9	.8
Miscellaneous industries	3.1	3.0	3.5	3.6	1.3	1.7	.9
Subtotal	12.8	10.9	10.1	9.6	6.2	7.0	6.0
Irrigation:							
Rice	--	--	--	2.0	1.7	1.5	1.5
Other crops	.5	.5	.5	.5	.5	.5	.5
Subtotal	.5	.5	.5	2.5	2.2	2.0	2.0
TOTAL*	26.6	25.4	24.8	27.3	23.4	25.1	23.3

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

ALTA LOMA SAND OF BEAUMONT CLAY

Most of the ground water withdrawn in Galveston County comes from the Alta Loma sand of the Beaumont clay. The Galveston municipal well field near Alta Loma and the industrial area of Texas City are the centers of largest withdrawal from the Alta Loma in Galveston County. In the Baytown-La Porte area and the southeastern part of the Pasadena area, both in Harris County, ground water is withdrawn from the Alta Loma sand at a somewhat greater rate than in Galveston County. (Areas outside the county are shown on fig. 6.)

Withdrawals by the city of Galveston in the Alta Loma area have become fairly stable, ranging between 10 and 12.2 mgd during the period 1943-57 (fig. 2). Pumpage from the Alta Loma sand in the Texas City area reached 18 mgd in 1944, decreased slowly to about 14.5 mgd in 1948, and decreased further to about 5.6 mgd in 1950 after surface water became available in July 1948. From 1950 to 1957 the rate of withdrawal from the Alta Loma sand in the Texas City area decreased slowly to about 3.6 mgd.

In the rest of Galveston County pumpage from the Alta Loma sand reached a maximum of about 3.7 mgd in 1954, about 2 mgd being pumped for cooling purposes on Galveston Island. Most of the remainder was used for rice irrigation in northern Galveston County. Pumpage from the Alta Loma sand in the same areas in 1957 was less than 3 mgd, the decrease being attributed chiefly to a reduction in use of water on Galveston Island.

UPPER PART OF BEAUMONT CLAY

More wells in Galveston County are screened in sands of the upper part of the Beaumont clay than in the Alta Loma sand, but most of them are domestic and stock wells of small capacity. Most of the large wells tapping the upper part of the Beaumont are in the Texas City area, where they supply water for municipal and industrial use. Water from the upper part of the Beaumont is more desirable for boiler makeup, drinking, and most other purposes because the chemical quality is better than that of water from the Alta Loma sand.

The rate of ground-water withdrawal from the upper part of the Beaumont clay in the Texas City area increased greatly during the war years and more slowly thereafter, reaching a peak of about 7.3 mgd in 1951 (fig. 3). Since 1951 the rate has shown a net decline, dropping to 4.7 mgd in 1957, the lowest rate since 1942. The pumpage for industry in the Texas City area decreased from about 5.5 mgd in 1951 to about 2 mgd in 1957, while the pumpage for public supply was increasing from about 1.8 mgd to about 2.7 mgd.

Ground-water withdrawals from the upper part of the Beaumont clay throughout the remainder of Galveston County are principally from public-supply wells or irrigation wells, the pumpage ranging from about 1 to 2 mgd during the period 1950-57. The sum of all the withdrawals from domestic, stock, oil-well supply wells, and other miscellaneous small wells is probably less than 1 mgd.

CHANGES IN WATER LEVELS IN WELLS

The water levels in many wells in Galveston County were sufficiently high during the 1900's and earlier that the wells flowed naturally. The water level stood as high as 32 feet above the land surface in a well in the Alta Loma sand near Dickinson in 1900 (Petitt and Winslow, 1955, p. 48). Similar water levels were reported in other wells about that time, not only in wells in the Alta Loma sand, but also in wells in the upper part of the Beaumont. The water levels in both aquifers slowly declined and by 1930 were at or slightly below the land surface.

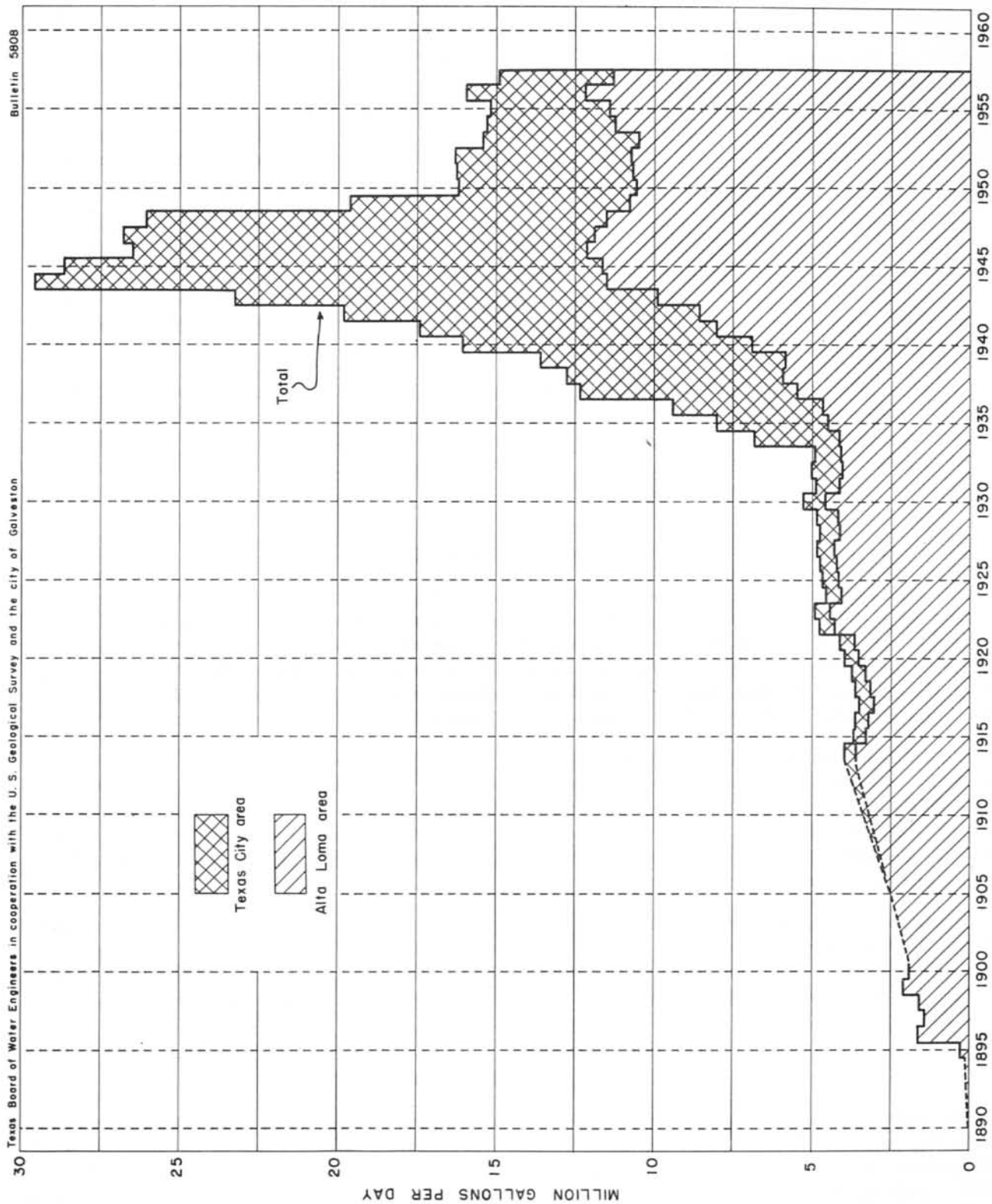


FIGURE 2.- Average daily pumpage from the Alta Loma sand in the Alta Loma and Texas City areas, 1890-1957.

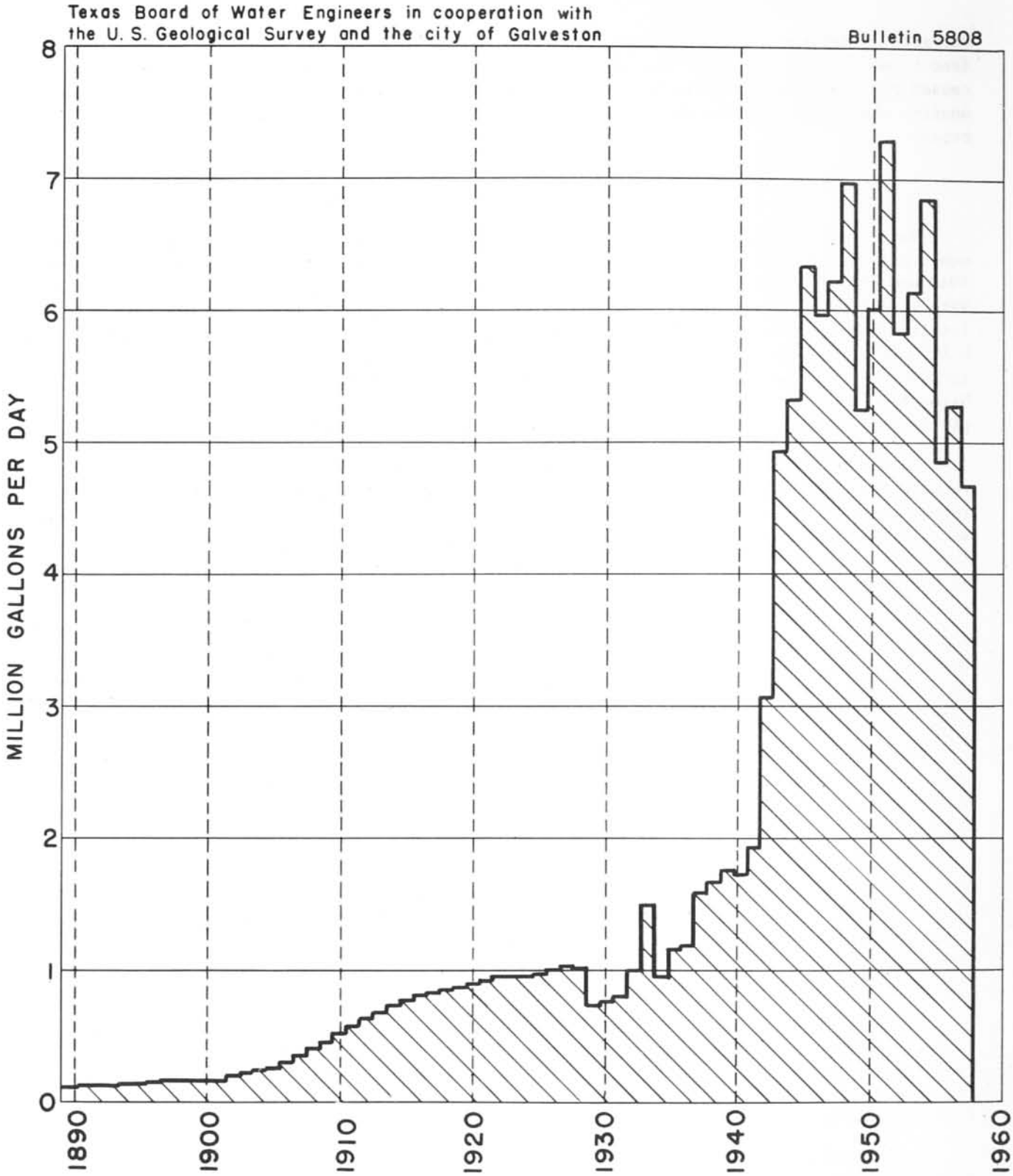


FIGURE 3. - Average daily pumpage from the upper part of the Beaumont clay in the Texas City area, 1890-1957.

The rate of decline increased during the 1930's, and by 1940 the water levels were 40 to 70 feet below the land surface. During the 1940's the rapidly increasing use of ground water caused rapid declines in water levels, but because of differences in rates of pumping and in aquifer characteristics the declines in the two principal aquifers proceeded at different rates.

ALTA LOMA SAND OF BEAUMONT CLAY

Water levels (wells D-14, E-79, L-63, L-68, and L-25, fig. 4) in and near the Galveston municipal well fields near Alta Loma declined rapidly in response to increased pumping between 1940 and 1945. During the period 1945-53, ground-water withdrawals were at a nearly constant rate in and near the well fields and the water levels fluctuated somewhat but declined very little. Water levels declined faster in the vicinity of the "new" field (wells E-84, E-78, E-87, E-83, and E-81, pl. 1) from 1954 to 1957 (wells D-14 and E-79, fig. 4) because of an increase in withdrawal from wells in the field and from other wells north of the "new" field. Water levels in the "old" well field (wells L-60, L-64, L-65, L-66, L-67, L-61, L-62, L-68, pl. 1) have been nearly stable during the period 1945-57 (well L-68, fig. 4).

In the Texas City area water levels in wells screened in the Alta Loma sand declined rapidly from 1940 to 1945 and then slowly until 1948 (wells F-34 and F-50, fig. 5). With the introduction of surface water in July 1948 and the resultant decrease in ground-water use, the water levels rose rapidly until 1950. From 1950 to 1957 the water levels changed very little. Water levels in the Texas City area were about the same during the period from 1950 to 1957 as they were in 1942-43.

In northern Galveston County water levels in wells screened in the Alta Loma sand declined steadily during the period 1940-57(wells A-7, B-40, and B-10, fig. 5, and well D-3, fig. 4). The rate of decline of about 4 feet per year is less than the rate in the Pasadena and Baytown-La Porte areas of Harris County (fig. 6), where the decline of water levels in the Alta Loma sand from 1940 to 1957 averaged more than 5 feet per year.

The hydrograph of well L-33 (fig. 5) shows the change in water level in a well in the Alta Loma sand in southern Galveston County. Although there have been no appreciable ground-water withdrawals in this part of the county, the water levels have declined, being affected by the large withdrawals in the Alta Loma and Texas City areas.

The approximate altitude of water levels in wells screened in the Alta Loma sand in May 1957 is shown in figure 6. A comparison with the map for May 1952 (Petitt and Winslow, 1955, fig. 21, p. 62) shows that the water level in the center of the cone of depression in the well field north of Alta Loma declined about 20 feet from May 1952 to May 1957. During the same period in Harris County, the water level dropped about 50 feet in the Pasadena area near Deer Park and about 20 feet at Baytown.

Profiles of water levels in wells in the Alta Loma sand from a point north of Deer Park in Harris County to a point south of Alta Loma for the years 1941, 1948, 1952, and 1957 are shown in A-A′ in figure 7. Profiles from a point northwest of Alta Loma to Texas City for the same years are also shown as B-B′ in figure 7. The estimated original water level (before 1890) is shown on both of the profiles.

Seasonal fluctuations of water level in the Alta Loma sand in the Galveston "new" well field increased in magnitude after 1953. Changes in water levels in a well screened in the main sand body of the Alta Loma sand and in a well screened in the underlying sand are shown on figure 8 together with the average daily pumpage each month from 1947 to 1957 from the city of Galveston's wells near Alta Loma. City of Galveston well 14 (E-92) was drilled in 1942 and was screened between 661 and 775 feet below the land surface. However, the well was

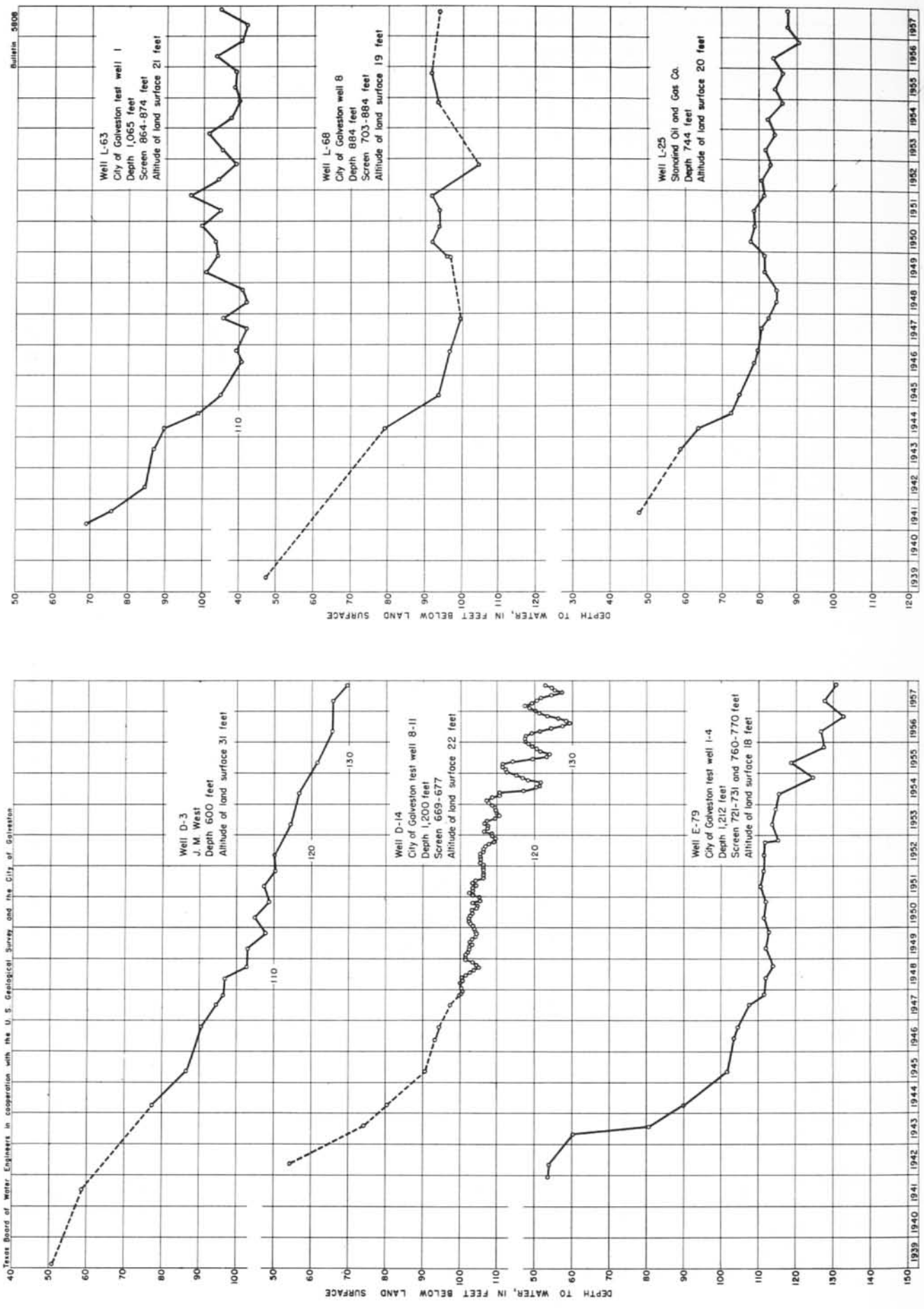


FIGURE 4. - Changes in water level in wells in the Alta Loma sand, Galveston County, Tex.

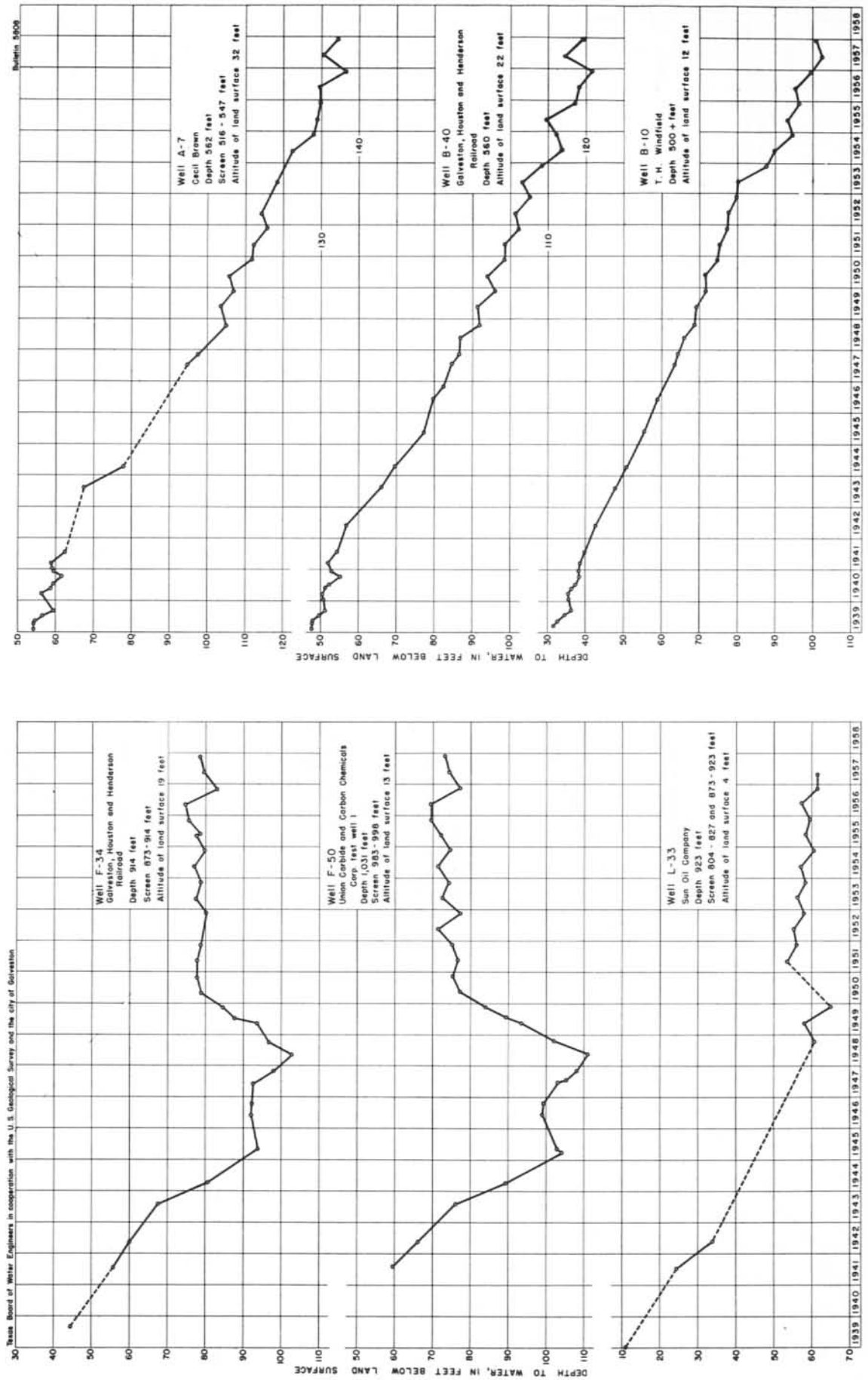


FIGURE 5. - Changes in water level in wells in the Alta Loma sand, Galveston County, Tex.

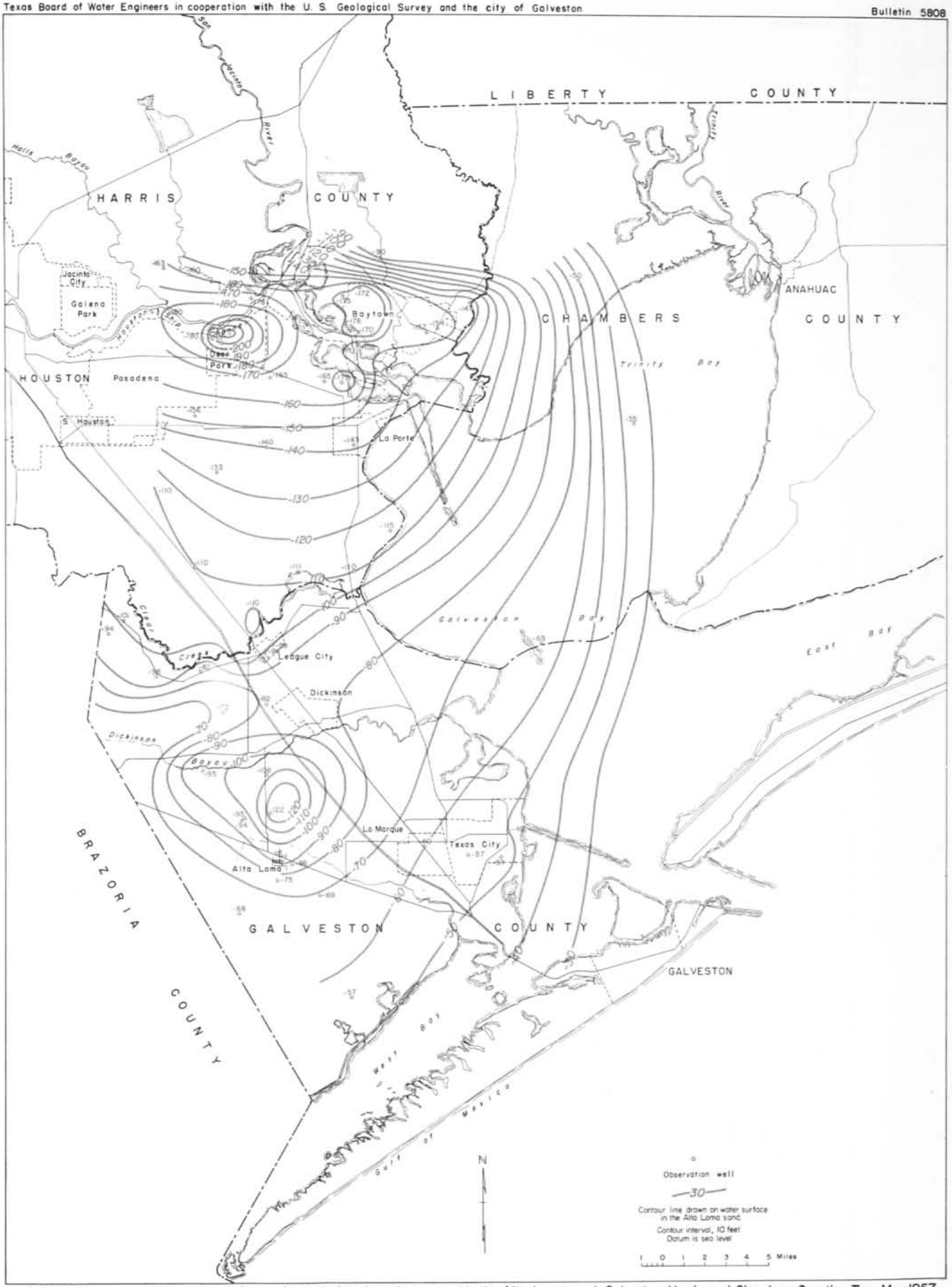


FIGURE 6. - Approximate altitudes of water levels, in feet, in wells screened in the Alta Loma sand, Galveston, Harris, and Chambers Counties, Tex., May 1957

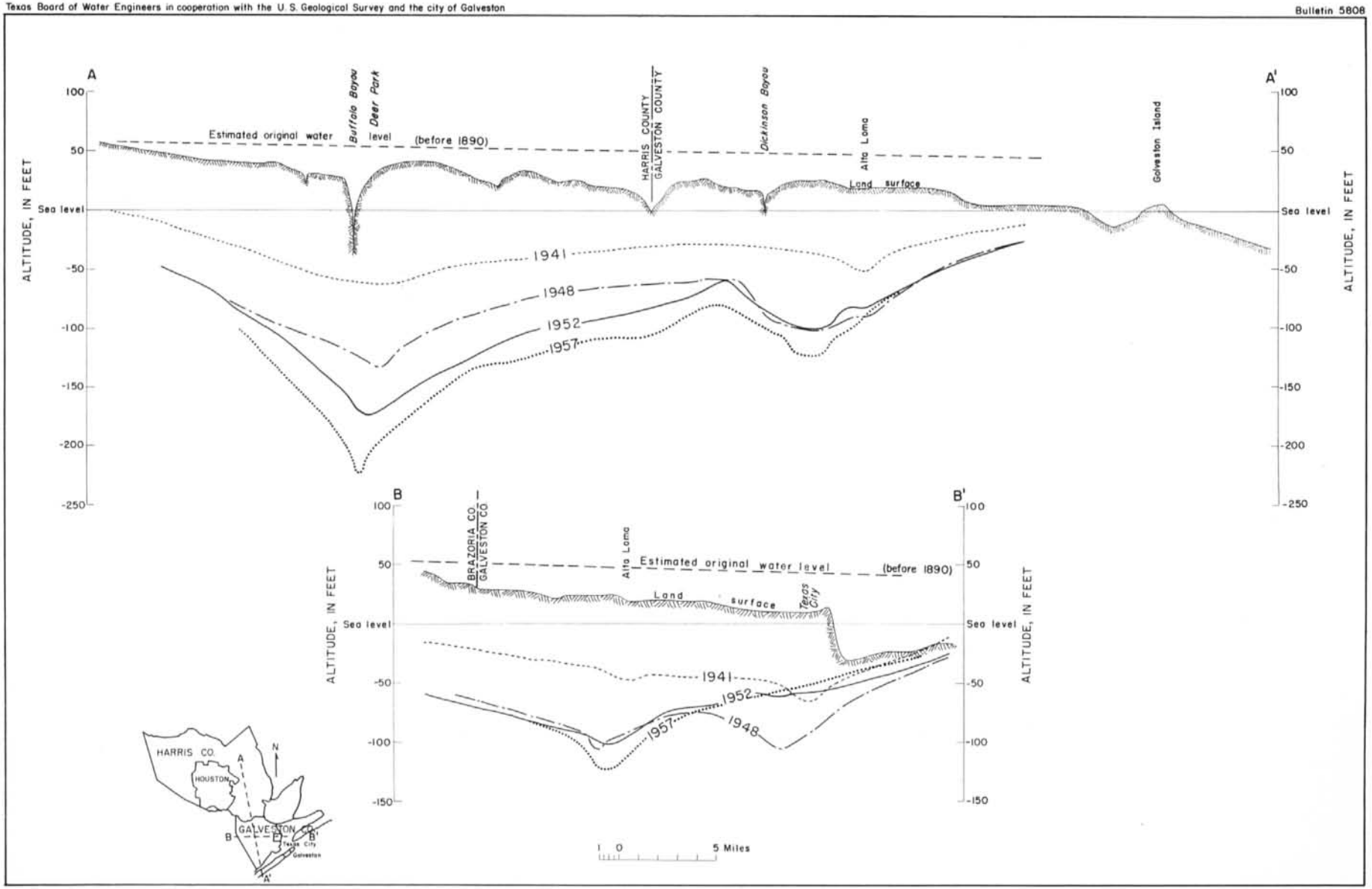


FIGURE 7.- Profiles of water levels in wells in the Alta Loma sand.

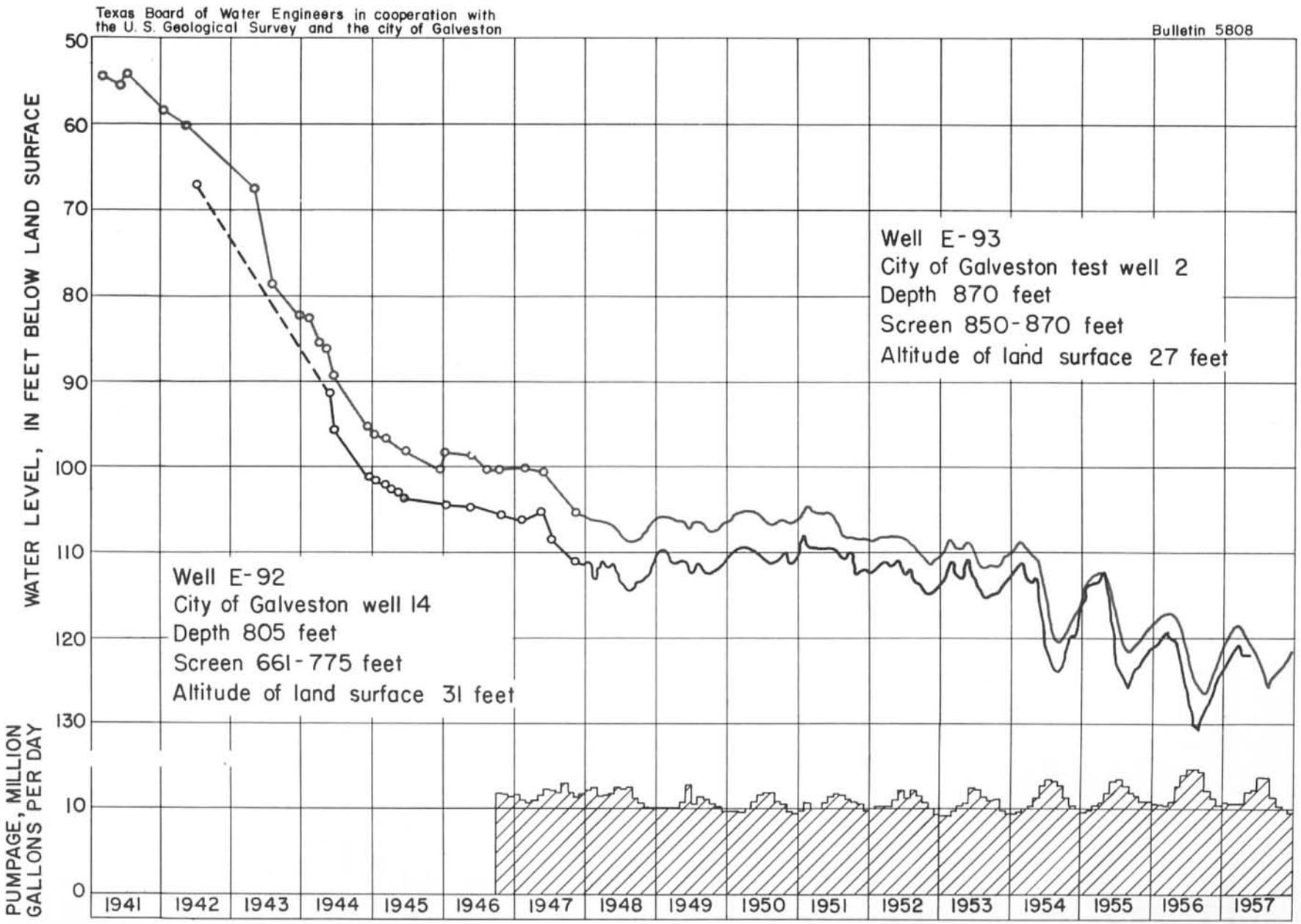


FIGURE 8. - Changes in water level in a well screened in the main sand body of the Alta Loma sand and in a well screened in the underlying sand near Alta Loma, compared with average daily pumpage each month from the city of Galveston's wells.

not equipped with a pump until 1957. City of Galveston test well 2 (E-93) was drilled nearby in 1941 and screened between 850 and 870 feet below the land surface. According to the electric log of test well 2, the main sand body of the Alta Loma sand (screened in well 14) is separated from the underlying sand (screened in test well 2) by 50 feet of clay between 800 and 850 feet below the land surface. In discussing the area containing these wells, Barnes (1943, p. 23) stated:

> "The exploratory drilling showed that the clays underlying the main water-bearing sand are neither thick nor continuous*** In fact, further study may indicate that the basal few feet of the sand section in some of the test wells may not belong to the main water-bearing sand but to the lenticular section below the main sand in which the separating clays are entirely absent."

The similarity in the hydrographs of the two wells (fig. 8) is evidence that the two sands are hydraulically connected, as no large amount of water has been withdrawn from the deeper sand in Galveston County. Test well 2 completed in the deeper sand yielded water of poor chemical quality, containing 990 ppm (parts per million) of chloride. The electrical logs of other wells and test holes in the Alta Loma area also indicate that the water in the sands underlying the Alta Loma sand contain water of much poorer quality than that in the Alta Loma sand.

The increased seasonal fluctuation in water levels in the Alta Loma area since 1953 is due in part to the seasonal withdrawals from rice-irrigation wells north of the "new" well field and in part to the somewhat greater seasonal range in rates of withdrawal from the city of Galveston's well fields (fig. 8).

UPPER PART OF BEAUMONT CLAY

The net declines of water levels in wells screened opposite sands in the upper part of the Beaumont clay in the Texas City area ranged from 60 to 80 feet in the period 1940-45 (wells F-43 and F-60, fig. 9) as the rate of ground-water withdrawal increased during World War II. After the war the rate of decline became much slower as industrial production was reduced. When industrial water supplies were supplemented with surface water in 1948, water levels rose noticeably, becoming relatively stable after 1951 (fig. 9).

Water levels in wells screened in the upper part of the Beaumont in other areas of Galveston County declined at a slow but rather steady rate (average of 2.5 to 3.5 feet per year from 1940 to 1957) compared with those in the Texas City area from 1940 to 1945.

The water levels in wells in the upper part of the Beaumont have declined at a much greater rate than the water levels in the Alta Loma sand in relation to the amount of water withdrawn. The beds of sand in the upper part of the Beaumont transmit water much less readily than does the Alta Loma sand, the sands of the upper part of the Beaumont being thinner, more lenticular, and less permeable.

SUBSIDENCE OF THE LAND SURFACE

Subsidence of the land surface that is occurring in Galveston County is related to the decline of water levels in wells, the decline of water levels being an indication of lowered artesian pressure in the water-bearing sands. The lowered pressure in the sands of the Beaumont clay has reduced the water content in the overlying and underlying clays. As a result the clay particles have been squeezed together, forming a more compact mass and causing the land surface to subside (Petitt and Winslow, 1955, p. 68-72).

FIGURE 9. - Changes in water level in wells in the sands of the upper part of the Beaumont clay, Texas City area, Galveston County, Tex.

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 Survey's 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. The releveling shows that the land surface subsided more than 4 feet in the Texas City area from 1936 to 1954. In other parts of Galveston County the subsidence ranged from only a few tenths of a foot to as much as a foot. The area of maximum subsidence coincides with the area of maximum water-level decline in the upper sands of the Beaumont.

The reduced rate of withdrawal during the period 1952-53 (fig. 3) is reported* to have been accompanied by a reduction in the rate of subsidence of the land surface, and the increased rate of withdrawal in 1954 by an increased rate of subsidence. The lower pumping rates of 1955, 1956, and 1957 also resulted in a reduced rate of subsidence during those years.

CHANGES IN CHEMICAL QUALITY OF GROUND WATER

ALTA LOMA SAND OF BEAUMONT CLAY

The chemical quality of water from the Alta Loma sand has deteriorated markedly in several places in Galveston County, a prime example being the "old" well field of the city of Galveston (fig. 10). The eight wells in the city of Galveston's "old" field at Alta Loma were drilled between 1914 and 1935. During that period the pumping rate increased very slowly from 3.3 mgd to 4.5 mgd, and the chloride content of the water increased very little. When well 8 was drilled in 1935, the center of pumping moved southeast from well 3 to well 4, and the chloride content of the water from well 4 increased until it was about the same as that from well 3 (fig. 10). The chloride content of water from well 8 also increased rapidly, and since 1939 it has become nearly equal to that from wells 3 and 4. However, the chloride content of water from well 5, which is between wells 4 and 8 (see inset map, fig. 10), was generally somewhat lower than that from wells 3, 4, and 8, and since 1950 it has been appreciably lower. The erratic fluctuations in chloride content of water from well 5 may be due to the physical condition of the well, the amount of time and the rate at which the pump was operated prior to sampling, or differences in bedding. The average chloride content of water from wells near the northwest (updip) end of the "old" well field (wells 1, 6, and 7) increased slowly until 1938, when it increased rapidly, but not as rapidly as it did in wells 3, 4, 5, and 8. Well 2, unlike the others, showed very little change until 1946, but after 1946 the chloride content increased progressively from less than 250 ppm to nearly 600 ppm. The chloride content of water from well 7 increased from less than 350 ppm in 1934 to between 550 and 600 ppm by 1946 and remained about the same from 1946 to 1955, when the well was last sampled. Water from wells 1 and 6 changed the least and was of the best quality at the time the wells were abandoned. Well 1-A, which replaced well 1, yielded water containing 420 ppm of chloride when tested for 24 hours on July 11, 1956.

The shape of the "chlorographs" for wells 3, 4, and 8 (fig. 10) suggests that the chloride content of the water from these wells has reached a maximum ranging between 750 and 900 ppm. However, in the Texas City area the water from wells screened through the full thickness of the Alta Loma sand has a chloride content of 1,000 to 1,200 ppm. Union Carbide and Carbon Co. test well 1 (F-50, pl. 1) yielded water from near the base of the Alta Loma sand containing 1,440 ppm of chloride in 1941. On Galveston Island, wells N-5a and N-9 yielded water containing about 3,400 ppm of chloride. Even though the Alta Loma contains water of poorer quality downdip from the "old" field, the quality of water produced from the "old" field probably will not deteriorate much further, provided that the pattern of pumping and rate of withdrawal in southern Galveston County are not materially changed.

* Personal communication, Mr. Kirby Miller, American Oil Co., Texas City, Tex.

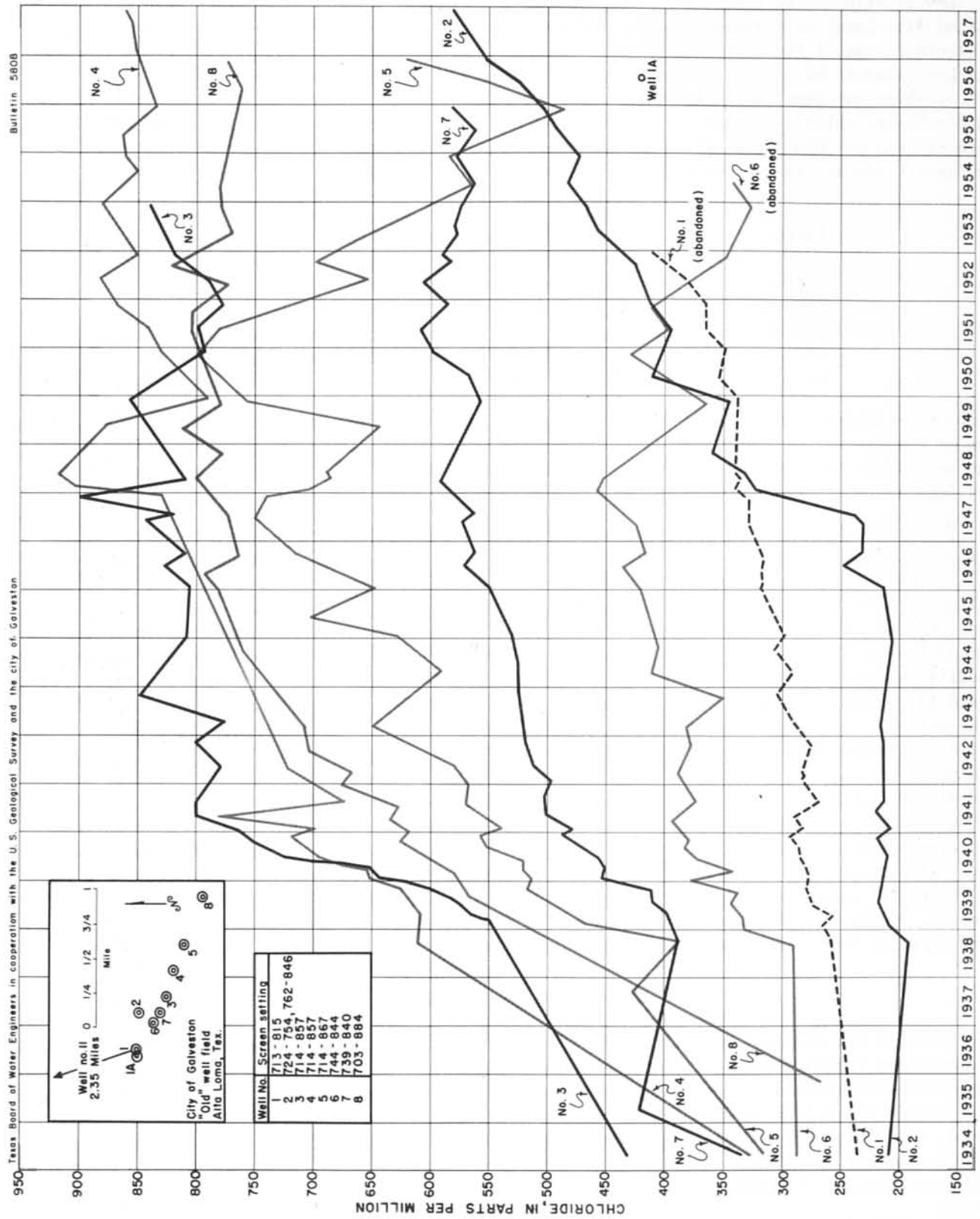


FIGURE 10. - Changes in chloride content of water from wells in the city of Galveston's "old" well field in the vicinity of Alta Loma, Galveston County, Tex., 1934-57.

Low-chloride water occurs in the upper part of the Alta Loma sand in wells south and southeast of Alta Loma, as evidenced by the analyses of water from wells L-25, L-33, and L-11, whereas electric logs of those and nearby wells indicate that the water in the deeper part of the Alta Loma sand is of much poorer quality. Barnes (1943, p. 22) stated that in four test wells, each of which was sampled in the upper and lower parts of the sand, the water nearer the bottom had the higher chloride content. The electric logs of all the test wells indicate that the concentration of chloride in the water becomes progressively greater with depth, forming a "vertical gradient" in the main sand. He stated:

> "In some cases this difference from the top to the bottom of the sand is estimated to be small, while in other cases the change is probably several hundred parts per million. The vertical gradient of the chloride concentration found in all the test wells is probably characteristic of the main sand in this locality, although the chloride in the basal few feet is partially controlled by local conditions."

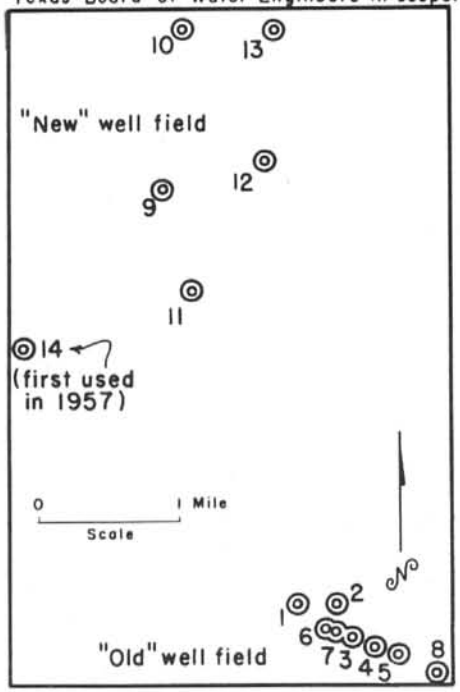
Petitt and Winslow (1955, p. 46) concluded that the salt water in the Alta Loma sand occurs in the form of a wedge in the lower part of the sand, the wedge thickening downdip. They stated also that salt water apparently is encroaching both from downdip and from the underlying sand where clay beds are not present.

The chemical quality of the water from the "new" well field has changed very little by comparison with that of the water from the "old" well field. The chloride content of water from well 11, which is nearest the "old" field, was the highest both in 1942 (245 ppm) and in 1957 (267 ppm). (See fig. 11.) Well 9 has yielded water very similar in chloride content to well 11 during the period of simultaneous record, 1943-57. Water from well 10 in the northwestern part of the "new" well field contained 149 ppm of chloride in 1942, but the chloride content steadily increased until in 1957 it was about the same as that of water from well 9. Wells 12 and 13, which yielded water containing 134 and 170 ppm of chloride, respectively, in 1943 both yielded water containing about 210 ppm of chloride in 1946. From 1946 to 1957, wells 12 and 13 continued to yield water of about the same chemical quality, analyses of water from both wells indicating between 205 and 222 ppm of chloride. In November 1957 the chloride content of water from both wells was 215 ppm, which was the lowest in either field. The inset map and the chlorographs in figure 11 show that in 1957 the chloride content of the water from the three westernmost wells (9, 10, and 11) was higher than that of water from the two easternmost wells (12 and 13). It is interesting to note that in 1942 city of Galveston test well 4-7 (E-86, 1.2 miles west of well 9) yielded water from 738-749 feet containing 360 ppm of chloride, whereas in the same year test well 7-10 (E-74, 1.5 miles east of well 12) yielded water from 756-763 feet containing 134 ppm of chloride.

UPPER PART OF BEAUMONT CLAY

Although the chemical quality of water from wells screened in the upper part of the Beaumont clay varies somewhat from place to place, generally the quality of water from any particular well sampled periodically has been relatively constant. However, analyses of water from wells M-2, F-45, and F-41 (fig. 12, pl. 1) in the Texas City area, where the withdrawals from the upper part of the Beaumont are largest, suggest an increasing trend in chloride content since 1954. The changes in quality between 1952 and 1956 were small; however, they may or may not be indicative of important changes in the future.

The increase in chloride content in some wells in the upper part of the Beaumont in the Texas City area does not necessarily mean encroachment of salt water updip from the southeast. The higher chloride water may be from a local source, such as that illustrated by figure 13.



Well No.	Screen setting
9	669 - 761
10	645 - 767
11	636 - 767
12	636 - 776
13	640 - 763
14	661 - 775

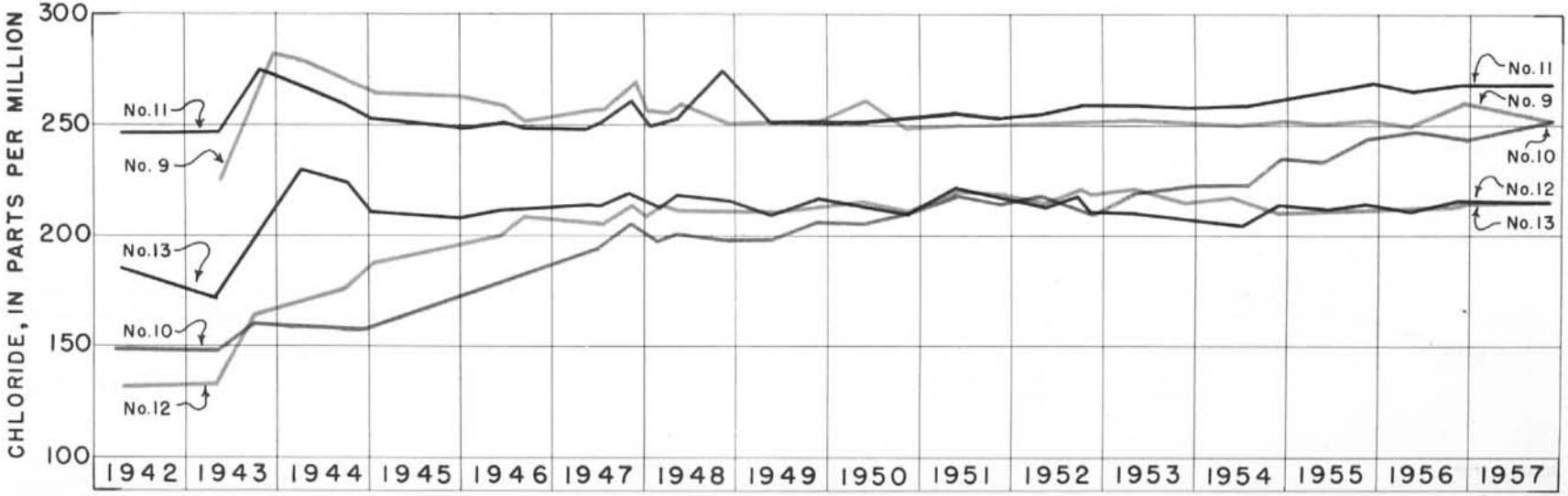


FIGURE 11.- Changes in chloride content of water from wells in the city of Galveston's "new" well field north of Alta Loma, Galveston County, Tex., 1942-57.

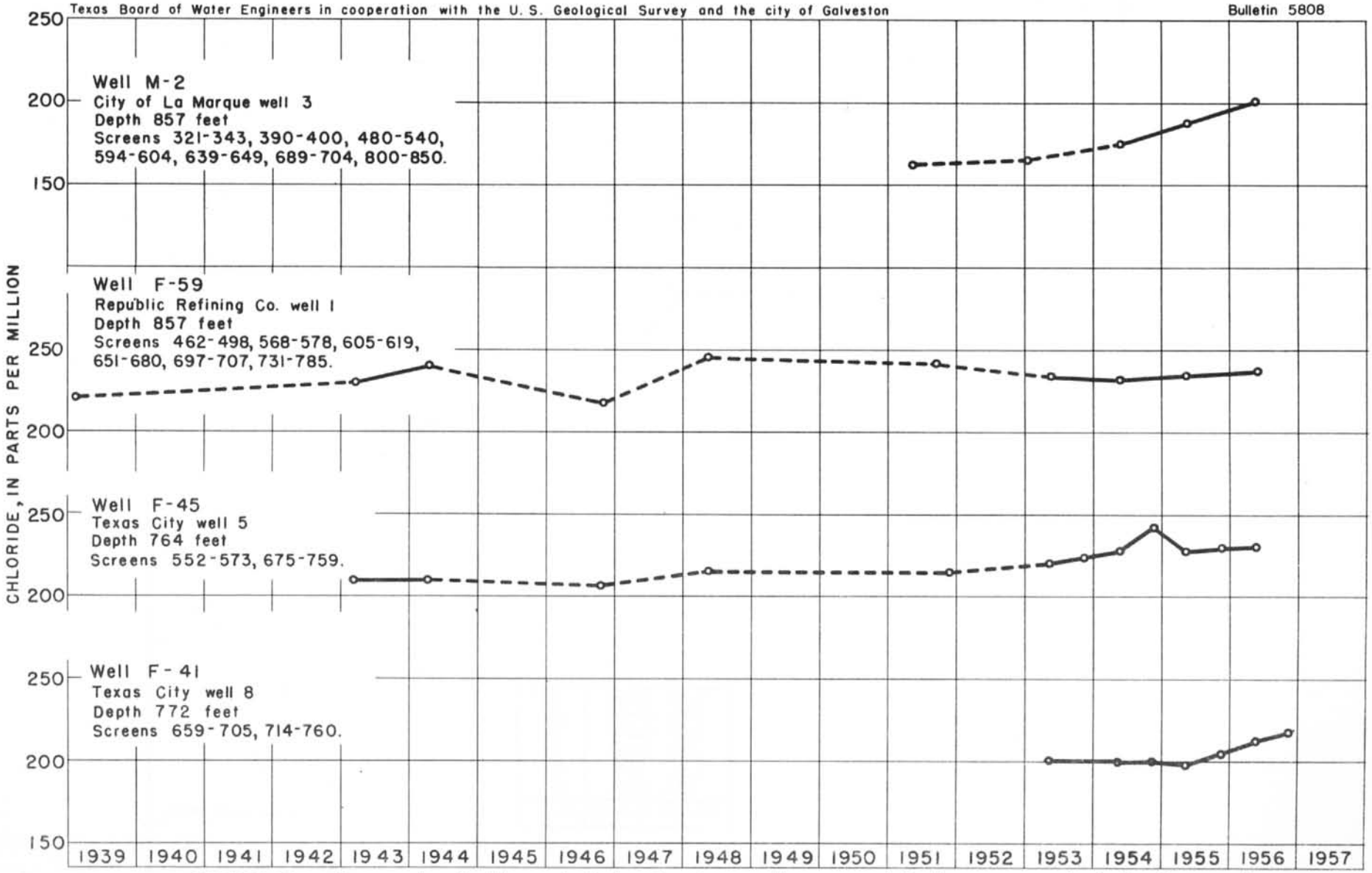


FIGURE 12. - Changes in chloride content of water from wells screened in the upper part of the Beaumont clay in the Texas City area, Galveston County, Tex.

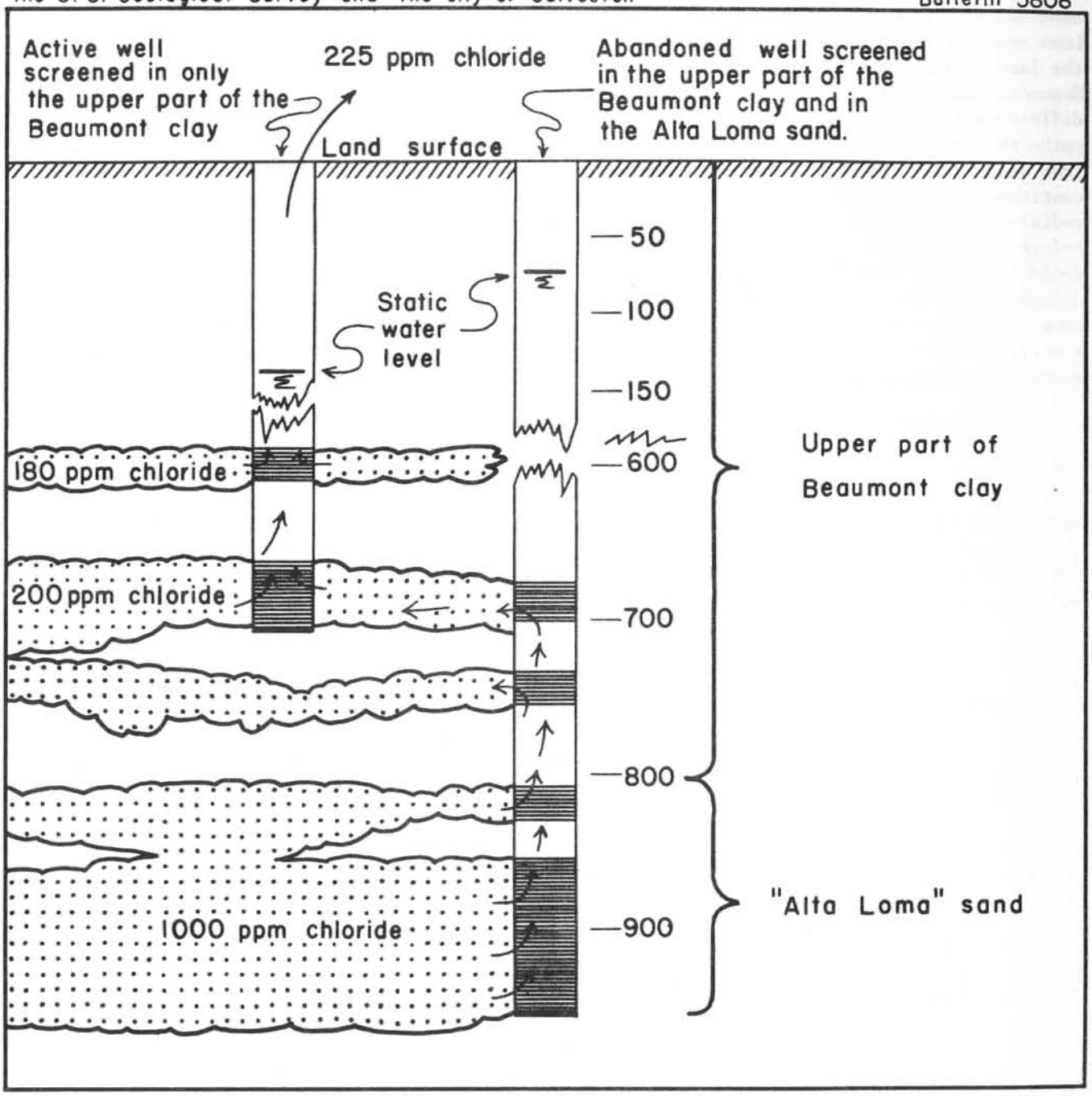


FIGURE 13.- Hypothetical diagram illustrating a possible method of local contamination of the upper part of the Beaumont clay with high-chloride water, Texas City area.

Several of the industrial wells that penetrate the Alta Loma sand also are screened in the upper part of the Beaumont and have become a source of contamination to the upper part. When surface water was introduced to the Texas City area in 1948, many of the industrial wells were no longer used and the rate of ground-water withdrawals decreased. The artesian pressure head in the Alta Loma sand increased so that the water levels in wells rose to within about 50 to 70 feet below the land surface, whereas the water levels in the wells screened only in the upper part of the Beaumont ranged from 110 to 140 feet below the land surface during the period 1945-57. The difference in pressure head between the aquifers results in the flow of high-chloride water along paths such as the one depicted in figure 13. The flow between sands in such a well might range from only a few tens of gallons to as much as a few hundred gallons per minute, but it would be continuous. Because of the quantity of water in the sands to be displaced and of the very slow radial movement of the high-chloride water from the well through the sands, it might take years before high-chloride water reached a pumped well 1,000 feet away. Furthermore, the pumped well would be drawing water from all directions, so that the composite water would contain less chloride than the contaminant. However, the chloride content would continue to increase as long as the source remained. After the high-chloride water has affected the quality of water in a well, it would take years of pumping before the quality would return to normal, even if the source of contamination were removed.

Local contamination from other sources by natural means is possible because of the lenticular character of the sands and clays that make up the upper part of the Beaumont clay. The sands of the upper part of the Beaumont may not be everywhere separated from the Alta Loma sand by a clay layer. In such areas water would move upward from the deeper Alta Loma sand into the shallower sand in the upper part of the Beaumont and then move laterally toward pumped wells. If the area of hydraulic connection between the sands were remote from the center of ground-water withdrawal, the higher chloride water would take many years to reach the nearest well, the length of time depending on the distance and rate of movement.

CONCLUSIONS

Municipalities and water districts pumped more water from wells in Galveston County than did industries during the period 1952 to 1957. In 1957 about 65 percent of the water pumped was for public supply, as compared with about 50 percent in 1951. The percentage pumped for public supply will probably be even larger in the years after 1957. The total pumpage remained about the same, however.

Water levels in wells in the Alta Loma and Texas City areas either changed very little or declined slowly from 1952 to 1957. In northern Galveston County, water levels declined at an average rate of 2.5 to 3.5 feet per year.

The chemical quality of the water from wells in the city of Galveston's "old" well field did not change appreciably from 1952 to 1957. The maximum chloride content of water from wells 3, 4, and 8 was between 750 and 900 ppm. The chloride content of water from wells in the "new" well field ranged from 215 to 267 ppm, although the chloride content in water from any one well was more or less constant from 1952 to 1957. The only well showing an increase was well 10, the chloride increasing from 215 ppm in 1951 to 252 ppm in 1957, which was about the same as the chloride content of the water from well 9 in 1957.

Even though the Alta Loma sand contains water of poorer quality downdip from the "old" field, the quality of water produced from the "old" field probably will not deteriorate much further, provided that the pattern of pumping and rate of withdrawal in southern Galveston County are not materially changed.

The land surface continued to subside in the period 1952-57, although in the Texas City area, where most of the subsidence has taken place, the rate of decline lessened.

Collection of data on water levels, pumpage, water quality, and land-surface subsidence should be continued.

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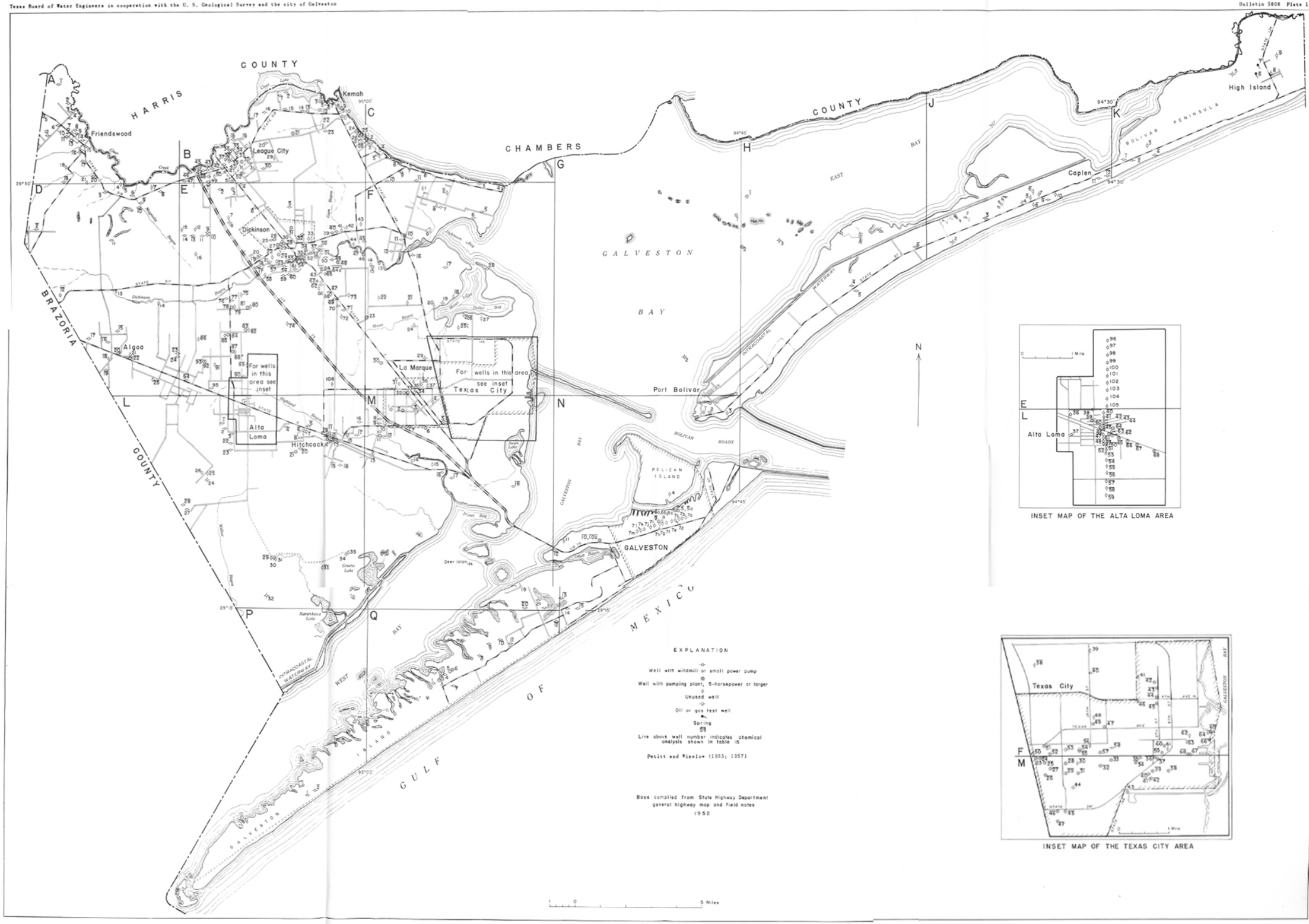
Year	Water-supply paper no.	Year	Water-supply paper no.
1935	777	1947	1099
1937	840	1948	1129
1939	886	1949	1159
1940	909	1950	1168
1941	939	1951	1194
1942	947	1952	1224
1943	989	1953	1268
1944	1019	1954	1324
1945	1026	1955	1407
1946	1074		



EXPLANATION

Well with windmill or small power pump

Well with pumping plant, 5-horsepower or larger

Unused well

Oil or gas test well

Spring

59

Line above well number indicates chemical analysis shown in table 15

Petitt and Winslow (1955; 1957)

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

0 5 Miles

N

INSET MAP OF THE ALTA LOMA AREA

INSET MAP OF THE TEXAS CITY AREA

MAP SHOWING LOCATION OF WELLS IN GALVESTON COUNTY, TEXAS