GROUND-WATER WITHDRAWALS AND CHANGES IN WATER LEVELS IN THE HOUSTON DISTRICT, TEXAS, 1975-79

By R.K. Gabrysch

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METRIC CONVERSIONS

For those readers interested in using the metric system, the metric equivalents of inch-pound units of measurements are given in parentheses. The inch-pound units of measurements used in this report may be converted to metric units by the following factors:

From	Multiply by	To obtain
acre-foot	0.001233	cubic hectometer (hm^3)
foot	0.3048	meter (m)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
pound-force per square inch (lbf/in^2)	6.895	kilopascal (kPa)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level."

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ABSTRACT

During 1975-79, total withdrawals of ground water in the Houston district decreased by 9.7 percent. This percentage represents a decrease from 505 million gallons per day (22.1 cubic meters per second) during 1975, to 456 million gallons per day (20.0 cubic meters per second) during 1979. The decrease resulted from an increased use of surface water that became available from Lake Livingston on the Trinity River during late 1976. During 1975-79, withdrawals of ground water decreased in the Pasadena, Katy, Baytown-La Porte, Johnson Space Center, Texas City, and Alta Loma areas but increased in the Houston area. The decreased withdrawals in the Katy area resulted partly from a small decrease in the acreage of rice planted, but mostly from a decrease in water needed for irrigation during 1979. The pumping of ground water increased in the Houston area because of the growth in population.

From spring 1975 to spring 1980, water levels rose in the southeastern one-half of the district and declined in the northwestern one-half. The maximum rise of water levels in wells in the Chicot aquifer was 110 feet (33.5 meters); the maximum rise in wells in the Evangeline aquifer was 150 feet (45.7 meters). The maximum decline of water levels in wells in the Chicot aquifer was 60 feet (18.3 meters); the maximum decline in wells in the Evangeline aquifer was 70 feet (21.3 meters).

No significant changes occurred in the chloride concentration in water from wells in the Alta Loma area during 1975-79. The concentration of chloride in water from a well completed in the middle part of the Chicot aquifer at Hitchcock is increasing, probably because of updip migration of the freshwater-saltwater interface.

INTRODUCTION

Collection of hydrologic data used in defining the ground-water resources in and around Houston, Texas, was begun by the U.S. Geological Survey about 1929. The present project of collection and dissemination of hydrologic data is being conducted by the Geological Survey in cooperation with the Texas Department of Water Resources, the City of Houston, and the Harris-Galveston Coastal Subsidence District. The purpose of this report is to update the published data on ground-water development in the Houston district. Some data collected before 1975 are included in this report to provide historic perspective. Water-level data collected during spring 1980 are included to show the effect of withdrawals made during the report period.

The definition of the ground-water hydrology of the district has improved as a result of additional information obtained from the data-collection and analysis programs. Hydrologic analysis, based on two analog models of the aquifers underlying the Houston district (Wood and Gabrysch, 1965; and Jorgensen, 1975), and studies of land-surface subsidence and saltwater encroachment (Gabrysch and Bonnet, 1975; Jorgensen, 1976) have greatly facilitated the understanding of this ground-water system.

The Houston district, as described in this report, includes all of Harris and Galveston Counties and parts of Chambers, Liberty, Montgomery, Waller, Fort Bend, and Brazoria Counties (fig. 1). Well drillers, industrial-plant officials, municipal officials, and many well owners contributed data used in this report.

AQUIFERS

Numerous reports on the ground-water hydrology of the Houston district have described the aquifers by using an interpretation of the subsurface geology. The authors have consistently stated that the structure and stratigraphy are very complex, and that delineation of the aquifers is extremely difficult. Although the first attempt to model the ground-water system during the early 1960's (Wood and Gabrysch, 1965) was only partly successful, it did develop a different approach to the analysis of the aquifers. Greater emphasis was placed on ground-water hydraulics, and as a result, the ground-water system was divided into two major aquifers, the Chicot and the Evangeline underlain by the Burkeville confining layer, which is composed principally of clay. A second analog model (Jorgensen, 1975) is more definitive than the earlier model and represents the system as it is presently defined.

The Evangeline aquifer is the major source of ground water in the Houston district. In Galveston County and southern Harris County, the Chicot aquifer is the major source of ground water because in these areas the Evangeline aquifer contains saline water.

The Alta Loma Sand of Rose (1943), hereafter referred to as the Alta Loma Sand, is the basal sand of the Chicot aquifer in some parts of the district. The Alta Loma Sand is the primary source of water from the Chicot aquifer except in the Texas City area. At Texas City, sand and gravel lenses in the middle part of the Chicot are the principal sources of water; there the Alta Loma Sand contains water with a chloride concentration that exceeds 500 mg/L (milligrams per liter).

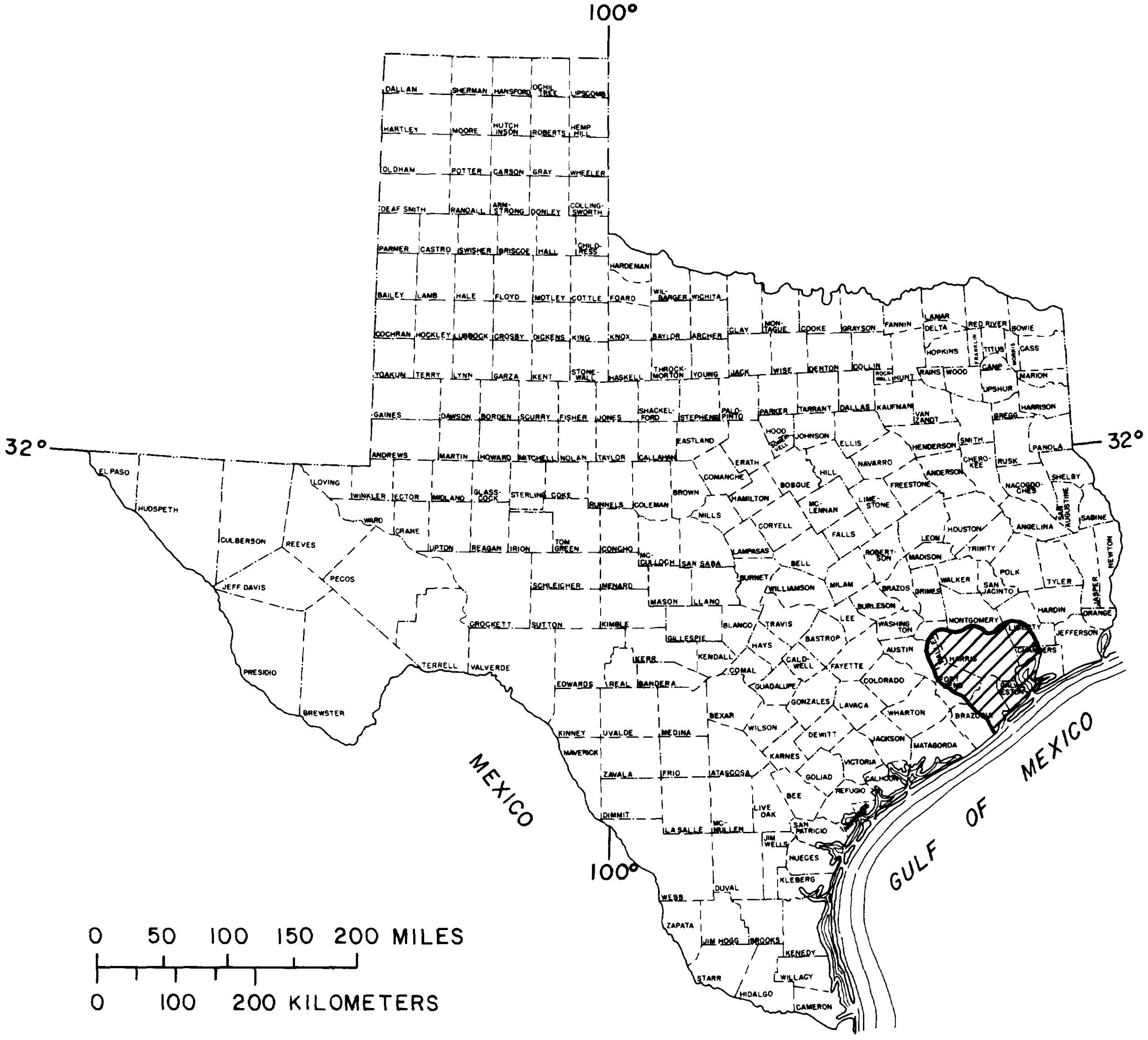

Figure 1.-Location of study area

DEVELOPMENT OF GROUND WATER

The major areas of ground-water development discussed in this report are the Houston, Pasadena, Katy, Baytown-La Porte, Johnson Space Center, Texas City, and Alta Loma areas (fig. 2). The history of development of ground water has been presented by Wood and Gabrysch (1965), Gabrysch (1972, 1980), and Jorgensen (1975).

Significant changes in ground-water withdrawals have occurred from 1976 through 1979. Historically, the rate of withdrawals steadily increased as the area developed, but withdrawals began to decrease during late 1976 when surface water from Lake Livingston on the Trinity River became available. Surface water from Lake Houston on the San Jacinto River was previously available in limited quantities. By the end of 1979, ground-water production was replaced by about 98 Mgal/d (4.3 m^3/s) of surface water, principally in the Pasadena, Baytown-La Porte, and Johnson Space Center areas. The location and magnitudes of decreases in withdrawals from the Chicot aquifer are shown in figure 3 and from the Evangeline aquifer in figure 4. However, the rate of ground-water withdrawals has continued to increase in the northern and western parts of the Houston district because of relocation of well fields and to meet increasing municipal needs. Average daily ground-water withdrawals in the Houston district for public supply, industrial use, and irrigation during 1975-79 are given in tables 1, 2, and 3.

Significant rises in ground-water levels have resulted from decreased withdrawals in southeastern Harris County, whereas significant declines have continued because of increased withdrawals in northern and western Harris County. Changes in water levels from spring 1975 to spring 1980 in wells completed in the Chicot aquifer are shown in figure 5; those in wells completed in the Evangeline aquifer are shown in figure 6. The maximum decline of water levels for the period in wells completed in the Chicot aquifer (fig. 5) was 60 feet (18.3 m), and the maximum rise of water levels was 110 feet (33.5 m). The maximum decline of water levels for the period in wells completed in the Evangeline aquifer (fig. 6) was 70 feet (21.3 m), and the maximum rise of water levels was 150 feet (45.7 m).

All rises in water levels have occurred since 1977 after increased use of surface water. Changes in water levels from spring 1977 to spring 1980 in wells completed in the Chicot aquifer are shown in figure 7; those in wells completed in the Evangeline aquifer are shown in figure 8. The locations of maximum rises for 1977-80 were approximately the same as for 1975-80. Comparison of figures 5 and 7 shows that the maximum rise of water levels in wells completed in the Chicot for 1977-80 was about 10 feet (3.0 m) more than the maximum rise for 1975-80. Comparison of figures 6 and 8 shows that the maximum rise of water levels in wells completed in the Evangeline for 1977-80 was about 10 feet (3.0 m) less than that for 1975-80.

The changes in magnitude and distribution of ground-water withdrawals have caused the water-level patterns to change and the major historical centers of cones of depression to shift. The altitude of water levels in wells completed in the Chicot and Evangeline aquifers during spring 1980 are shown in figure 9 (Chicot) and figure 10 (Evangeline).

Table 1.--Average daily withdrawal of ground water in the Harris County area, 1975-79

Area	Use	Ground water withdrawal (million gallons per day)				
		1975	1976	1977	1978	1979
Houston	Public supply:					
	City of Houston	150.7	163.4	185.2	188.9	203.0
	Suburban	23.5	24.8	28.5	29.4	22.9
	Industry	8.1	9.0	8.0	8.1	6.9
	Irrigation	.8	.8	.8	.9	.7
	Subtotal	183.1	198.0	222.5	227.3	233.5
Pasadena	Public supply	16.3	16.7	16.9	16.6	15.1
	Industry	93.9	89.1	66.4	46.3	33.0
	Subtotal	110.2	105.8	83.3	62.9	48.1
Katy	Public supply	11.4	15.3	24.2	29.9	31.5
	Industry	11.6	10.8	12.9	14.2	13.1
	Irrigation	110.1	104.5	84.7	112.3	82.8
	Subtotal	133.1	130.6	121.8	156.4	127.4
Baytown-La Porte	Public supply	8.5	9.3	9.8	11.4	10.6
	Industry	17.6	17.2	12.3	10.2	3.8
	Subtotal	26.1	26.5	22.1	21.6	14.4
Johnson Space Center	Public supply	6.5	4.9	3.4	4.0	3.4
	Industry	13.6	15.6	4.0	1.0	0.5
	Irrigation	.1	.1	.1	.1	.1
	Subtotal	20.2	20.6	7.5	5.1	4.0
Other Harris County areas	Public supply	5.6	5.3	6.6	7.2	8.7
	Industry	--	--	--	0.1	0.3
	Irrigation	.3	.7	.8	2.3	1.3
	Subtotal	5.9	6.0	7.4	9.6	10.3
Total (rounded)		479.0	488.0	465.0	483.0	438.0

Table 2.--Average daily withdrawal of ground water in Galveston County, 1975-79

Area	Use	Ground water withdrawal (million gallons per day) 1975	1976	1977	1978	1979
Texas City	Public supply	6.9	7.3	7.7	7.3	7.3
	Industry	7.4	6.7	3.3	2.4	1.6
	Subtotal	14.3	14.0	11.0	9.7	8.9
Alta Loma	Public supply	7.1	6.1	4.1	2.7	1.6
Other Galveston County areas	Public supply and industry	5.7	6.5	6.8	7.7	7.8
Total (rounded)		27.0	27.0	22.0	20.0	18.0

Table 3.--Average daily withdrawal of ground water in the Houston district, 1975-79

Use	Ground water withdrawal (million gallons per day) 1975	1976	1977	1978	1979
Public supply	239	256	290	301	308
Industry	155	152	110	86	63
Irrigation	111	106	86	116	85
Total	505	514	486	503	456

Houston Area

The Houston area is in the central and south-central parts of Harris County and includes most of the city of Houston and the closely adjoining metropolitan areas (fig. 2).

Withdrawals

Ground-water withdrawals in the Houston area are principally for municipal supply, but small volumes of ground water are used by small industries and farms. Most of the withdrawals are from the Evangeline aquifer. During 1975, ground-water withdrawals in the area were 183.1 Mgal/d (8.0 m^3/s) of which the city of Houston used 150.7 Mgal/d (6.6 m^3/s). During 1975, the city of Houston also used 73.7 Mgal/d (3.2 m^3/s) of water from Lake Houston. During 1979, withdrawals were 233.5 Mgal/d (10.2 m^3/s) of which the city of Houston used 203.0 Mgal/d (8.9 m^3/s). During 1979, the city of Houston also used 138.4 Mgal/d (6.1 m^3/s) of water from Lake Houston.

From 1975 to 1979, the average rate of total ground-water withdrawals increased about 6 percent per year, and the use of surface water by the city of Houston increased about 20 percent per year. The total water used increased by an average of 8.7 percent per year.

Changes in Water Levels

Water levels in wells completed in the Chicot aquifer declined in the western two-thirds of the Houston area while water levels rose in the eastern one-third of the area (figs. 2 and 5). The maximum decline of water levels in wells in the Chicot aquifer was in the southern part of the area where water levels declined as much as 40 feet (12.2 m) from 1975 to 1980. During the same period, water levels in wells in the Chicot rose as much as 40 feet (12.2 m) on the eastern side of the area as a result of the decreased withdrawals in southeastern Harris County.

Water levels in wells completed in the Evangeline aquifer had about the same trend as those in the Chicot (figs. 2 and 6). Declines in water levels of as much as 70 feet (21.3 m) occurred in the extreme western part of the area; rises in water levels of as much as 60 feet (18.3 m) occurred in the extreme southeast part of the area during 1975-80.

Hydrographs of water levels in two wells in the Houston area are shown in figure 11. In the Evangeline aquifer, the water level in well LJ 65-21-402 declined about 55 feet (16.8 m) from February 1975 to February 1980, of which 42 feet (12.8 m) occurred between February 1978 and February 1980. The decline is characteristic of declines on the western side of the area. The average decline for the first 3 years of the 5-year period at this site was about 5 feet (1.5 m) per year. The average decline for the last 2 years was 21 feet (6.4 m) per year. The increased rate of decline reflected the increased rate of withdrawals.

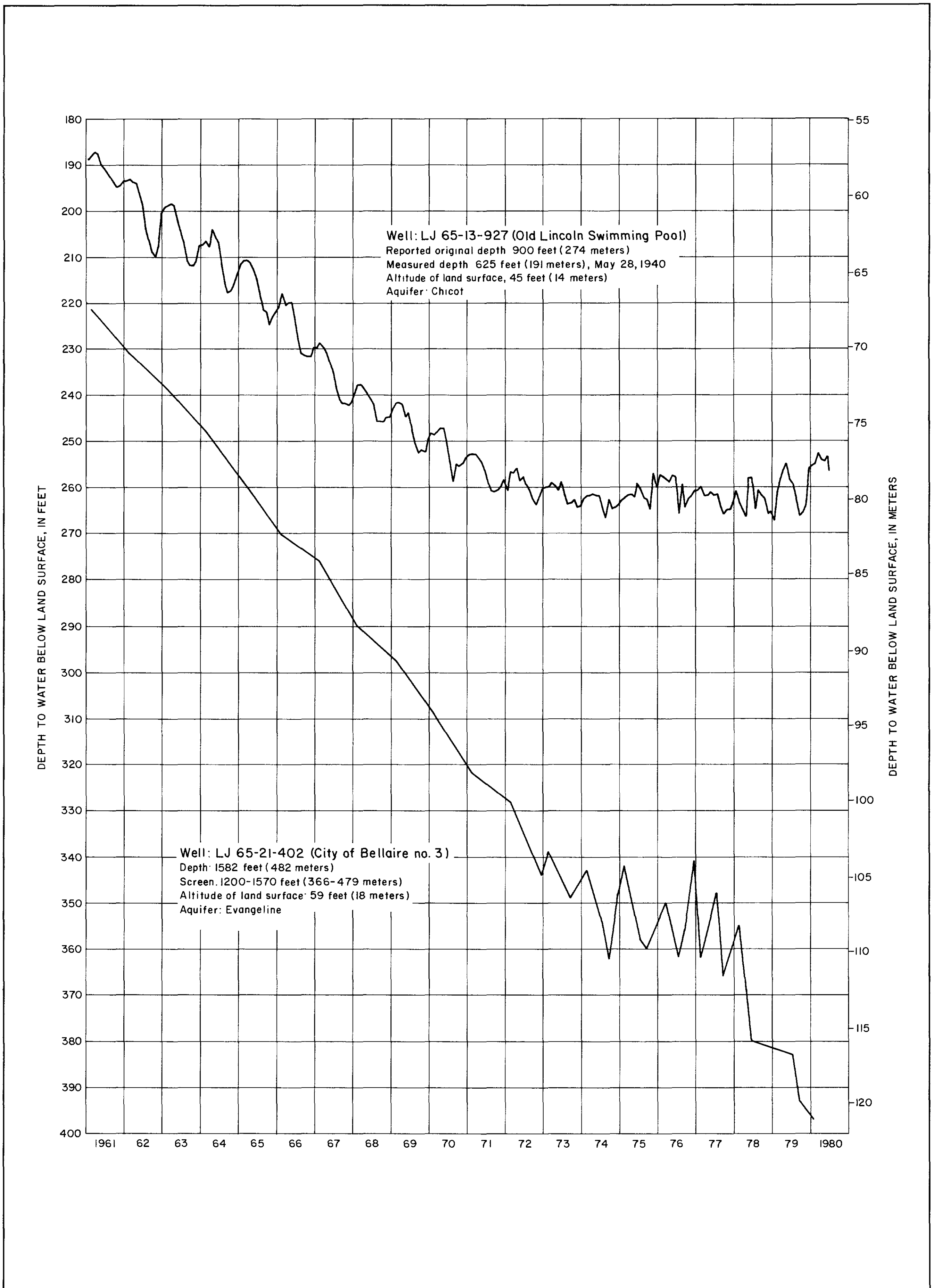

Figure 11.-Hydrographs showing changes in water levels in two wells in the Houston area

In the Chicot aquifer the water level in well LJ 65-13-927 rose about 7 feet (2.1 m) during 1975-80. The well is located in the east-central part of the area and reflects the net effect of changes in withdrawal rates for the Chicot aquifer.

Pasadena Area

The Pasadena area, which is east of the Houston area and mostly west of the San Jacinto River (fig. 2), includes a large industrialized zone along the Houston Ship Channel. Large ground-water withdrawals began in the Pasadena area after 1937. Surface-water supplies were added from Sheldon Reservoir in in 1942 and from Lake Houston in 1954. During 1977, Lake Livingston on the Trinity River became the primary source of water for the area.

Withdrawals

The principal use of water in the Pasadena area continues to be industrial. The principal source of water, however, has changed from ground water to surface water. The maximum withdrawals of ground water in the area occurred during 1968 when 125.7 Mgal/d (5.5 m^3/s) were pumped. Since that time, as the use of surface water increased and conservation measures were practiced, ground-water use slowly decreased to 105.8 Mgal/d (4.6 m^3/s) during 1976. During late 1976, the use of surface water from Lake Livingston resulted in an even greater decrease of ground-water withdrawals. During 1979, ground-water withdrawals were 48.1 Mgal/d (2.1 m^3/s). Of this volume, 15.1 Mgal/d (0.66 m^3/d) was for municipal purposes and 33.0 Mgal/d (1.4 m^3/s) was for industrial purposes.

Changes in Water Levels

Water levels in wells completed in both the Chicot and Evangeline aquifers have risen throughout the Pasadena area as a result of the decreased ground-water withdrawals. For 1975-80, the maximum rise in water levels was 90 feet (27.4 m) in wells completed in the Chicot aquifer (fig. 5) and about 150 feet (45.7 m) in wells completed in the Evangeline aquifer (fig. 6).

Because the aquifer system is artesian, the response to a change in withdrawals is rapid. The rapid response to the decrease in withdrawals is shown in figure 12 by hydrographs of water levels in wells LJ 65-23-220 (Chicot) and LJ 65-23-219 (Evangeline). The rises in water levels began during late 1976, corresponding to the decreases in withdrawals. The shape of the hydrographs indicates that the principal recovery of water levels resulting from the decreased withdrawals has occurred. Very little additional change in water levels as a result of the decreased withdrawals should be expected.

Katy Area

The Katy area includes much of the northern and western parts of Harris County, southeastern Waller County, and the northern part of Fort Bend County (fig. 2). This area, which is mostly agricultural, is the largest area in the

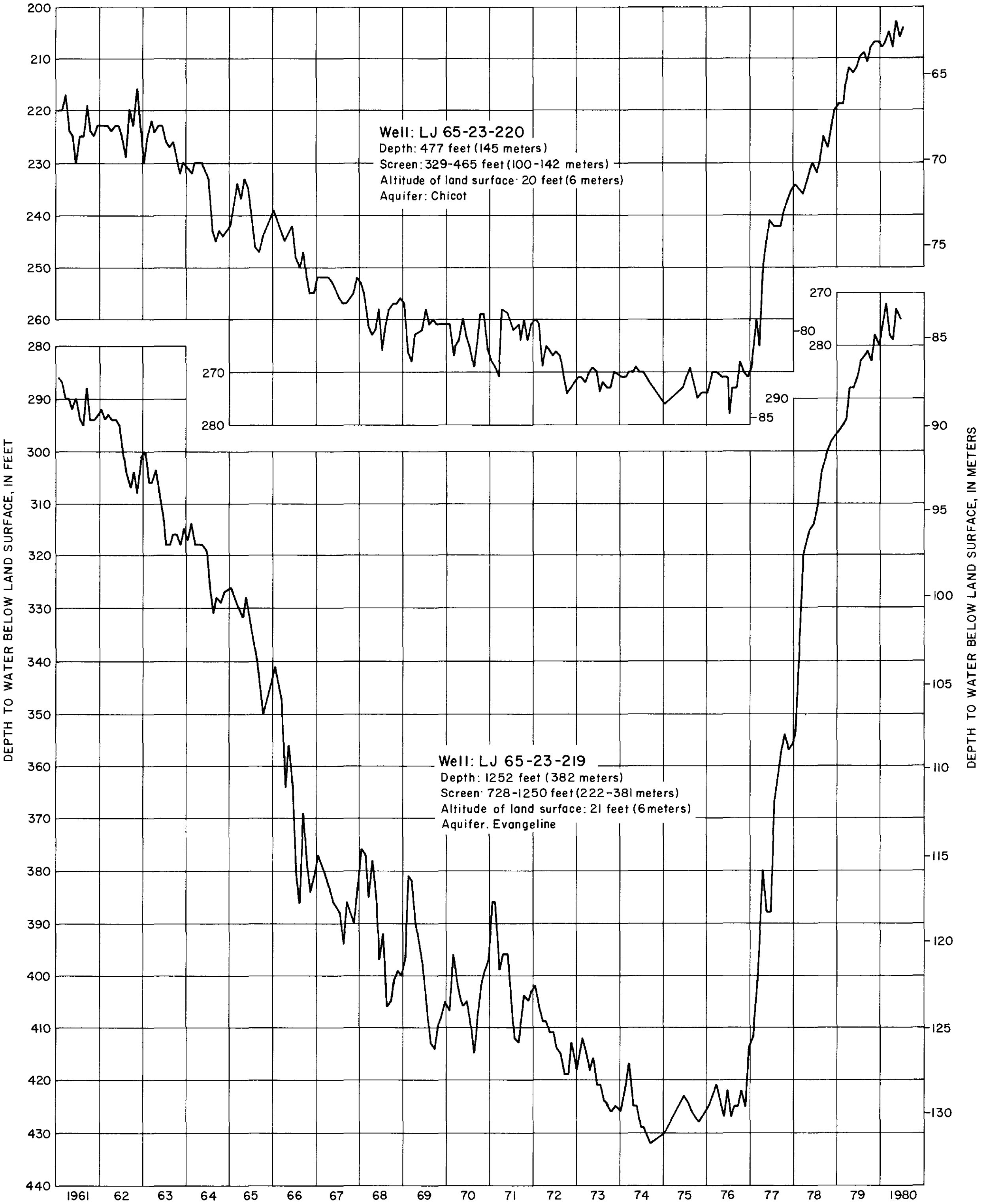

Figure 12.-Hydrographs showing changes in water levels in two wells in the Pasadena area

Houston district. Encroachment of municipal development, however, is decreasing the size of the agricultural area and changing the use of water.

Withdrawals

All water used in the Katy area is ground water, and more than 65 percent of the water is used for irrigation of rice. Estimates of the volume of water used for rice irrigation are based on the volume of water pumped per acre and the total acreage cultivated. The volume of water pumped per acre was estimated from the results of tests using selected wells.

The yield of water per unit of power consumption was determined for each of the selected wells two or three times during the irrigation season. The average yield per unit of power, times the total power used for irrigation season, provides a reasonable estimate of the total withdrawals. The number of acres planted in rice each year was obtained from the allotment records of the U.S. Department of Agriculture. The acreage planted and the estimated withdrawals for 1970-79 are given in table 4.

Withdrawals for irrigation occur during about 150 days, but for comparison, the annual withdrawal was divided by 365 days to obtain an average daily rate on a 12-month basis. Estimates of withdrawals for 1975-79 are given in table 1.

Changes in Water Levels

Water levels in wells completed in the Chicot aquifer in the Katy area declined between 1975 and 1980. The decline ranged from less than 10 feet (3.0 m) to about 60 feet (18.3) as shown in figure 5. For most of the area, the decline was less than 20 feet (6.1 m). Water levels also declined in wells completed in the Evangeline aquifer with the declines ranging from less than 10 feet (3.0 m) to about 70 feet (21.3 m) during the same period (fig. 6). In the western two-thirds of the area, water levels declined less than 20 feet (6.1 m). In the eastern one-third of the area, the decline generally was between 20 and 40 feet (6.1 and 12.2 m).

Declines of water levels in wells in the Katy area are illustrated in figure 13. Wells LJ 65-03-502 and LJ 65-10-902 are completed in both the Chicot and Evangeline aquifers, which is typical of irrigation wells in the area. Well LJ 65-10-902 is located in the south-central part of the area close to the city of Katy and to the Houston area. The rate of decline, as indicated by the hydrograph, increased from a constant rate of about 2.2 feet (0.7 m) per year from 1961 to 1977, to about 3 feet (0.9 m) per year between 1977 and 1980. The increased rate of decline indicates the effect of the increased withdrawals on the western side of the Houston area as well as more concentrated withdrawals associated with municipal development in the Katy area. Well LJ 65-03-502, which is located in the north-central part of the area, had a decline trend similar to that of well LJ 65-10-902 until 1972. Well LJ 65-03-502 is remote to the increased withdrawals on the western side of the Houston area and the municipal development in the Katy area. Therefore the increased withdrawals cause less decline in water levels in this well than in well LJ 65-10-902. Since 1972, the net decline in well LJ 65-03-502 has been only about 1 foot (0.3 m).

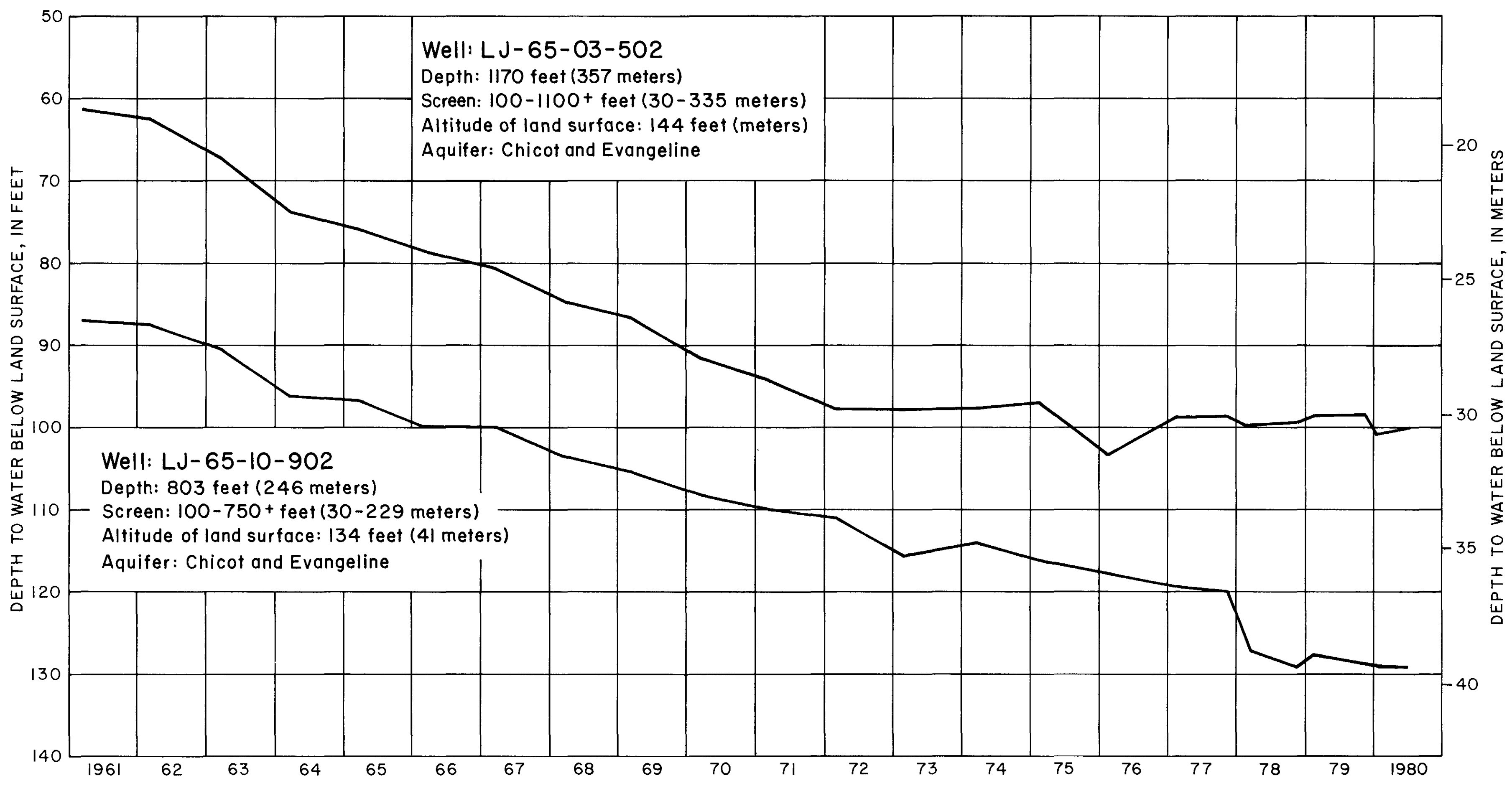

Figure 13.-Hydrographs showing changes in water levels in two wells in the Katy area

Table 4.--Rice acreage and volume of ground water pumped in the Katy area, 1970-79

Year	Acreage	Withdrawals (acre-feet per acre)	Total withdrawals (acre-feet)
1970	48,508	2.45	118,845
1971	46,791	2.64	123,528
1972	48,797	2.52	122,968
1973	53,486	2.00	106,972
1974	55,426	2.64	146,325
1975	47,085	2.62	123,363
1976	48,553	2.41	117,012
1977	41,778	2.27	94,837
1978	49,927	2.56	127,814
1979	46,501	1.99	92,723

Baytown-La Porte Area

The Baytown-La Porte area extends eastward from the Pasadena area to the Chambers County line (fig. 2). Previously, the area continued southward to the Galveston County line; however, extensive ground-water development in the southern part of the area has necessitated a division into two parts. For purposes of discussion, the northern part is now called the Baytown-La Porte area and the southern part is called the Johnson Space Center area. Records have been adjusted, and withdrawals have been distributed to show separate development in the two areas since 1960.

Withdrawals

Ground-water withdrawals in the Baytown-La Porte area are principally from the Alta Loma Sand. The principal use of ground water during 1975 was for industrial purposes, when withdrawals by industry were 17.6 Mgal/d (0.77 m^3/s) or 67 percent of the 26.1 Mgal/d (1.1 m^3/s) pumped (table 1). The conversion to surface water caused the ground water used by industry to decrease to 3.8 Mgal/d (0.17 m^3/s) during 1979. Use of ground water for public supply increased from 8.5 Mgal/d (0.37 m^3/s) during 1975, to 11.4 Mgal/d (0.50 m^3/s) during 1978, and decreased slightly to 10.6 Mgal/d (0.46 m^3/s) during 1979. During 1979, the principal use of ground water was public supply, which accounted for 74 percent of the 14.4 Mgal/d (0.63 m^3/s) withdrawn.

Changes in Water Levels

Water levels in wells completed in the Chicot and in the Evangeline aquifers have risen throughout the Baytown-La Porte area as a result of the decreased ground-water withdrawals. The maximum rise in water levels in wells completed in the Chicot aquifer for 1975-80 was about 110 feet (33.5 m) as shown in figure 5, and the maximum rise in water levels in wells completed in the Evangeline aquifer was about 130 feet (39.6 m) as shown in figure 6.

A hydrograph of water levels in well LJ 65-24-501 (fig. 14) shows the rapid response to the decrease in ground-water withdrawals since 1976 (figs. 3 and 4). The water level in the well rose about 2 feet (0.6 m) between February 1975 and January 1977, and about 116 feet (35.4 m) between January 1977 and February 1980. Very little additional rise in water levels as a result of the substantial decreases in withdrawals is expected. However, a conversion to surface water planned by the cities of Baytown and Highlands should result in additional decreases in withdrawals and, therefore, a rise in water levels.

Johnson Space Center Area

The Johnson Space Center area is bounded on the north by the Baytown-La Porte area, on the west by the Pasadena and Houston areas, on the south by Galveston County, and on the east by Galveston Bay (fig. 2). The principal use of ground water has changed from industry to public supply.

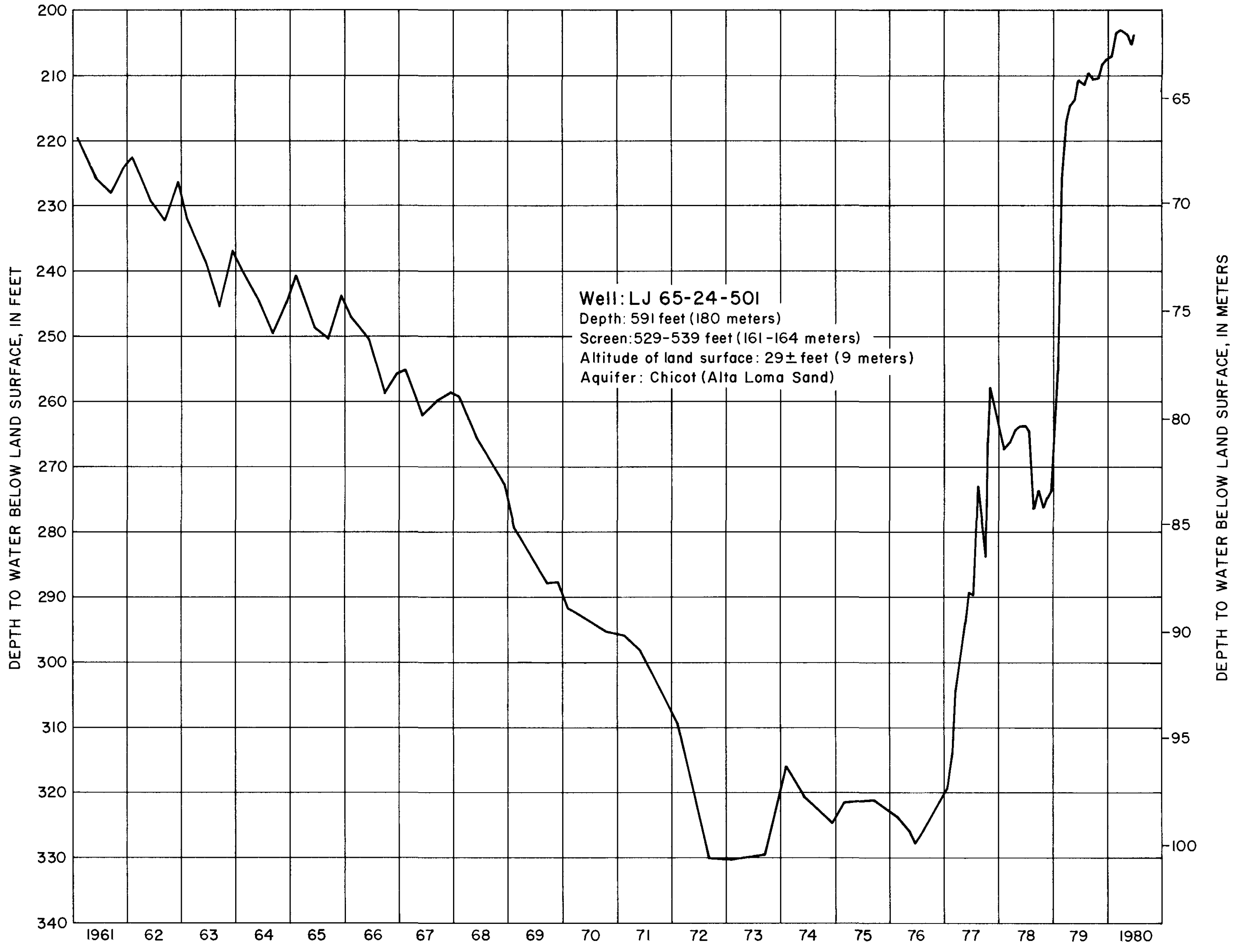

Figure 14.-Hydrographs showing changes in water levels in a well completed in the Alta Loma Sand of Rose (1943) in the Baytown - La Porte area

Withdrawals

Ground water in the Johnson Space Center area has been pumped from the lower part of the Chicot aquifer and the upper part of the Evangeline aquifer. As in nearby areas, users of water in the Johnson Space Center area also have decreased their reliance on ground water. From 1975 to 1979, total withdrawals were decreased from 20.2 to 4.0 Mgal/d (0.88 to 0.18 m^3/s), of which 3.4 Mgal/d (0.15 m^3/s) was for municipal supply, and 0.5 Mgal/d (0.02 m^3/s) was for industry (table 1). During 1979, all ground water withdrawn came from the Chicot aquifer.

Changes in Water Levels

Water levels in wells completed in the Chicot and Evangeline aquifers rose throughout the Johnson Space Center area during 1975-80. The rise in potentiometric surface in the Chicot aquifer ranged from about 30 to 80 feet (9.1 to 24.4 m); the rise in potentiometric surface in the Evangeline ranged from 20 to 80 feet (6.1 to 24.4 m) as shown in figures 5 and 6.

A hydrograph of water levels in well LJ 65-32-406 completed in the Alta Loma Sand is shown in figure 15. The graph reflects the steady decline of water levels in the area from 1963 to 1976. During 1976, three major ground-water users began using surface water from Lake Livingston. As a result, a rise in water levels began. The interruptions of the pattern of rise during mid-1977 and 1978 is a result of withdrawals by these three users who maintain their wells for peak needs. The very rapid rise in the water level from November 1978 to January 1979 was the result of pressure increase associated with leaking gas from a ruptured gas-production well in southeastern Harris County. The effect of this rupture is described in more detail later in this report. Very little additional change in water levels as a result of the decreased withdrawals is expected.

Texas City Area

The Texas City area, which is in the southeastern part of Galveston County (fig. 5), includes the cities of Texas City and La Marque and the adjoining areas. The economy of the area is industrial.

Withdrawals

Withdrawals of ground water in the Texas City area is mostly from sands in the middle part of the Chicot aquifer. In this area, the Alta Loma Sand contains water that is more mineralized than in adjacent areas, which restricts its use for most purposes. Withdrawals for public supply increased slightly from 6.9 Mgal/d (0.30 m^3/s) during 1975, to 7.3 Mgal/d (0.32 m^3/s) during 1979 (table 2). Withdrawals for industrial use decreased from 7.4 Mgal/d (0.32 m^3/s) during 1975 to 1.6 Mgal/d (0.07 m^3/s) during 1979 because of the increased use of surface water. Total ground-water withdrawals in the area during 1979 were 8.9 Mgal/d (0.39 m^3/s), a decrease of 5.4 Mgal/d (0.24 m^3/s) or 38 percent for 1975-79. Further decrease in ground-water withdrawals is planned.

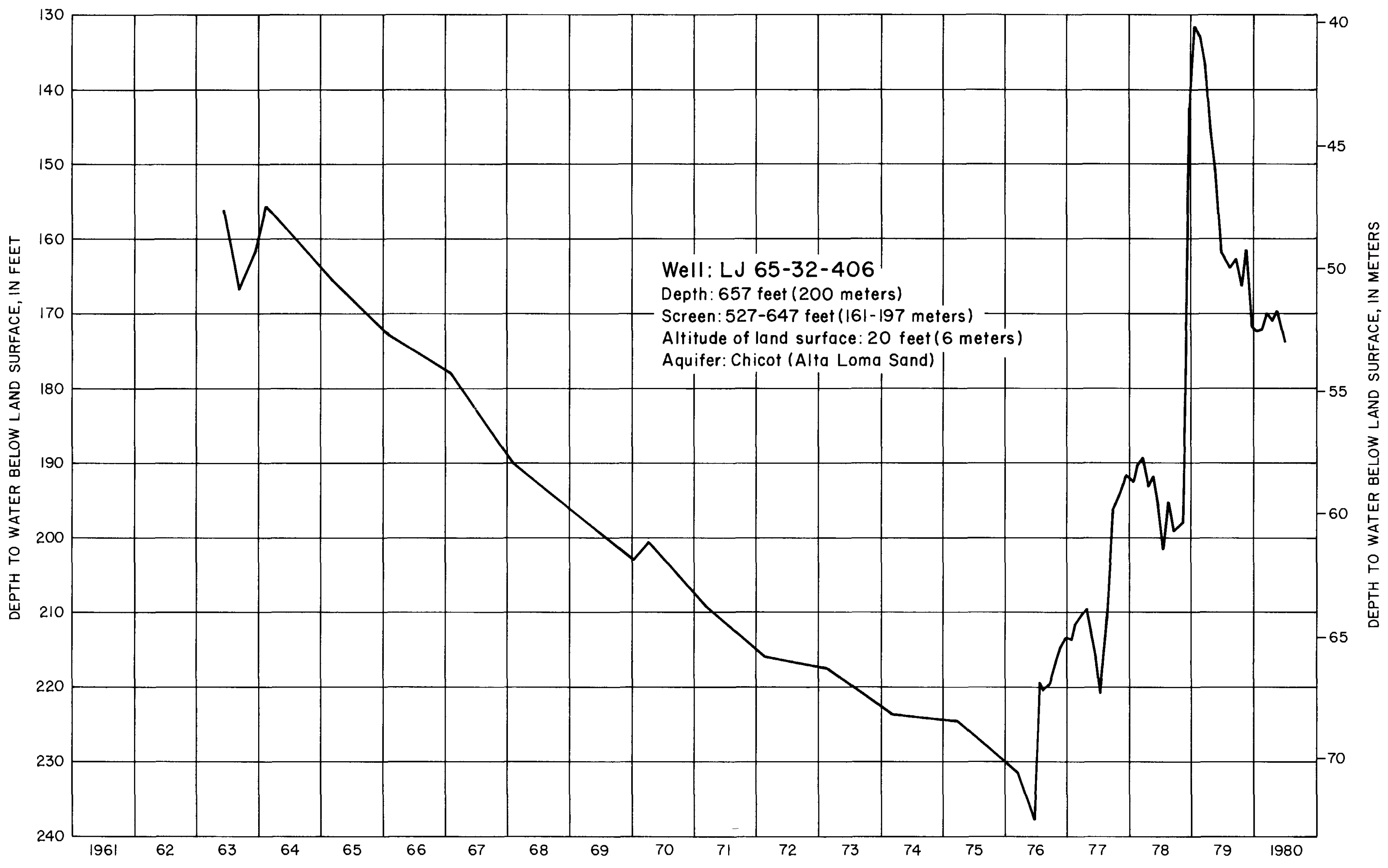

Figure 15.-Hydrograph showing changes in water levels in a well completed in the Alta Loma Sand of Rose (1943) in the Johnson Space Center area

Changes in Water Levels

Water levels in wells completed in the Alta Loma Sand in the lower part of the Chicot aquifer have risen between 10 and 20 feet (3.0 and 6.1 m) between 1975 and 1980 (fig. 5) as a result of decreased withdrawals. The levels have risen in wells completed in the middle of the aquifer as well as in those completed in the lower part.

Hydrographs of water levels in wells completed in the middle (well KH 64-33-905) and lower (wells KH 64-33-805 and 810) parts of the aquifer are illustrated in figure 16. As indicated by the hydrographs, the water level in well KH 64-33-805 fluctuated only slightly between 1970 and 1976, and began to rise during 1977. The water level in well KH 64-33-905 fluctuated within a larger range between 1970 and 1976, but also began to rise during 1977. The water level in that well rose 21 feet (6.4 m) between April 1975 and February 1980. Also, as indicated by the hydrographs, the water levels in wells completed in the lower part of the aquifer are about 70 feet (21.3 m) higher than those completed in the middle part of the aquifer. Only a slight change in water levels is expected until additional planned decrease in withdrawals occurs.

Alta Loma Area

The Alta Loma area, which contains the well fields for the town of Alta Loma and the city of Galveston, is in the west-central part of Galveston County (fig. 3). Ground-water withdrawals are for public supply.

Withdrawals

All withdrawals in the Alta Loma area are for public supply, and all the water is obtained from the Chicot aquifer. Withdrawals have decreased with increased surface-water use that began during 1973. During 1972, ground-water withdrawals were 13.0 Mgal/d (0.57 m^3/s). Following a plan of staged increases in the use of surface water, ground-water use decreased to 7.1 Mgal/d (0.31 m^3/s) during 1975, and to 1.6 Mgal/d (0.070 m^3/s) during 1979 (table 2). Ground-water use in the Alta Loma area has decreased about 88 percent since the use of surface water began.

Changes in Water Levels

As a result of the sizeable decreases in ground-water withdrawals, significant rises in water levels have occurred. During 1975-80, the levels in wells in the northern part of the area have risen as much as 30 feet (9.1 m) as shown in figure 5.

The hydrograph of well KH 65-40-707 in figure 17 shows the constant trend of decline until late during 1973 and the rises in levels during 1973-74, 1977-78, and 1978-79. Little additional change in the water level is expected.

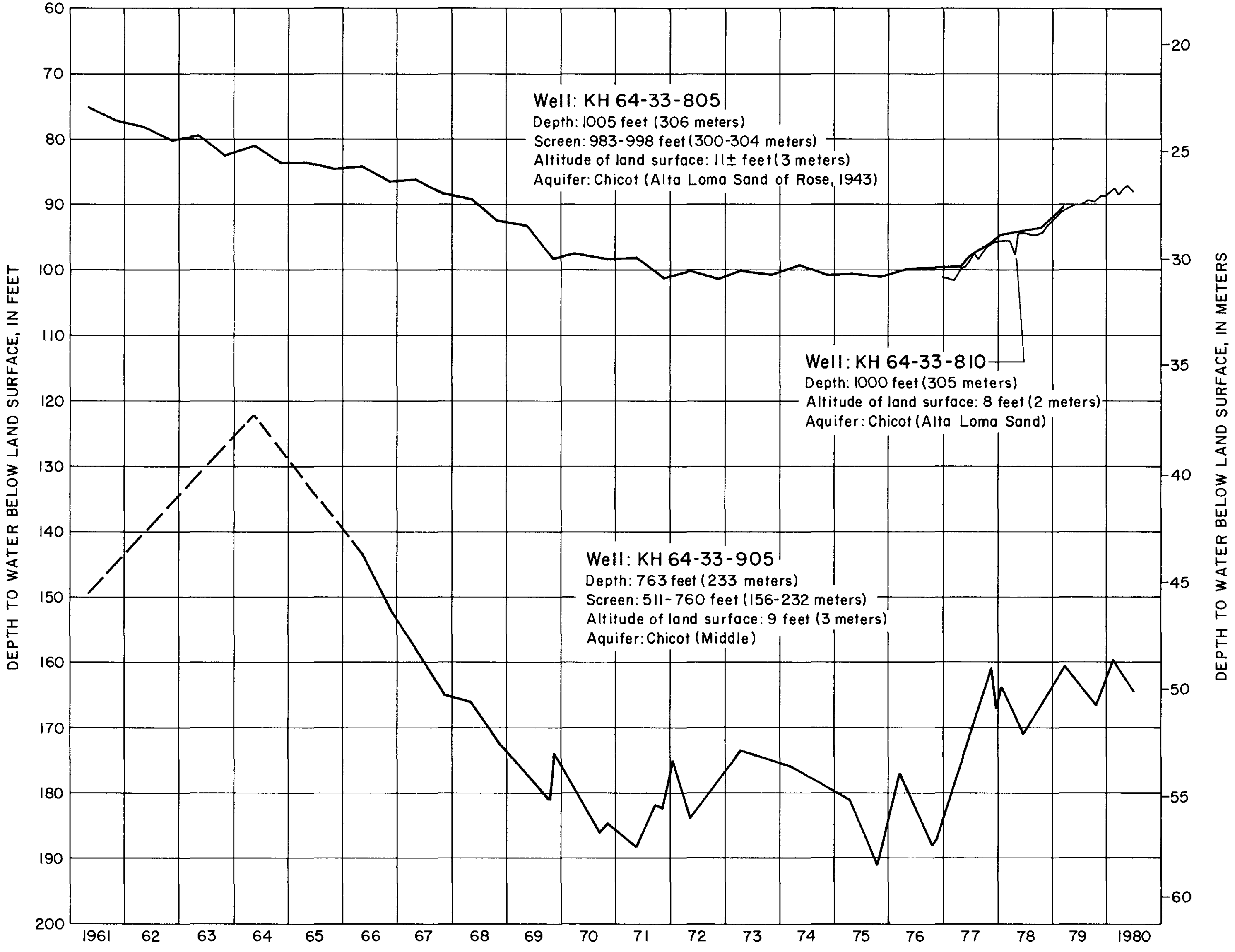

Figure 16.- Hydrographs showing changes in water levels in three wells in the Texas City area

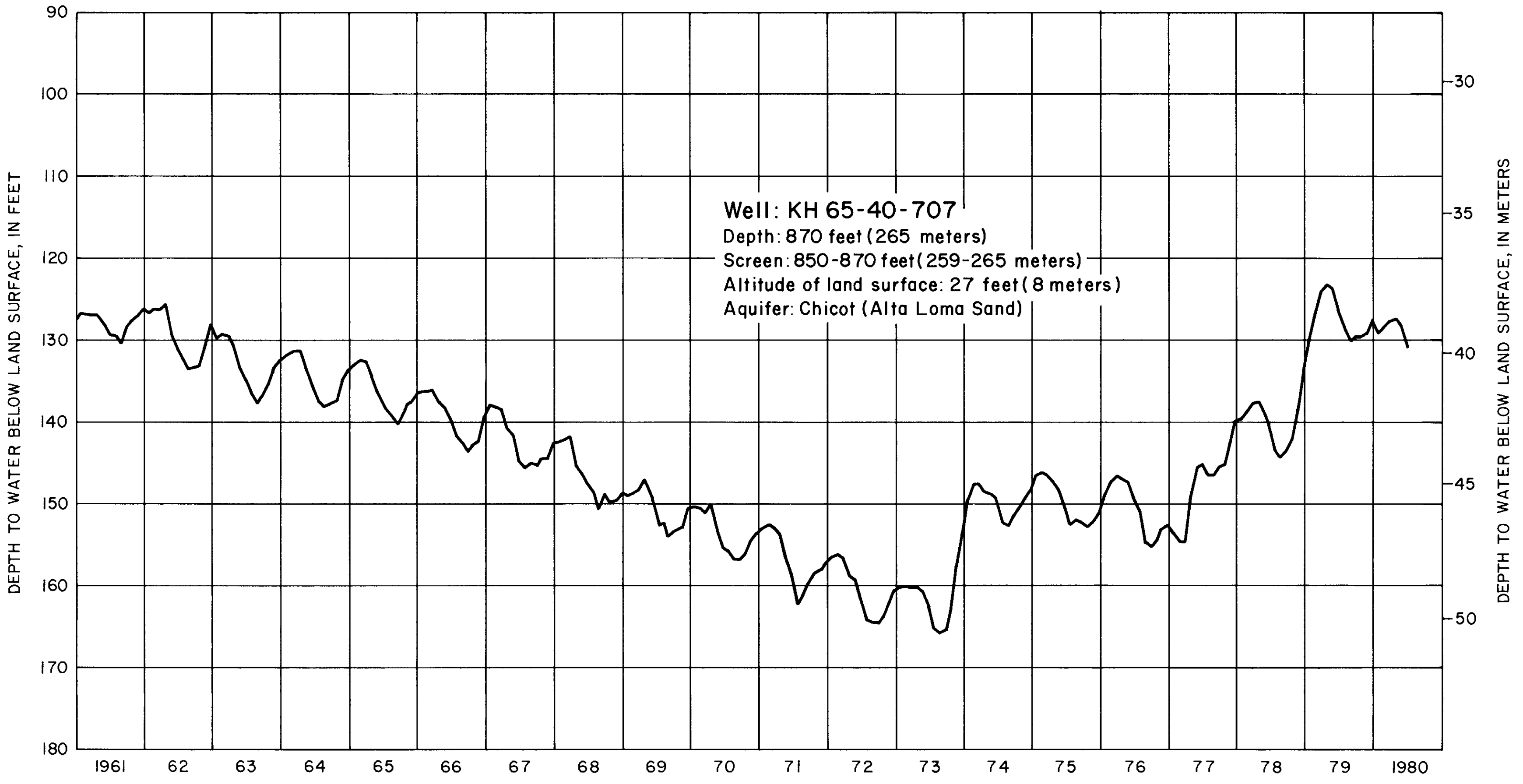

Figure 17.-Hydrographs showing changes in water levels in a well completed in the Alta Loma Sand of Rose (1943)

CHANGES IN WATER LEVELS DUE TO GAS LEAK

A gas-production well in southeastern Harris County ruptured in the Chicot aquifer during November 1978. As a result of the pressure leak, water levels in wells completed in the Chicot rose rapidly throughout a large area. The magnitude and areal distribution of this rise in water levels is shown in figure 18.

Water from an oilfield water-supply well near the location of the ruptured gas-production well began spraying above the top of the casing. Records of the completion interval of the water well are not available but the well was reported to be shallow, and the bottom is probably in the lower part of the Chicot aquifer. The water level under normal conditions was estimated from contour maps to be 200 feet (61.0 m) below land surface. After the rupture occurred, the reported shut-in pressure of the water well was 92 lbf/in^2 (634 kPa), or equivalent to 212 feet (64.6 m) of water.

A program of monthly measurements of water levels in a network of wells in this area was started during 1977 to document the rise in water levels associated with the decrease in ground-water withdrawals. Water-level data from this program were used to analyze the impact of the leaking gas well.

The hydrograph of water levels in well LJ 65-31-202, figure 19, is typical of those that were affected by the leaking well. The rise in water level in the well between November 1978 and January 1979, attributed to the leak, was about 79 feet (24.1 m). Characteristic of this event is the rapid rise in water levels followed by a slower decline. However, the magnitude and duration of the decline are obscured by the regional rise in water levels. The effect of the gas pressure in well LJ-65-31-202, due to the leak, appears to have dissipated by 1980.

Hydrographs of water levels in wells completed in the Evangeline aquifer generally did not indicate a pressure increase below the Chicot. However, rises of the water levels were measured in two wells completed in the upper part of the Evangeline to the east of the gas well and to the extreme northeast of the area affected.

The location of geologic faults with offset at the land surface as mapped by Verbeek and Clanton (1979) also are shown in figure 18. Rises in water levels occurred very quickly in all wells measured; the peak rise generally was recorded by January 1979, only 2 months after the rupture. However, at one of the more distant wells the peak rise was not recorded until June 1979. The response of the system to pressure change across the faults indicates that at least in southeastern Harris County, faults are not regional barriers to ground-water flow in the Chicot aquifer. The lack of regional response in the Evangeline aquifer is evidence that the clay layers in the ground-water system are barriers to flow in the vertical direction and the faults are not avenues of flow. Locally, however, some degree of vertical interconnection is likely. The elongation of the configuration of the lines showing water-level rises (fig. 18) in a northeasterly direction indicates a difference in transmissivity (ability of the aquifer to transmit water) in that direction.

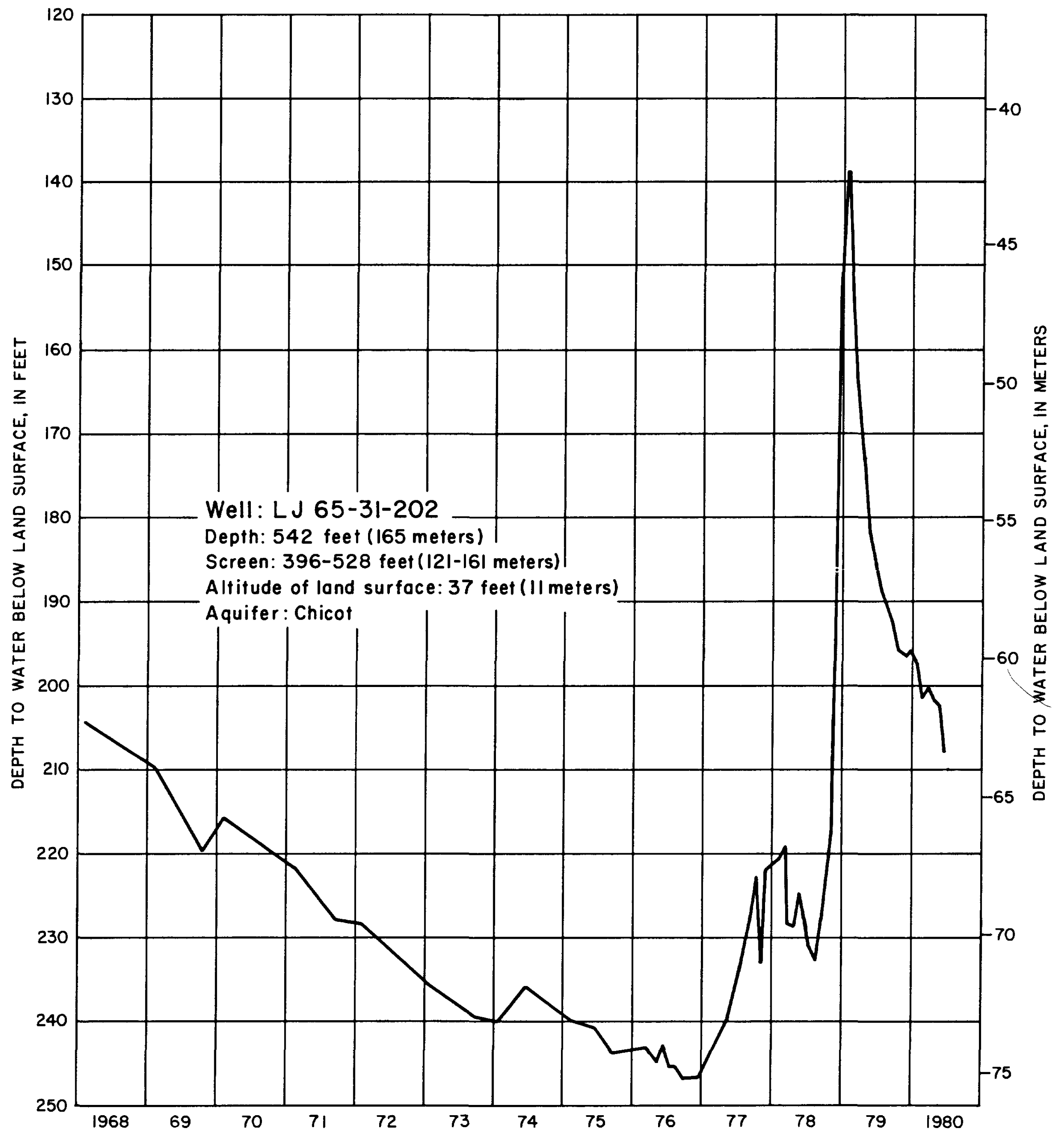

Figure 19.-Hydrograph showing changes in water levels in a well completed in the Chicot aquifer near a ruptured gas well in southeastern Harris County

CHANGES IN CHEMICAL QUALITY OF GROUND WATER

In general, ground water of chemical quality suitable for most uses can be obtained in most areas of the Houston district. However, deterioration in water quality has been noted in samples from a few wells near the freshwater-saltwater interface in both Harris and Galveston Counties. The increase in concentrations of chemical constituents probably is a result of updip migration of the saltwater toward the cone of depression caused by withdrawals.

Wells in southern Harris County, from which periodic samples were obtained for monitoring changes in chloride concentration of the ground water, have been destroyed. Prior to their destruction, however, increases in chloride concentrations were detected. Wells in Galveston County from which samples have been collected for many years are still available for water-quality observation. Changes in chloride concentrations are being monitored in the city of Galveston's "old" well field at Alta Loma, in the "new" well field north of Alta Loma, and in wells along Texas Highway 6 in Galveston County, also in the Alta Loma area (fig. 2).

The chloride concentration in water from wells KH 65-48-204, 211, and 213 (fig. 20) fluctuated during the period shown. The fluctuations in the chloride concentrations probably were due to withdrawal patterns in the well field. The historical increase in chloride concentration in water from the wells in the "old" well field probably was due to an advance of the freshwater-saltwater interface. Because of the decreased withdrawals in the Alta Loma area, the interface probably will recede and the chloride concentration probably will decrease. Such a trend is indicated by the graphs for wells KH 65-48-211 and 213 after 1974.

The increase in chloride concentration in water from wells in the "new" well field north of Alta Loma has been gradual. Changes in chloride concentrations in water from two wells for 1960-78 is shown in figure 21. During 1943, the chloride concentration in water from well KH 65-40-401 was 148 mg/L. During 1972, the maximum chloride concentration was 320 mg/L. The chloride concentration in water from well KH 65-40-401 decreased to 270 mg/L during 1978.

The chloride concentration in water from well KH 65-40-704 increased from 290 mg/L during 1972 to 300 mg/L during 1977. Although water samples from the wells were not collected during 1979, it is probable that changes in chloride concentration were small because the rises in water levels would impede encroachment.

Changes in chloride concentrations in water from a well completed in the Alta Loma Sand (KH 65-48-316) and from a well completed in the Chicot aquifer sand beds above the Alta Loma Sand (KH 65-48-301) in the southwest part of the Texas City area are shown in figure 22. The chloride concentration in water from well KH 65-48-316 increased rapidly after it was put into production. During April 1970, the chloride concentration was 410 mg/L; by November 1970, it was 745 mg/L. The concentration increased to 800 mg/L by November 1974, and was 780 mg/L during May 1978. The chloride concentration in water from well KH 65-48-301 gradually increased from 102 mg/L when the well was drilled during 1958 to 250 mg/L during July 1979. The increase probably is due to updip migration of the saltwater-freshwater interface.

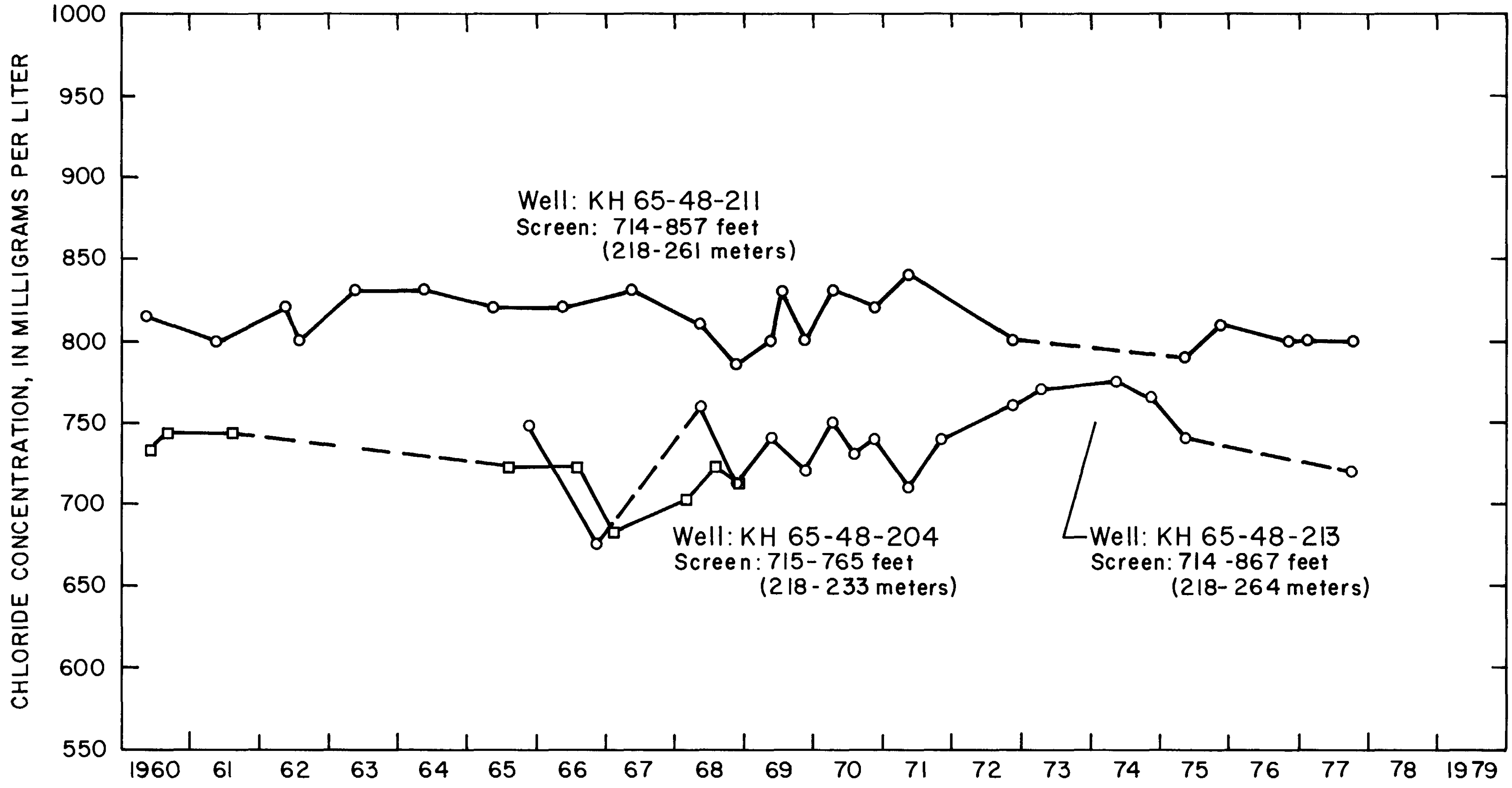

Figure 20.-Changes in chloride concentrations in water from three wells in the city of Galveston's "old" well fiel at Alta Loma

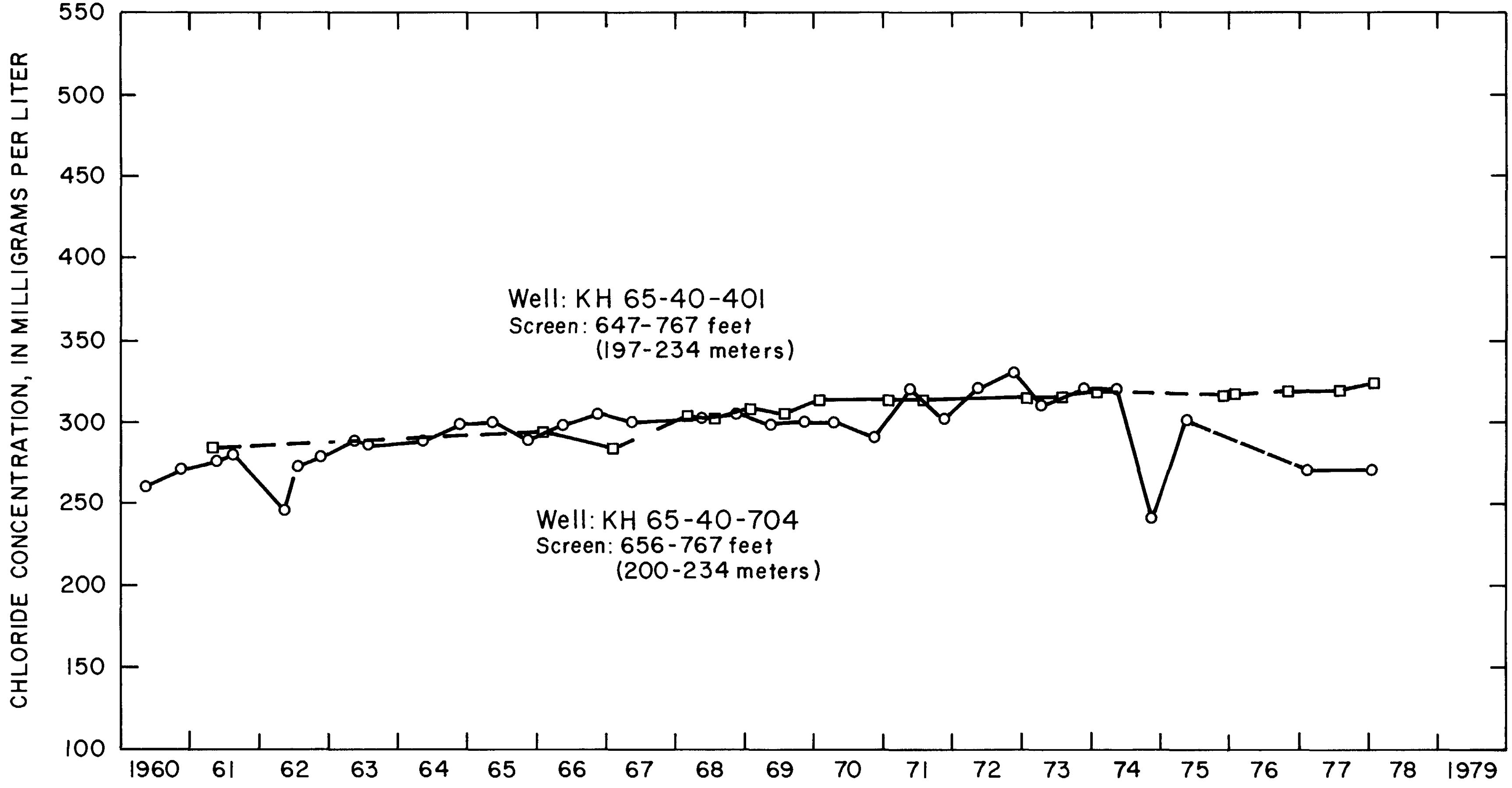

Figure 21.-Changes in chloride concentrations in water from two wells in the city of Galveston's "new"

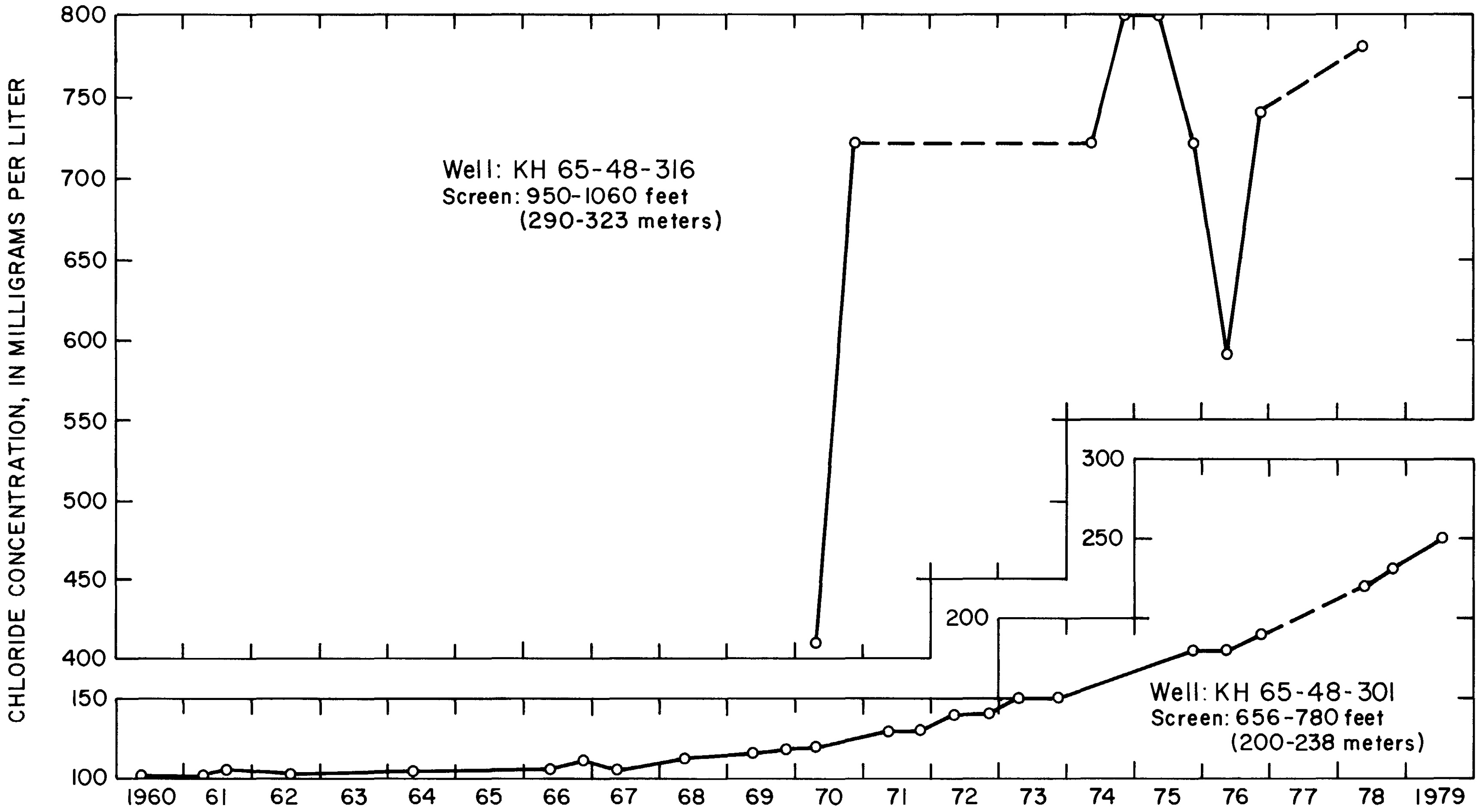

Figure 22.-Changes in chloride concentrations in water from two wells in the Texas City area

SUMMARY AND CONCLUSIONS

Withdrawals of ground water in the Houston district during 1979 were about 456 Mgal/d (20 m^3/s) as compared to 505 Mgal/d (22.1 m^3/s) during 1975. Ground-water withdrawals decreased during 1977 after surface water from Lake Livingston was made available in the Pasadena, Baytown-La Porte, and Johnson Space Center areas. Water levels in wells rose in southeastern Harris County and in Galveston County, but declined in the northern and western parts of Harris County.

Water levels rose as much as 110 feet (33.5 m) in wells completed in the Chicot aquifer during 1975-80 in the Baytown-La Porte area and declined as much as 60 feet (18.3 m) in the northeastern part of the Katy area. The greatest depth to water was 275 feet (83.8 m) below sea level in the Houston-Pasadena areas.

Water levels rose as much as 150 feet (45.7 m) in wells completed in the Evangeline aquifer in the Pasadena area and declined as much as 70 feet (21.3 m) in the Houston area during 1975-80. The greatest depth to water was 350 feet (106.7 m) below sea level in the Houston area.

Chloride concentrations in water from wells in the Alta Loma area have not changed significantly during 1975-79. Slight decreases in chloride concentrations in water from some wells in the "old" well field indicate a slight recession of the freshwater-saltwater interface as a result of decreased withdrawals. Chloride concentrations in water from wells in the southwest part of the Texas City area has increased during the past 10 years. The increase in concentration was large and rapid in water from a well completed in the Alta Loma Sand. The chloride concentration increased from 410 mg/L during 1970 to 780 mg/L during 1978. Chloride concentration in water from a shallower well completed in the middle part of the Chicot aquifer gradually has increased from 102 mg/L during 1960 to 250 mg/L during 1979. The increases are probably due to updip migration of the freshwater-saltwater interface.

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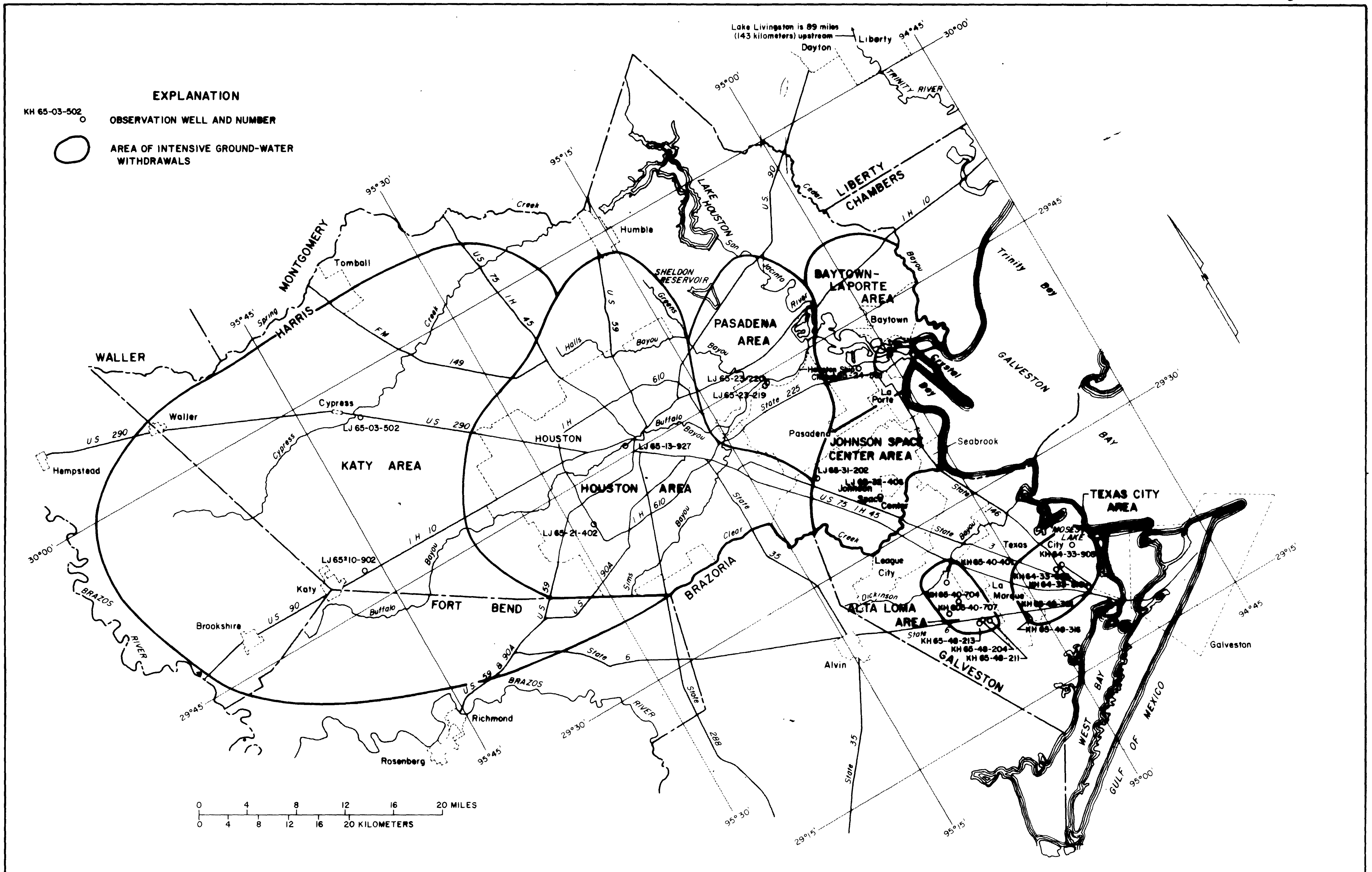


Base from Texas Department of Highways and Public Transportation General Highway Map

Figure 2.-Location of observation wells and areas of intensive ground-water withdrawals

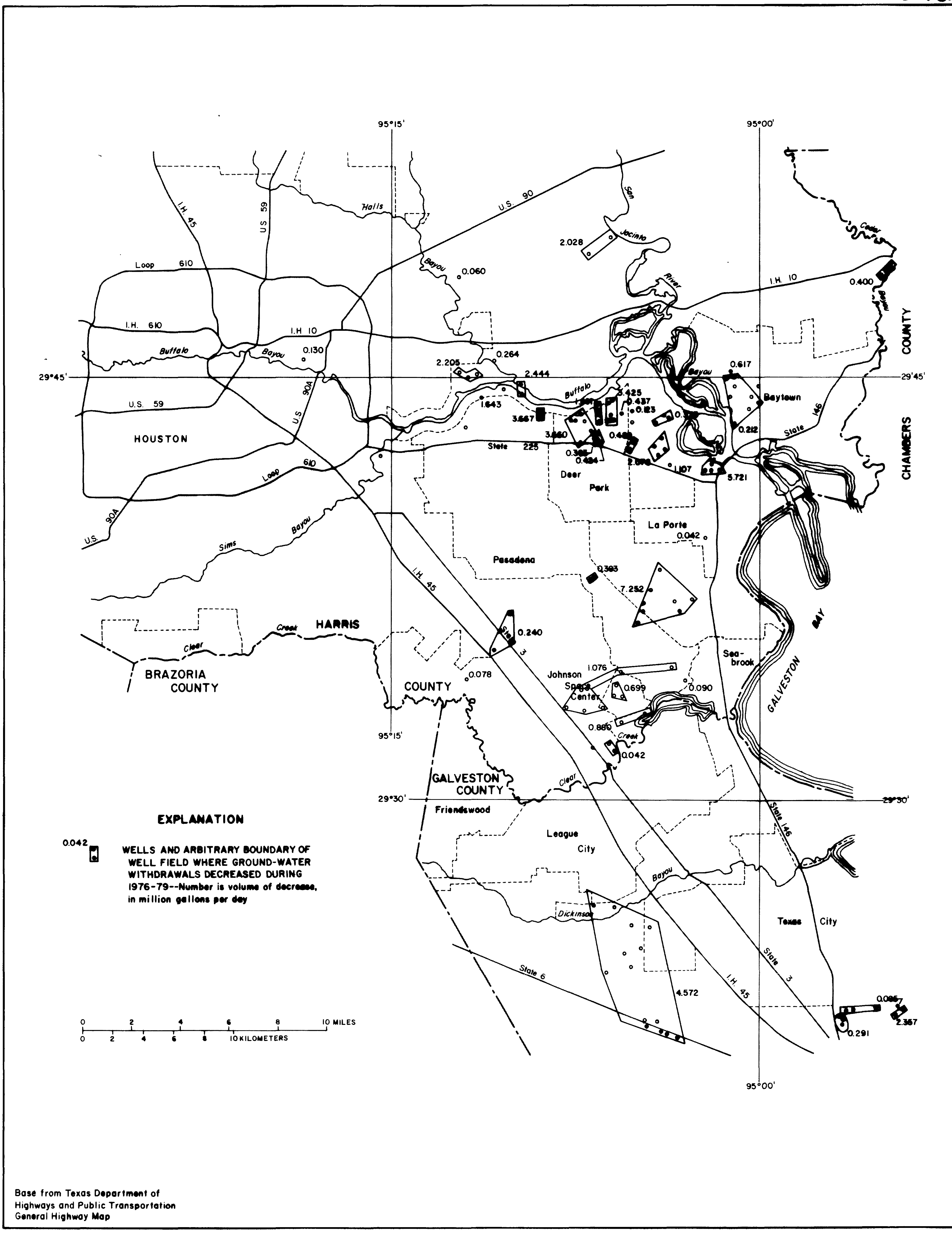


Figure 3.-Location and rate of decrease in ground-water production from the Chicot aquifer, 1976-79

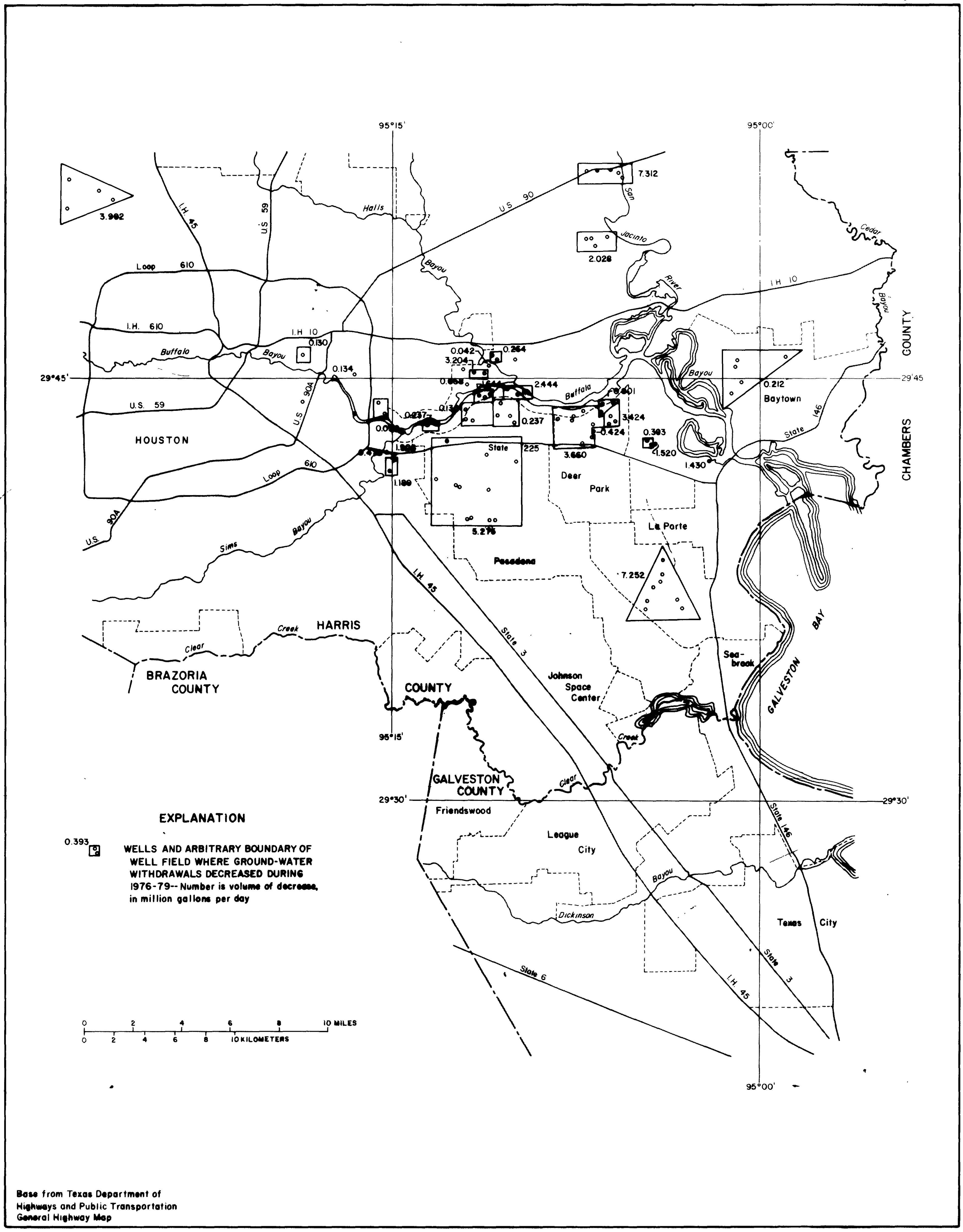
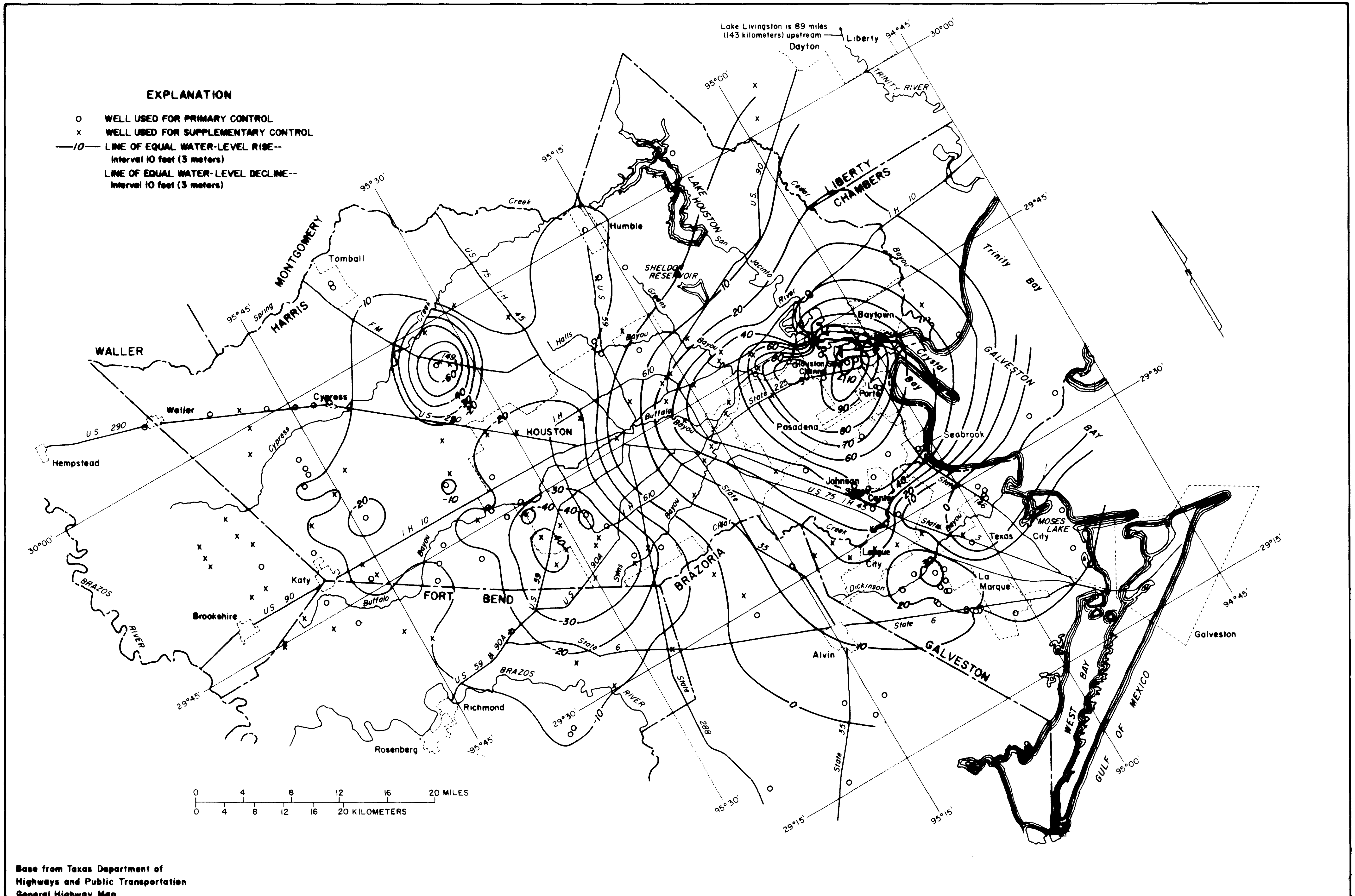


Figure 4.-Location and rate of decrease in ground-water production from the Evangeline aquifer, 1976-79



Base from Texas Department of Highways and Public Transportation General Highway Map

Figure 5.- Approximate water-level changes in wells completed in the Chicot aquifer, spring 1975 to spring 1980

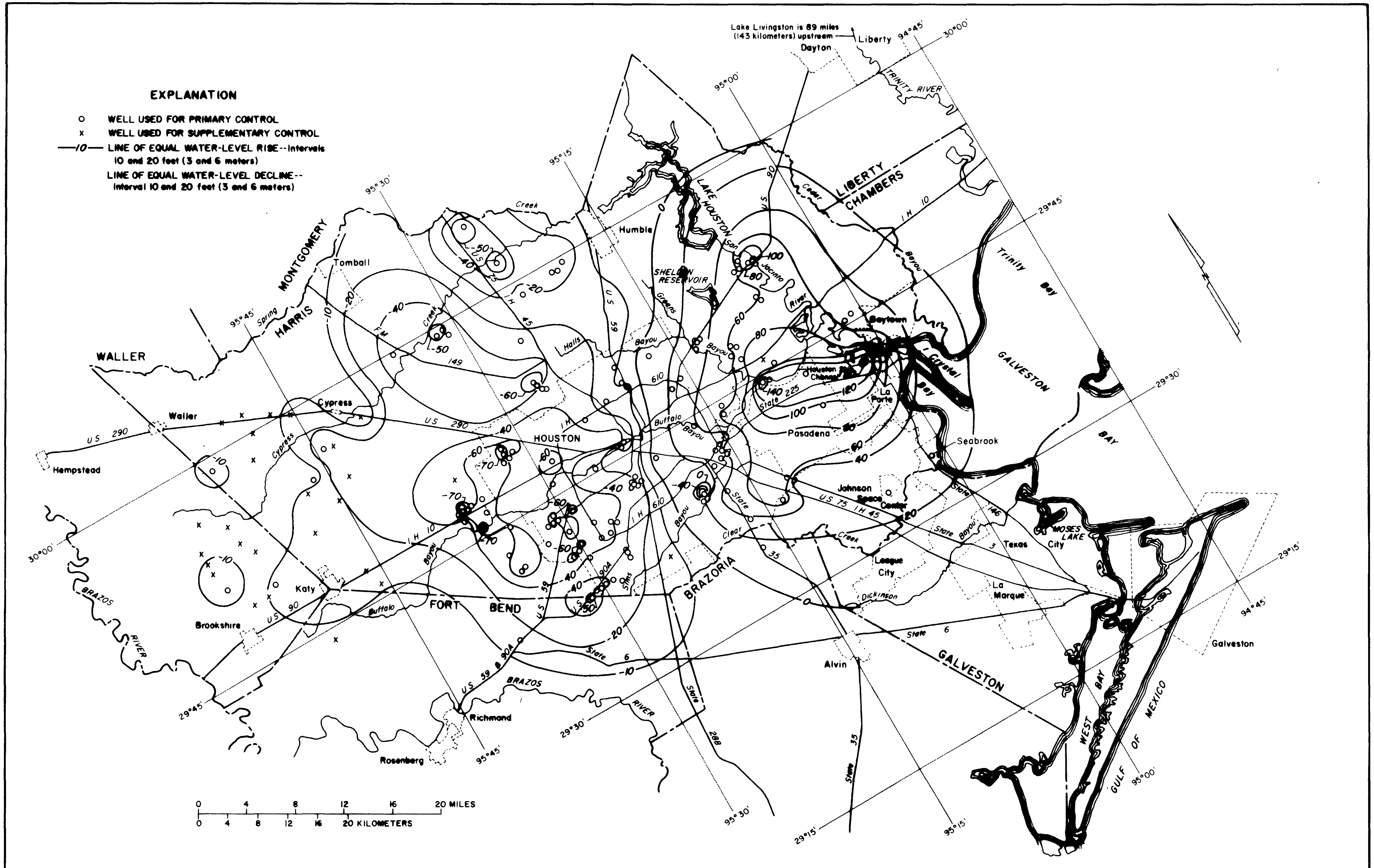


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Figure 6.-Approximate water-level changes in wells completed in the Evangeline aquifer, spring 1975 to spring 1980

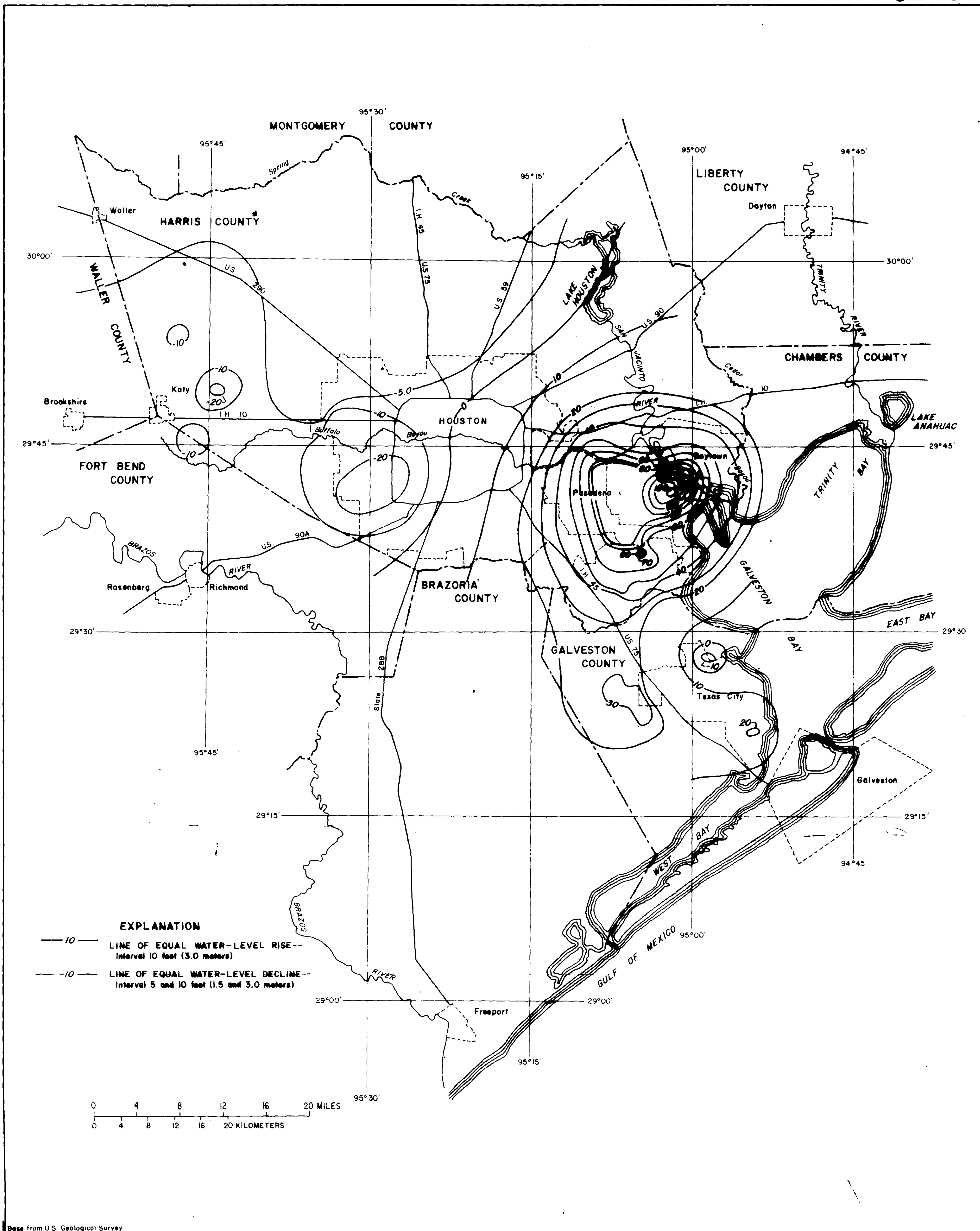

Figure 7.-Approximate water-level changes in wells completed in the Chicot aquifer, spring 1977 to spring 1980

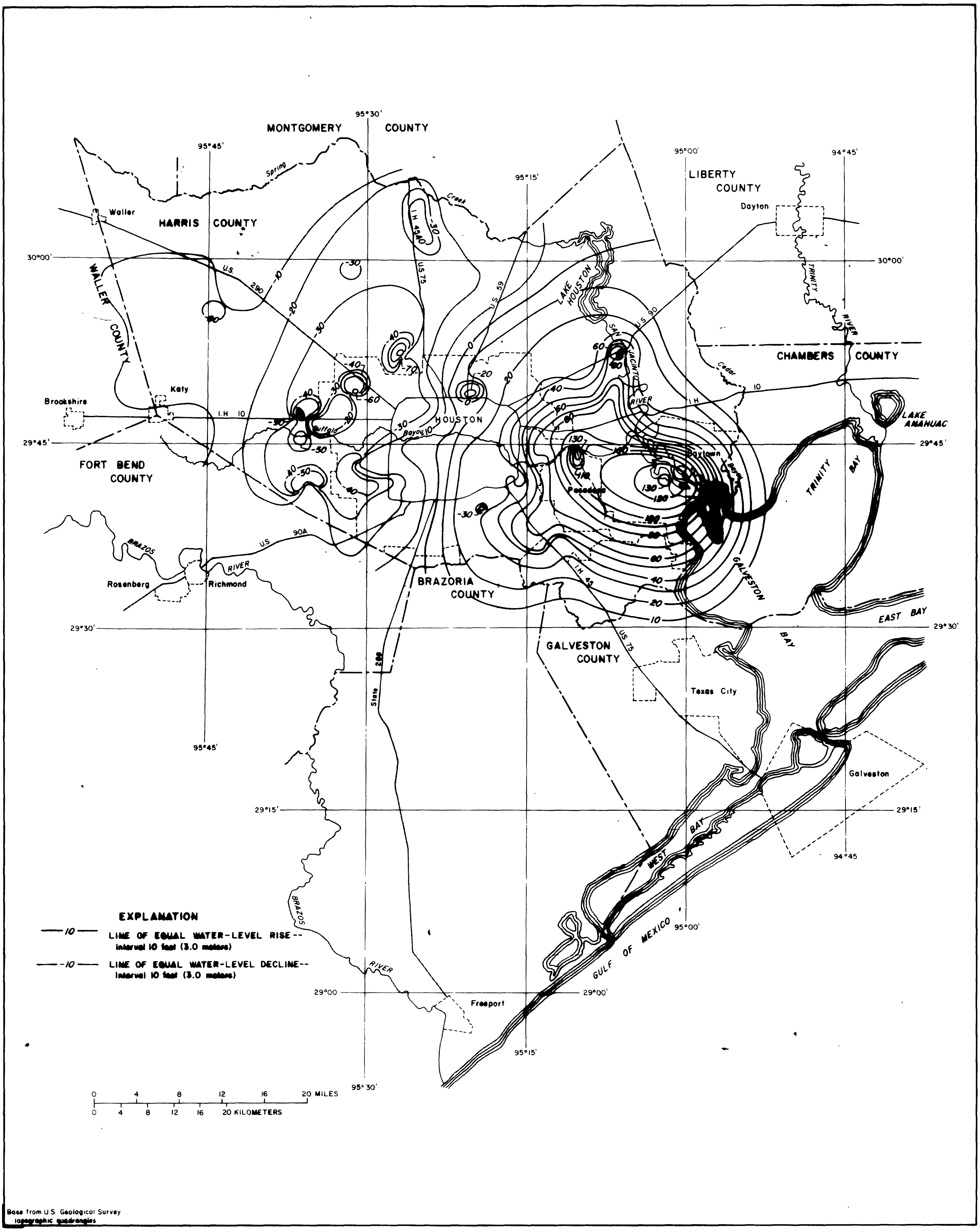

Figure 8.-Approximate water-level changes in wells completed in the Evangeline aquifer, spring 1977 to spring 1980

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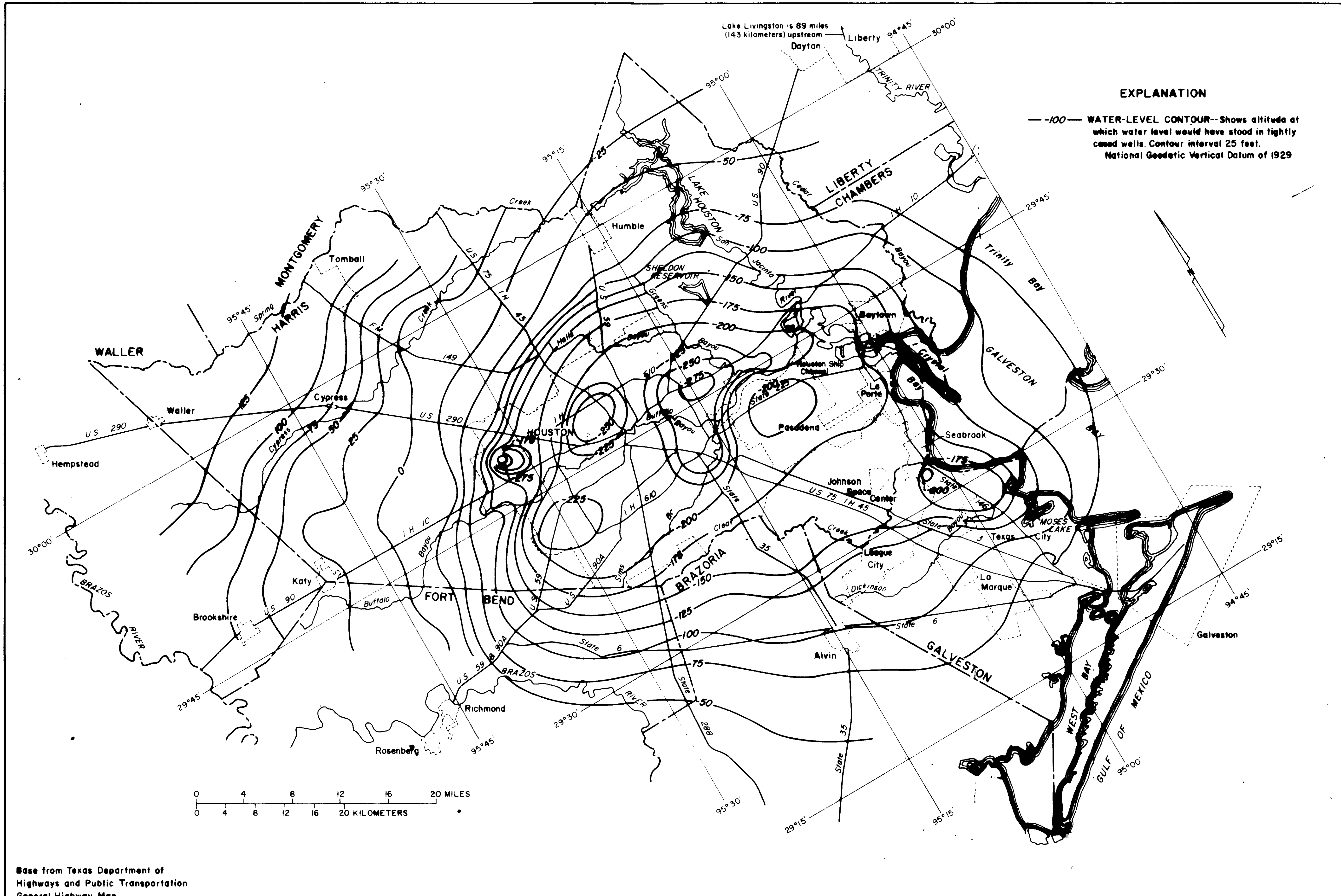
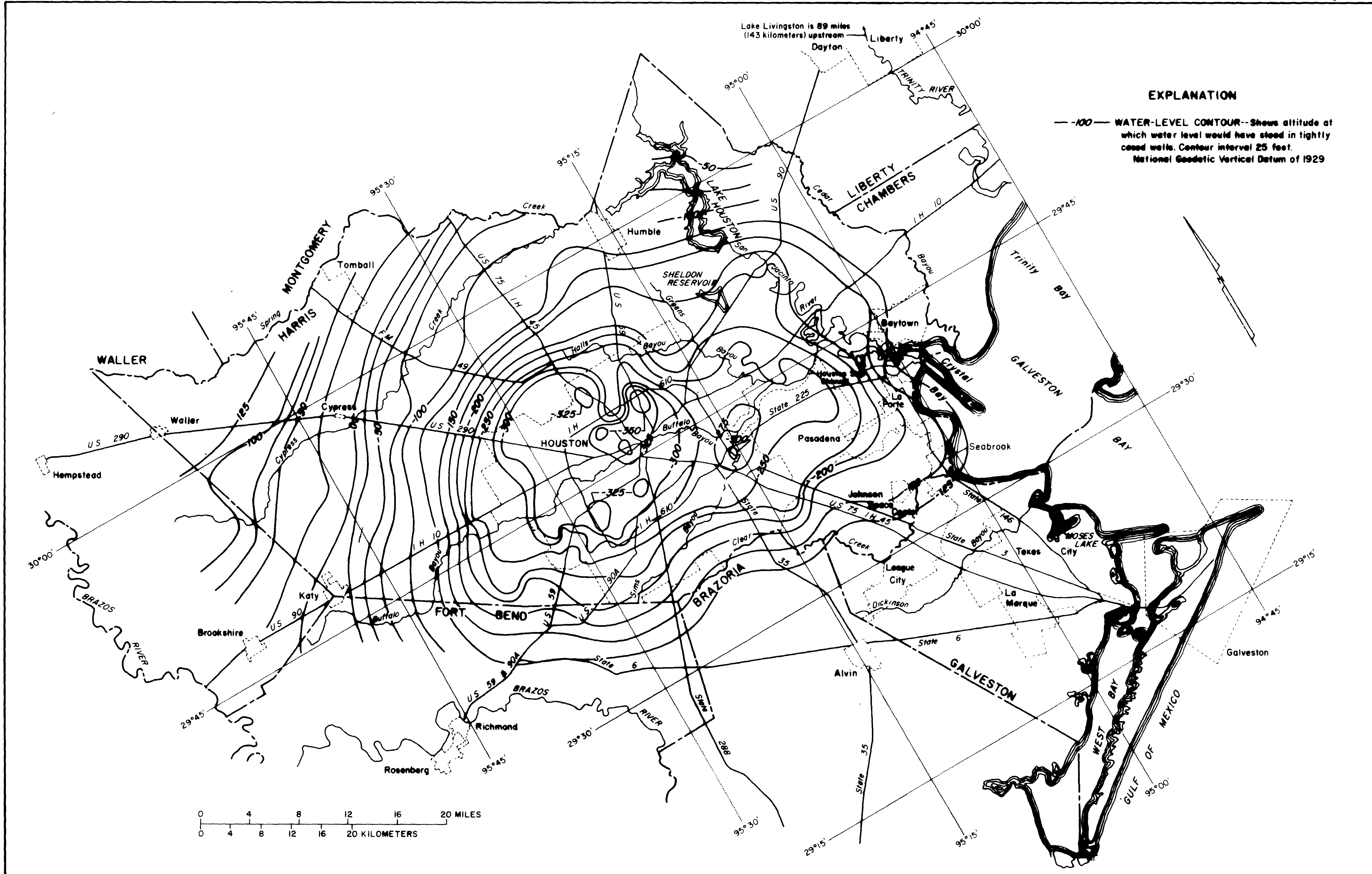


Base from Texas Department of Highways and Public Transportation General Highway Map

Figure 9.-Approximate altitude of water levels in wells completed in the Chicot aquifer, spring 1980



Base from Texas Department of Highways and Public Transportation General Highway Map

Figure 10.-Approximate altitude of water levels in wells completed in the Evangeline aquifer, spring 1980

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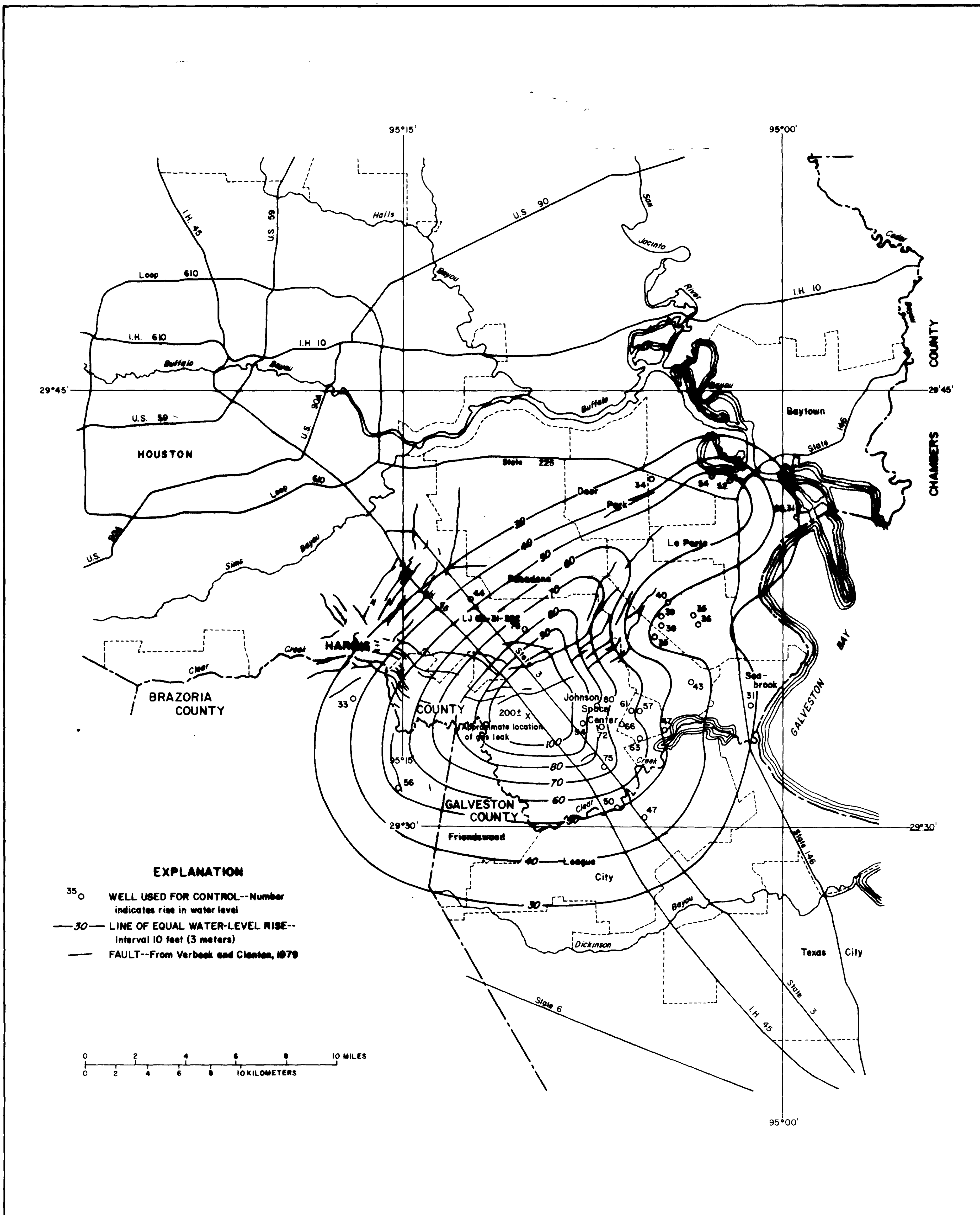

Base from Texas Department of Highways and Public Transportation General Highway Map

Figure 18.-Changes in water levels in wells completed in the Chicot aquifer caused by a leaking gas well