Report 309

Ground-Water Conditions in Texas, 1980-1985

October 1988

Texas Water Development Board

TEXAS WATER DEVELOPMENT BOARD

REPORT 309

GROUND-WATER CONDITIONS IN TEXAS, 1980-1985

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GROUND-WATER UNIT

October 1988

TEXAS WATER DEVELOPMENT BOARD

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ABSTRACT

In 1984, the total water use in Texas was 15,552,222 acre-feet, of which ground water comprised 60 percent (8,854,470 acre-feet), with pumpage for agricultural purposes accounting for 78 percent of the latter. The average annual quantity of ground water available from the State's aquifers was estimated to be 12.9 million acre-feet in 1980 and is expected to be 9.6 million acre-feet in 2030 based on current and projected rates of water use.

Irrigation pumpage experienced a 23 percent decline in 1984 from that recorded in 1980. Correspondingly, water levels rose in the southern High Plains, the irrigated areas of West Texas, and upper Gulf Coast. These rises were due to a combination of factors including reduced pumpage, recharge, and water-level equalization. Large declines of water levels continue to occur, however, in the Central Texas area where large quantities of ground water are withdrawn from the Trinity Group aquifers for municipal and industrial use. Except for the Dell City area, no areas of large scale water-quality degradation have been identified.

Ground-water overdraft and quality degradation are of particular interest to entities involved in water resources planning and development because of the State's expanding economic activities, many of which are ground-water dependent.

Aquifer monitoring networks and related activities are essential to the ability to continually and accurately determine the status of the State's ground-water resources. It is imperative that these monitoring networks and related activities be properly maintained as needed to insure the proper quantification, protection, and orderly development of these resources for future generations of Texans.

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GROUND-WATER CONDITIONS IN TEXAS

1980 - 1985

INTRODUCTION

Purpose

The development of the State's ground-water resources has been essential to satisfy numerous beneficial purposes. The need, however, has created may local, regional, and statewide problems of varying degree. Ground-water overdraft and quality degradation are of particular interest to entities involved in water resources planning and development because of expanding economic activities that are ground-water dependent. The continued use of the State's ground-water resources to satisfy the numerous beneficial purposes it serves has resulted in the implementation of various local, regional, and statewide programs to safeguard development of this natural resource. This report is intended to present information on the ground-water conditions of the State's aquifers and thereby aid local and regional water users in operating their systems and planning to meet future water needs.

Scope

Aquifer monitoring networks and related activities are essential to the ability to continually and accurately determine the occurrence, availability, and dependability of ground water in the State's aquifers. The Board operates several programs that are financed solely through State-provided funds to achieve these objectives. This initial report on statewide ground-water conditions: (1) assesses the data collected annually since 1980 by the Board and other cooperating agencies involved in monitoring the State's ground-water resources, and (2) presents these data to describe the continuing development and use of these aquifer resources and the effects and results of their uses. Four broad information topics are presented: (1) condensed descriptions of the major and minor aquifers and their water-bearing properties; (2) changes, if any, in water quantity identified by changes in the depths to water since 1980; (3) changes, if any, in water quality identified by changes in the chemical constituents of the ground waters sampled and analyzed since 1980; and (4) quantities of ground-water pumpage (usage) for municipal, industrial, irrigation, and other purposes as compiled by the Texas Water Development Board for 1980 and 1984.

Changes in the depth to water were determined by reviewing the records of the 8,200 wells which comprise the statewide water-level observation well network. The Board is responsible for measuring 5,400 of the wells and the remaining 2,800 wells are serviced by other entities. The Board does not measure wells in areas where other entities collect data. Maps and hydrographs showing changes in water levels were prepared for the period 1980 to 1985 and are presented in this report.

MAJOR AQUIFERS

A major aquifer is defined as one which yields large quantities of water in a comparatively large area of the State. The location and extent of the major aquifers are shown on Figure 1, and their water-bearing relationships, characteristics, and properties are described below.

High Plains (Ogallala)

The High Plains aquifer of Texas occurs in all or parts of 46 counties in the Panhandle region (Figure 1). The aquifer consists of the saturated sediments of the Ogallala Formation, and saturated sediments of Cretaceous, Jurassic, and Triassic ages which contain potable water and that are in hydraulic continuity with the Ogallala Formation. Hydraulically connected Cretaceous water-bearing strata occur in all or parts of 14 counties in the southern High Plains and in northwest Dallam County. Jurassic water-bearing strata occur in north central Dallam County, and Triassic water-bearing strata occur in Hansford, Hutchinson, Moore, and Randall Counties to the north and in all or parts of Andrews, Crosby, Dickens, Gaines, Garza, and Motley Counties to the south and southwest.

The Ogallala Formation, which is the major water-bearing unit of the High Plains aquifer, is composed predominantly of unconsolidated, fine- to coarse-grained, gray to red sand, clay, and silt. In places, it contains some quartz gravel and caliche. Water-bearing areas of the Ogallala are hydraulically connected laterally except where the Canadian River has eroded partially or totally through the formation. In this region, the river has separated the High Plains proper into two areas referred to as the North High Plains and the South High Plains. Ground water moves slowly through the Ogallala Formation in a generally southeastward direction. Its limited effective recharge, which is derived from precipitation on the land surface, is impeded by relatively impervious clay layers and caliche which overlie much of the formation. The Ogallala Formation has a maximum known thickness of almost 900 feet. Its saturated thickness ranges from a few feet to more than 525 feet with the greatest saturated thickness occurring in the North High Plains. Yields of individual wells range from less than 100 to more than 2,000 gal/min. Ogallala ground water is generally hard and contains between 300 and 1,000 mg/l of dissolved solids. High chloride concentrations occur locally in the ground water near large saline playa lakes and elsewhere in the South High Plains where the water table is shallow.

Most of the water pumped from the High Plains (Ogallala) aquifer is used for irrigation, which is widespread throughout the region, while moderate to heavy pumpage for municipal supplies occurs locally. In recent years, reduced irrigation pumpage has resulted in a decreasing rate of water-level declines. Figure 2 shows the changes in water levels for the period 1980 through 1985. This map illustrates that much of the area south of Lubbock has experienced water-level rises locally, up to six feet per year. Areas of less pronounced rises, generally less than two feet per year, are occurring in the North High Plains, primarily in the vicinity of the Canadian River "breaks." Water-level declines are still occurring, however, in the heavily irrigated areas between Lubbock and Amarillo and north of the Canadian River. In these areas the rate

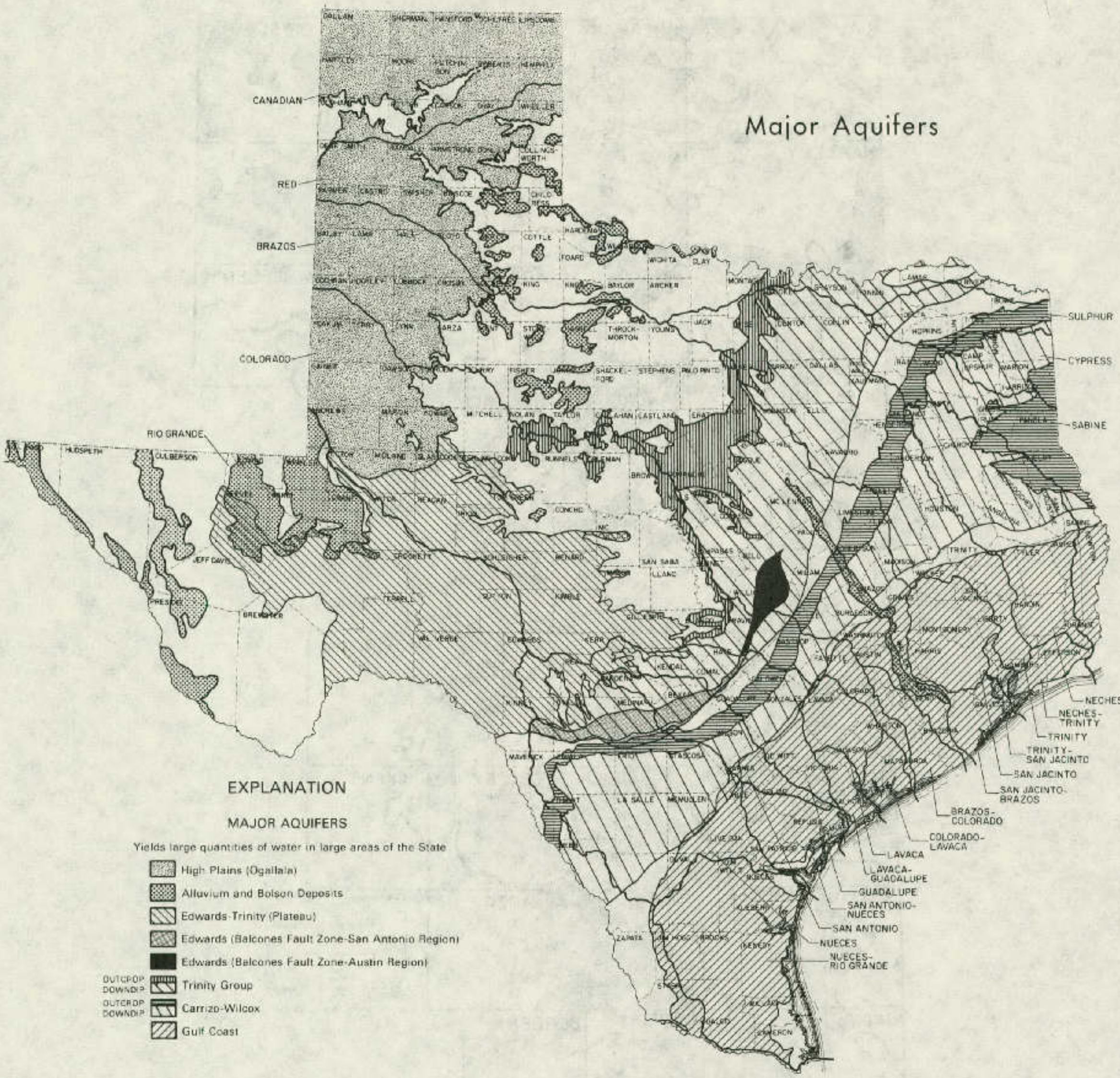


Figure 1

Map of Texas Showing Major Aquifers, and River and Coastal Basins

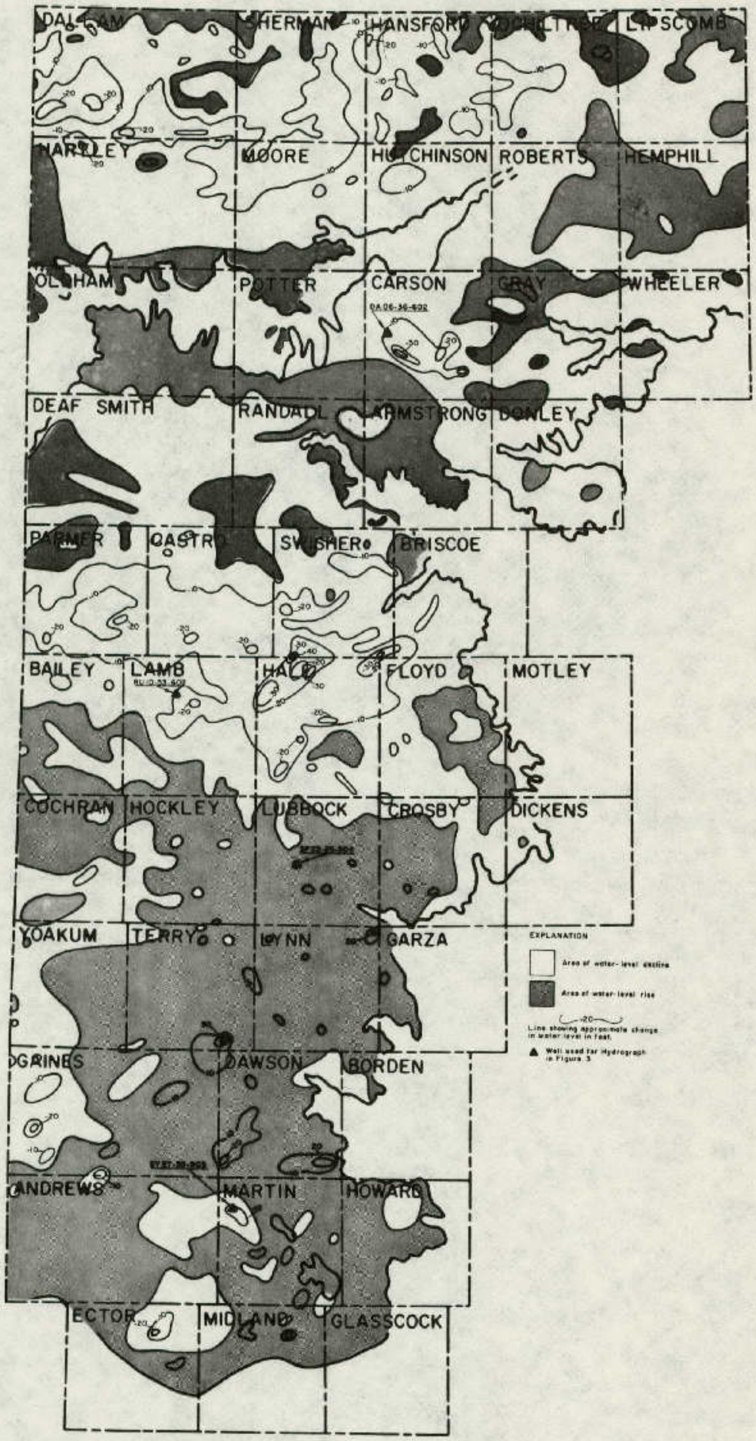


Figure 2
Map Showing Approximate Changes of Water Levels in the High Plains Aquifer for the Period 1980-85

of decline is typically about two feet per year, with some local areas experiencing declines of up to six feet per year. Hydrographs of selected wells in Carson, Lamb, and Martin Counties show that water levels are declining at rates of two to six feet per year, while in Lubbock County water levels are rising a little over one foot per year (Figure 3).

Estimated pumpage from the High Plains aquifer in 1984 totaled 5,321,379 acre-feet, a 26 percent reduction from the 1980 total (Table 1). This reduction is primarily the result of a 27 percent decrease in pumpage for irrigation purposes, although irrigation still accounts for 96 percent of the total annual pumpage. This trend of reduced irrigation pumpage is a contributing factor to the general rise in water levels occurring over a vast portion of the High Plains.

Carrizo-Wilcox

The Carrizo-Wilcox aquifer is one of the most extensive aquifers in Texas, extending from Mexico northeastward through Texas into Arkansas and Louisiana (Figure 1). The aquifer consists predominantly of hydraulically connected ferruginous, cross-bedded sand with clay, sandstone, silt, lignite, and gravel of the Wilcox Group and overlying Carrizo Formation. Recharge to the Carrizo-Wilcox aquifer is by precipitation and by streams crossing the outcrop area. The Wilcox Group and Carrizo Formation dip beneath the land surface toward the Gulf except in the East Texas structural basin adjacent to the Sabine Uplift where the formations form a trough. The aquifer ranges in thickness from a few feet to more than 3,000 feet, and yields of high-capacity wells range from 500 to 3,000 gal/min. The Carrizo-Wilcox aquifer yields fresh to slightly saline water. In the outcrop area, although the aquifer contains hard water, it is usually low in dissolved-solids content. Downdip, the water is softer but contains more dissolved solids. For irrigation use, the water has a low to high salinity hazard and low to medium sodium (alkali) hazard. In Dimmit and Zavala Counties, saline water from overlying sediments has leaked through individual well bores and contaminated the aquifer's native ground water and the potential exists for movement of the contaminated water toward other wells during periods of heavy pumpage.

Maps constructed to determine water-level changes for the periods 1975 through 1985 and 1980 through 1985 indicated that in general no significant declines have occurred as a result of pumpage from the Carrizo-Wilcox aquifer in South and Central Texas. Within the Winter Garden area, reductions in pumpage due to (1) high fuel costs, and (2) changes in crops irrigated and irrigation practices, have apparently slowed, and even temporarily halted, the former downward trend of water levels in this heavily irrigated area. This is best illustrated by the hydrograph, Figure 4, of a well located in the Winter Garden area near the City of Carrizo Springs. The hydrograph shows that prior to 1980 there was a general decline in water levels, but that since 1980 there has been a general rise in water levels through 1985.

Additionally, municipal and industrial well fields in Angelina and Nacogdoches Counties which had previously experienced large water-level declines now appear to have stabilized and, in recent years, water levels have risen (Figure 5). Similar rises can also be seen in Anderson County in the vicinity of Palestine. In some portions of East Texas, however, municipal requirements

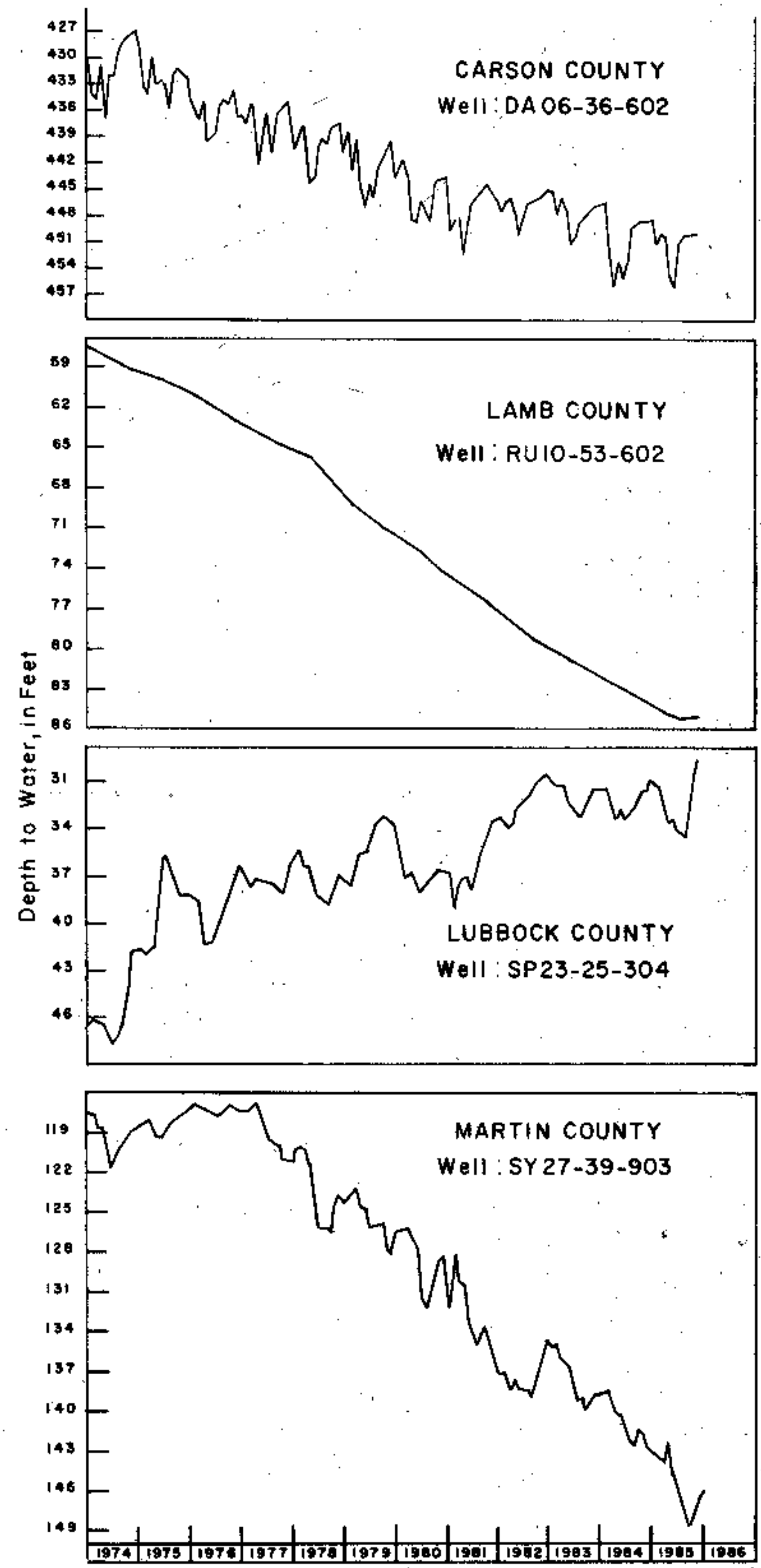


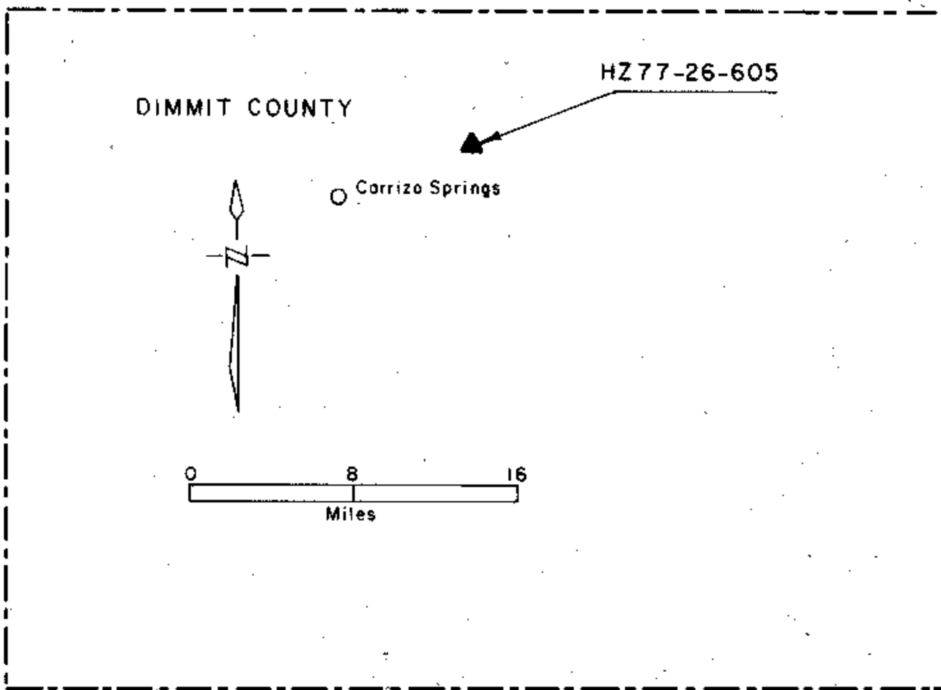
Figure 3

Hydrographs of Selected Wells Completed in the High Plains Aquifer

Table 1. ESTIMATED GROUND-WATER PUMPAGE (IN ACRE-FEET) BY AQUIFERS, 1980 AND 1984

	Municipal		Manufacturing		Livestock		Irrigation		Steam Elec.		Mining		TOTALS	
	1980	1984	1980	1984	1980	1984	1980	1984	1980	1984	1980	1984	1980	1984
Alluvium-El Paso1/	86,700	93,398	5,178	6,578	453	880	4,500	8,222	6,983	5,052	0	184	103,814	114,314
Alluvium-Salt Bolson2/	984	1,740	6	0	605	506	99,100	21,349	0	0	0	1,555	100,695	25,150
Alluvium-Pecos	10,984	10,634	9	6	1,180	1,934	160,318	90,545	3,500	3,000	13,508	10,680	189,499	116,799
Alluvium-Seymour3/	11,543	11,563	26	91	660	521	167,693	146,931	0	0	147	1,592	180,069	160,698
Alluvium-Brazos River	0	0	0	0	85	168	27,427	40,179	0	0	1,100	61	28,612	40,408
Blaine Gypsum	175	361	0	0	212	124	10,941	14,845	0	0	0	0	20,328	15,330
Blossom Sand	1,361	1,171	1	0	295	166	0	0	0	0	0	0	1,657	1,337
Bone Spring-Victorio Peak Limestone	775	667	0	0	0	120	132,200	100,000	0	0	0	0	132,975	100,787
Capitan Limestone	0	14	0	0	0	60	4,600	119	0	0	0	110	4,600	303
Carrizo-Wilcox	119,880	144,705	26,173	24,910	12,715	12,813	264,912	269,956	1,315	9,465	12,247	13,268	437,242	475,117
Dockum Group (S.R.)	10,847	12,081	35	291	192	449	14,931	9,614	3,504	3,132	13,529	10,113	43,038	35,680
Edwards-BFZ	262,436	306,568	9,383	6,382	802	1,476	132,737	191,999	724	0	2,268	680	408,350	507,105
Edwards-Trinity HP	4/	223	4/	9	4/	289	4/	14,918	4/	0	4/	944	4/	16,383
Edwards-Trinity Plateau	23,680	24,550	644	1,218	11,659	7,970	154,715	181,960	2,087	2,391	14,368	16,185	207,153	234,274
Ellenburger-San Saba	2,184	3,598	0	20	872	1,550	958	1,999	0	0	0	38	4,014	7,205
Gulf Coast	537,876	588,574	111,836	95,798	13,018	12,126	669,579	550,607	26,405	18,343	25,422	19,310	1,384,136	1,284,758
Hickory Sandstone	3,853	4,306	1,633	2,422	1,745	1,482	19,311	17,807	0	0	0	166	26,542	26,183
High Plains (Ogallala)	94,137	107,358	35,980	34,776	38,645	52,916	6,977,496	5,091,364	6,481	9,605	74,350	25,360	7,227,089	5,321,379
Igneous Rocks	2,569	2,755	4	0	100	394	600	1,301	0	0	0	100	3,273	4,550
Marathon Limestone	86	65	0	0	0	20	0	0	0	0	0	0	86	85
Marble Falls	784	275	81	200	176	306	0	213	0	0	0	147	1,041	1,141
Nacatoch Sand	3,213	2,863	4	17	755	625	515	1,374	2	0	0	88	4,489	4,967
Other Undif.	20,992	20,788	600	2,420	14,560	8,844	55,895	85,239	334	205	17,019	7,171	109,400	124,667
Queen City	12,539	6,864	55	56	4,824	4,751	6,904	5,099	170	0	2,447	4,506	26,939	21,276
Rustler	0	6	0	0	197	162	0	124	0	0	0	68	197	360
Sparta	4,406	4,370	26	147	2,053	1,860	5,061	2,791	0	0	173	63	11,719	9,231
Trinity Group	111,242	119,575	4,796	6,161	11,861	10,595	34,671	48,833	1,014	2,065	1,772	2,818	165,356	190,047
Woodbine	17,180	8,600	2,044	1,378	2,066	1,636	2,907	2,441	452	352	19	529	24,668	14,936
GRAND TOTALS	1,340,426	1,477,672	198,514	182,880	119,730	124,743	8,956,971	6,899,829	52,971	53,610	178,369	115,736	10,846,981	8,854,470

1/ Includes some pumpage in Red Light Draw Bolson
2/ Includes some pumpage in Green River Valley, Presidio, and Redford Bolsons
3/ Includes some pumpage from Leona Alluvium
4/ Pumpage from the Edwards-Trinity (High Plains) aquifer for 1980 is included with that of the Ogallala Formation; for 1984 it is reported separately



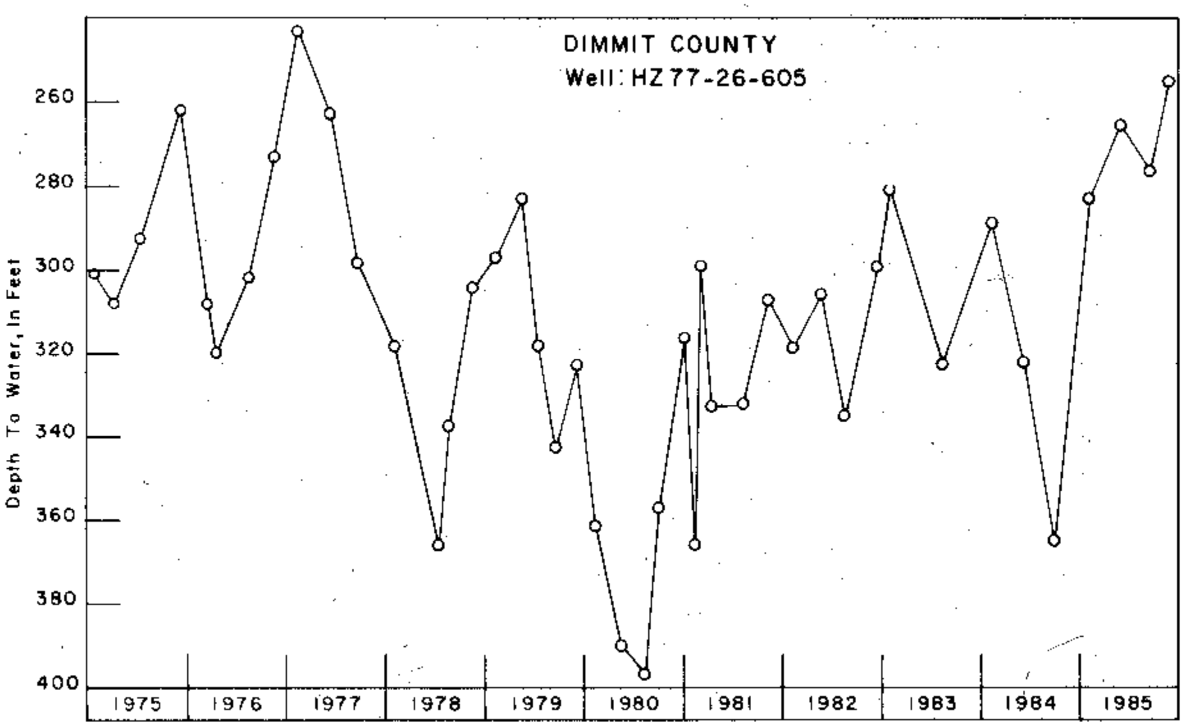


Figure 4

Hydrograph of Well Completed in the Carrizo-Wilcox Aquifer Near Carrizo Springs in Dimmit County

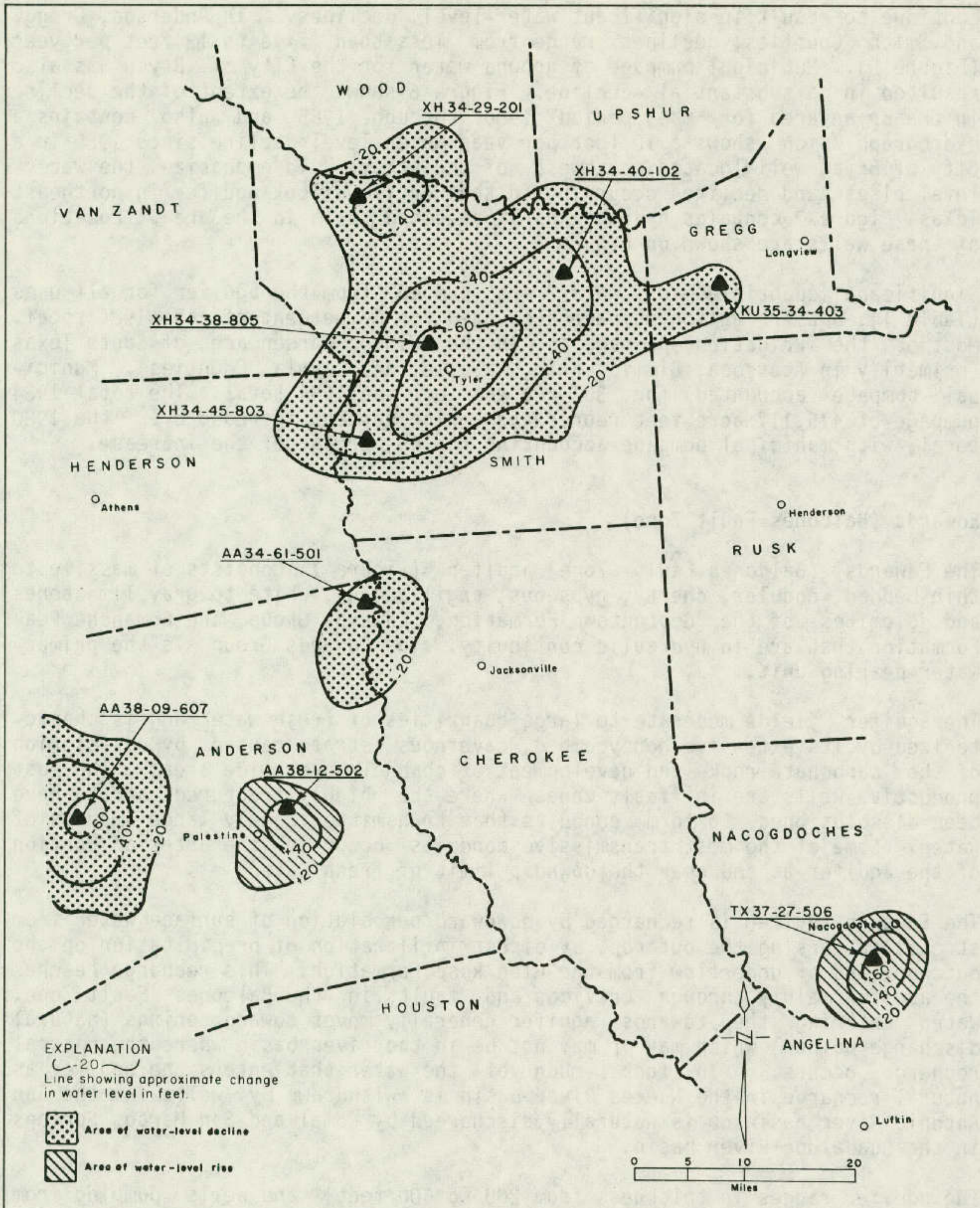


Figure 5

Map Showing Approximate Changes of Water Levels in the Carrizo-Wilcox Aquifer for the Period 1980-85 continue to result in significant water-level declines. In Anderson, Gregg, and Smith Counties, declines range from less than five to 12 feet per year (Figure 5). Municipal pumpage of ground water for the City of Bryan has also resulted in a substantial decline. Figure 6 shows the extent of the decline in the Bryan area for the period 1980 through 1985 and also contains a hydrograph which shows a 10 foot per year water-level decline since 1980 in a City of Bryan well located northwest of the city. To emphasize the water-level rises and declines occurring in the Carrizo-Wilcox aquifer in northeast Texas, Figure 7 contains hydrographs of selected wells in the area. Locations of these wells are shown on Figure 5.

Significant quantities of water are pumped from the aquifer for all uses (Table 1), but irrigation pumpage accounted for 57 percent of the 1984 total. Most of the irrigation pumpage is in the Winter Garden area of South Texas (primarily in Atascosa, Dimmit, Frio, LaSalle, and Zavala Counties). Municipal pumpage accounted for 30 percent of the 1984 total. The total 1984 pumpage of 475,117 acre-feet represents a nine percent increase over the 1980 total, with municipal pumpage accounting for 66 percent of the increase.

Edwards (Balcones Fault Zone)

The Edwards (Balcones Fault Zone) aquifer (Figure 1) consists of massive to thin-bedded, nodular, cherty, gypseous, argillaceous, white to gray limestones and dolomites of the Georgetown Formation, Edwards Group, and Comanche Peak Formation that are in hydraulic continuity. The Edwards Group is the primary water-bearing unit.

The aquifer yields moderate to large quantities of fresh water and is characterized by its extensive honeycombed, cavernous strata caused by dissolution of the carbonate rock and development of channels over wide areas. The most productive wells are in fault zones where the highly fractured strata have been dissolutioned to form conduits that transmit extremely large amounts of water. Some of the most transmissive conduits occur in the artesian portion of the aquifer at and near the downdip limit of fresh water.

The Edwards aquifer is recharged by downward percolation of surface water from streams traversing the outcrop, by direct infiltration of precipitation on the outcrop, and by underflow from the Glen Rose Formation. This recharge reaches the aquifer mainly through crevices and faults in the Balcones Fault Zone. Water entering the Edwards aquifer generally moves toward springs (natural discharge points) which may or may not be in the river basin where the natural recharge occurs. In fact, much of the water that enters the aquifer as natural recharge in the Nueces River basin is withdrawn by wells in the San Antonio River basin or is naturally discharged by Comal and San Marcos Springs in the Guadalupe River basin.

The aquifer ranges in thickness from 200 to 600 feet, and wells pumping from the aquifer are among the world's largest with some yielding more than 16,000 gal/min. Ground water withdrawn from the aquifer is generally fresh and is used for public supply, irrigation, industrial, domestic, and livestock watering purposes.

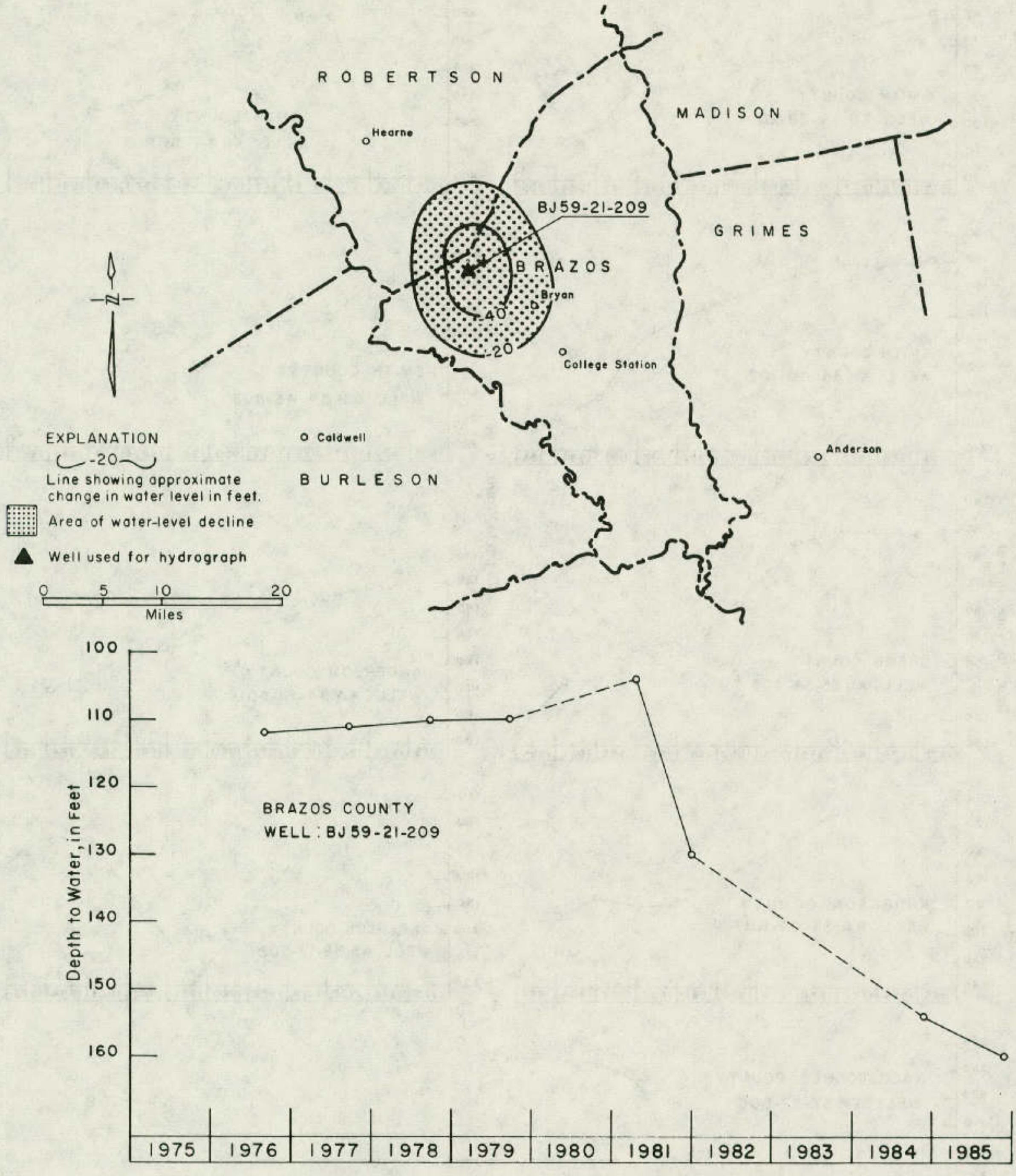


Figure 6

Map Showing Water-Level Declines in the Carrizo-Wilcox Aquifer for the Period 1980-85, and Hydrograph of Well Completed in the Carrizo-Wilcox Aquifer in the Vicinity of Bryan in Brazos County

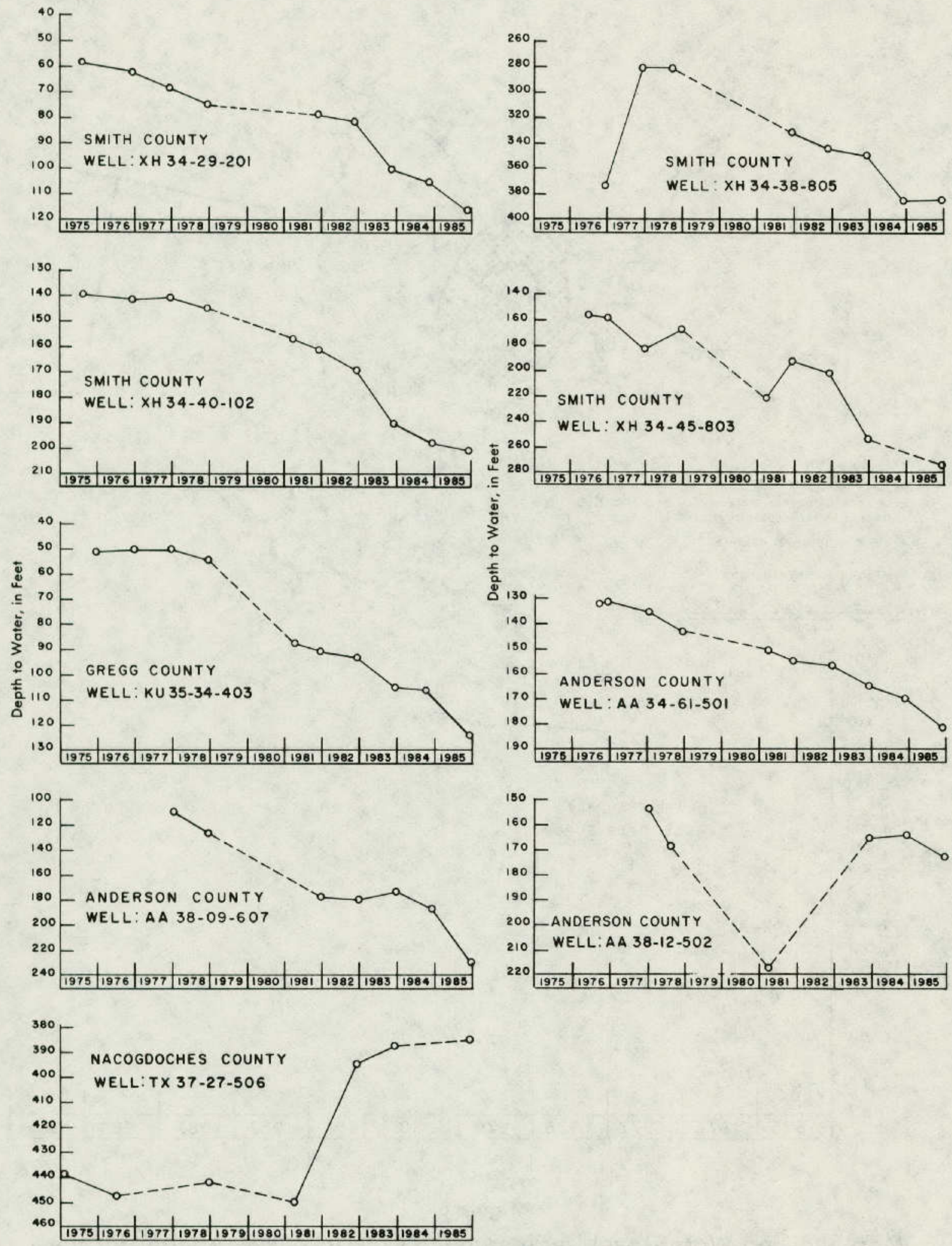


Figure 7
Hydrographs of Selected Wells Completed in the
Carrizo-Wilcox Aquifer in Northeast Texas
(Well locations shown on Figure 5)

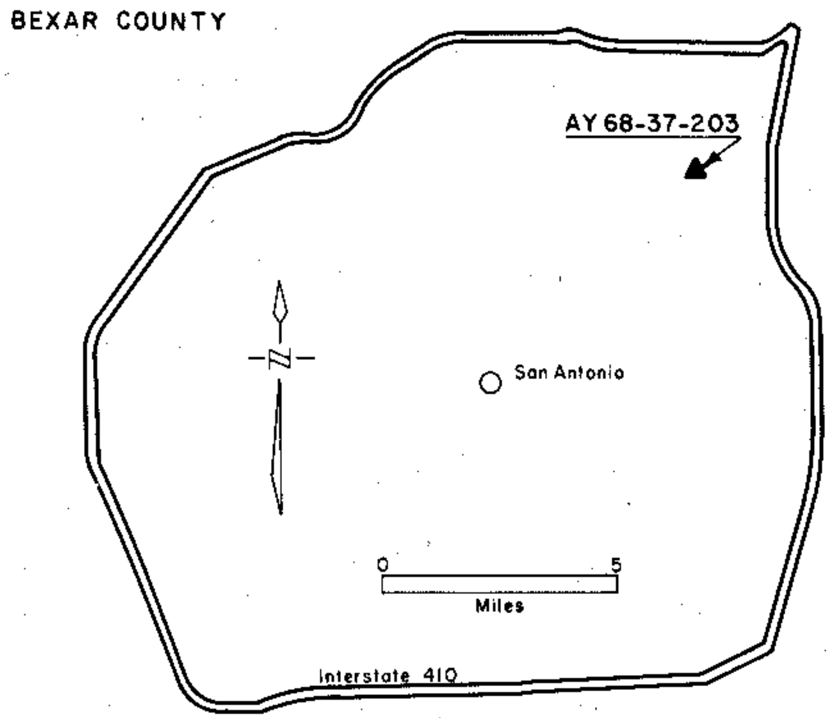
Ground water moves rapidly through the Edwards aquifer. The volume of water in storage as well as the rate of spring flow changes rapidly in response to precipitation and pumpage. Figure 8 shows the hydrograph of an index observation well in San Antonio which reflects the aquifer's water-level response to recharge and discharge conditions during the period 1975 through 1985.

The total 1984 pumpage of 507,105 acre-feet represents a 24 percent increase from the 1980 total, primarily reflecting increases of 17 percent in municipal pumpage and 45 percent in irrigation pumpage (Table 1). With the exception of Kinney County, ground-water pumpage from the Edwards aquifer has increased since 1980 in all counties.

Trinity Group

The aquifers of Trinity Group are composed of the Paluxy, Twin Mountains (Travis Peak in southern Central Texas), and Glen Rose Formations. Where the Glen Rose thins and is no longer a mappable unit, the Paluxy and the Twin Mountains coalesce and become the Antlers Formation. The Trinity Group extends over a large area of North and Central Texas (Figure 1) and is composed primarily of sand with interbedded clay, limestone, dolomite, gravel, and conglomerate. Recharge to the aquifers is primarily in the form of infiltration of precipitation and seepage of surface water from lakes, ponds, streams, and return flows. Aquifer thicknesses range from approximately 100 feet to about 1,200 feet and wells can yield as much as 2,000 gal/min, but in thinner sections most wells yield less than 100 gal/min. Water quality is acceptable for most municipal and industrial purposes; however, the fluoride content in many places exceeds the U.S. Environmental Protection Agency's Safe Drinking Water Act Interim Primary Standards for municipal supplies. Usable quality water (less than 3,000 mg/l dissolved solids) occurs to depths of about 3,500 feet.

Water-level declines in North Central Texas and Central Texas are reflected by data from wells completed primarily in the aquifers of the Trinity Group for the period 1980 through 1985 (Figure 9). The greatest declines were approximately 180 feet at Waco in McLennan County, and in excess of 100 feet near Gatesville in Coryell County. Other, less severe declines, ranging from about 50 feet to under 100 feet, are also shown in Figure 9. Many cities in areas of large decline, such as Gatesville, are shifting a portion or all of their water demands to surface water sources. Figures 10 and 11 are hydrographs which reflect water-level changes in specific wells completed in aquifers of the Trinity Group during the period 1976 to 1986. The average annual decline rates for wells shown range from a low of seven feet per year in Dallas County to 17 feet per year in Gatesville in Coryell County and 18 feet per year in McLennan County. Figure 12 is a map which portrays the water-level declines primarily in Denton County reflected by data from wells completed in the Trinity Group's Paluxy Formation. As indicated, declines exceeded 40 feet during the period 1980 through 1985. Also shown is a hydrograph which reflects the water-level changes from 1976 to 1986 in a well completed in the Paluxy Formation in Denton County. The average annual decline rate from 1976 to 1986 was nine feet per year, whereas that from 1980 through 1985 was eight feet per year. Water-quality problems, such as the potential for encroachment



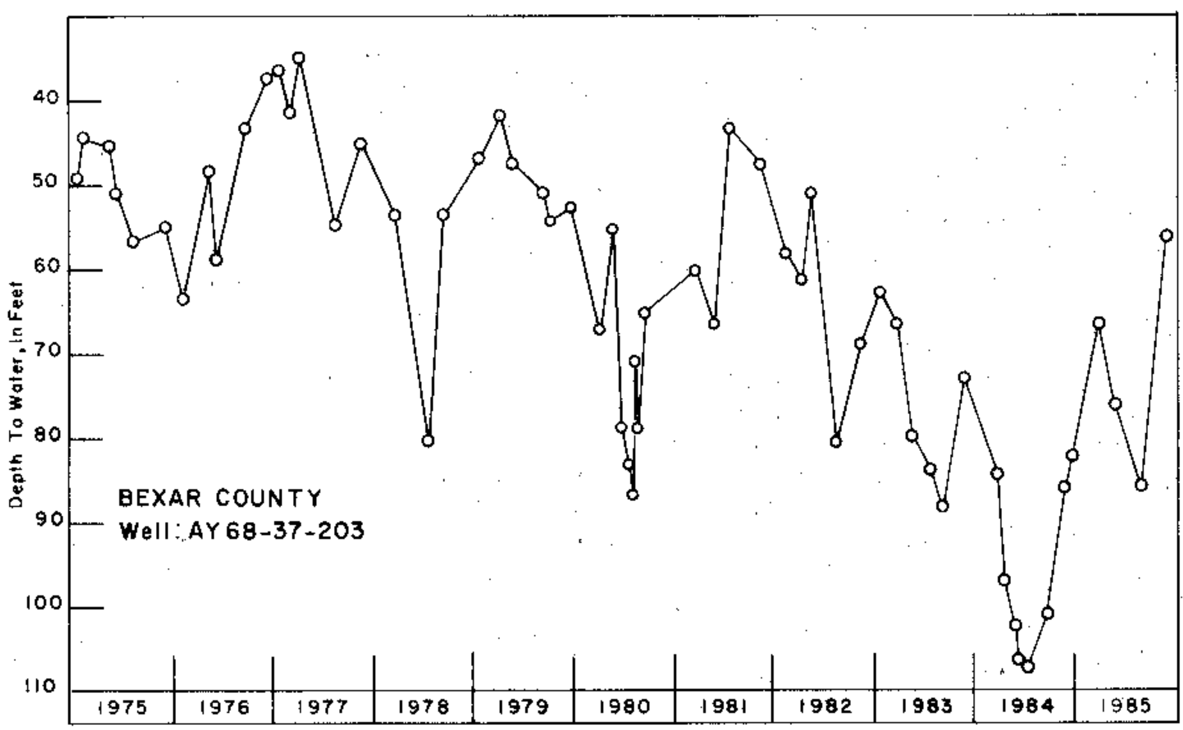


Figure 8

Hydrograph of Well Completed in the Edwards (Balcones Fault Zone) Aquifer in San Antonio in Bexar County

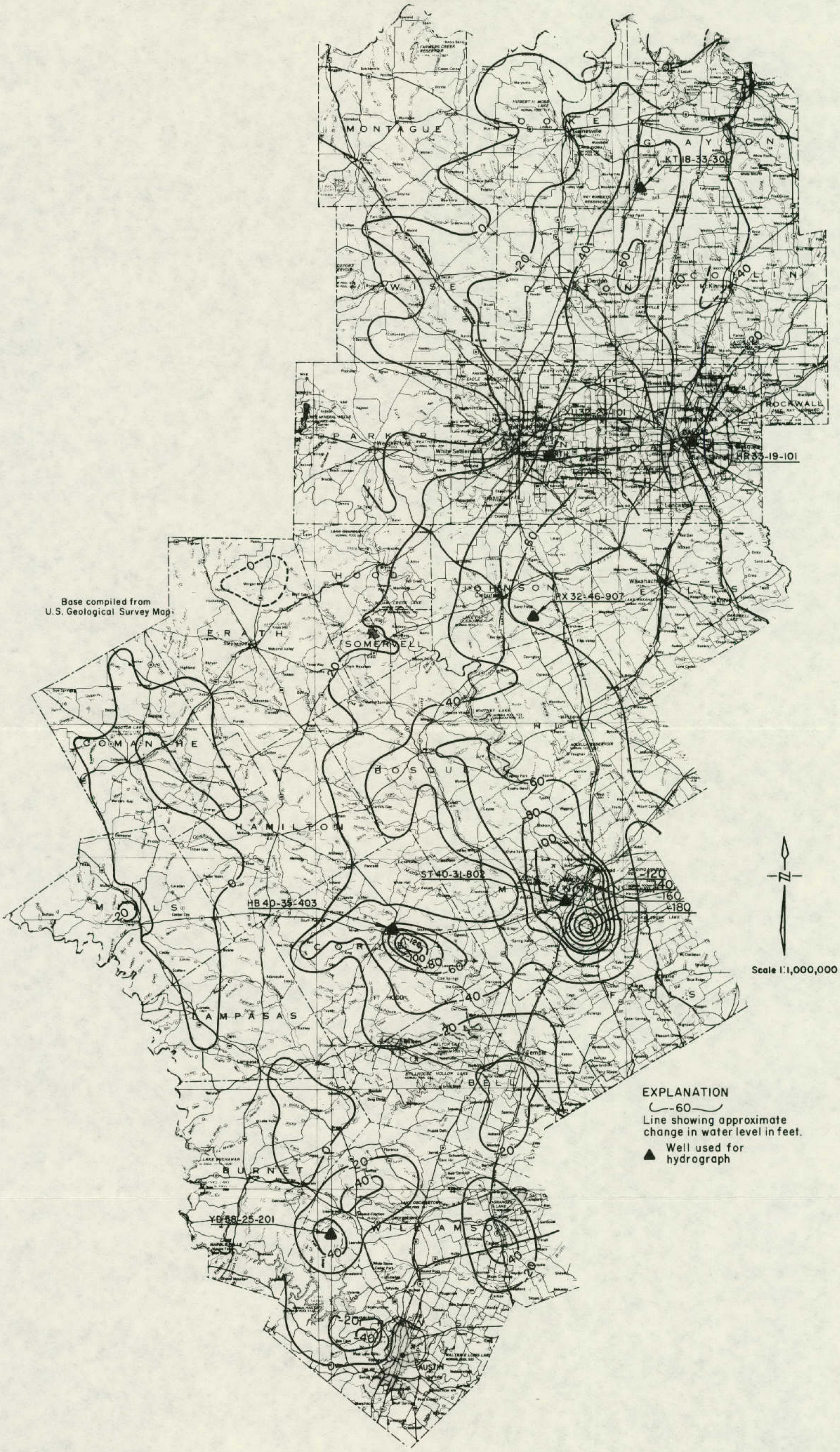


Figure 9

Map Showing Approximate Changes of Water Levels in the Trinity Group Aquifer in North-Central and Central Texas for the Period 1980-85

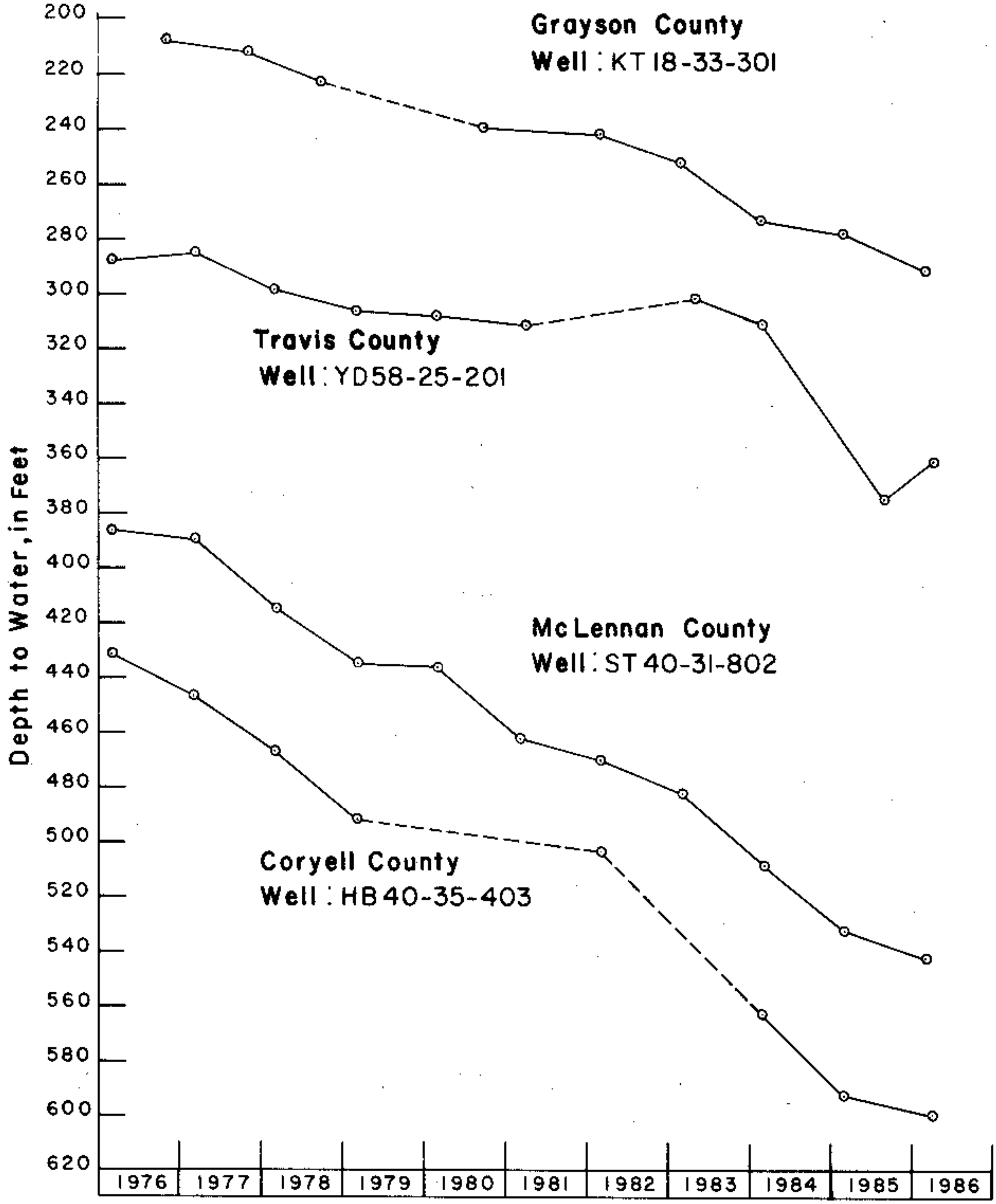


Figure 10

Hydrographs of Selected Wells Completed in Various Formations of the Trinity Group Aquifer in North-Central and Central Texas

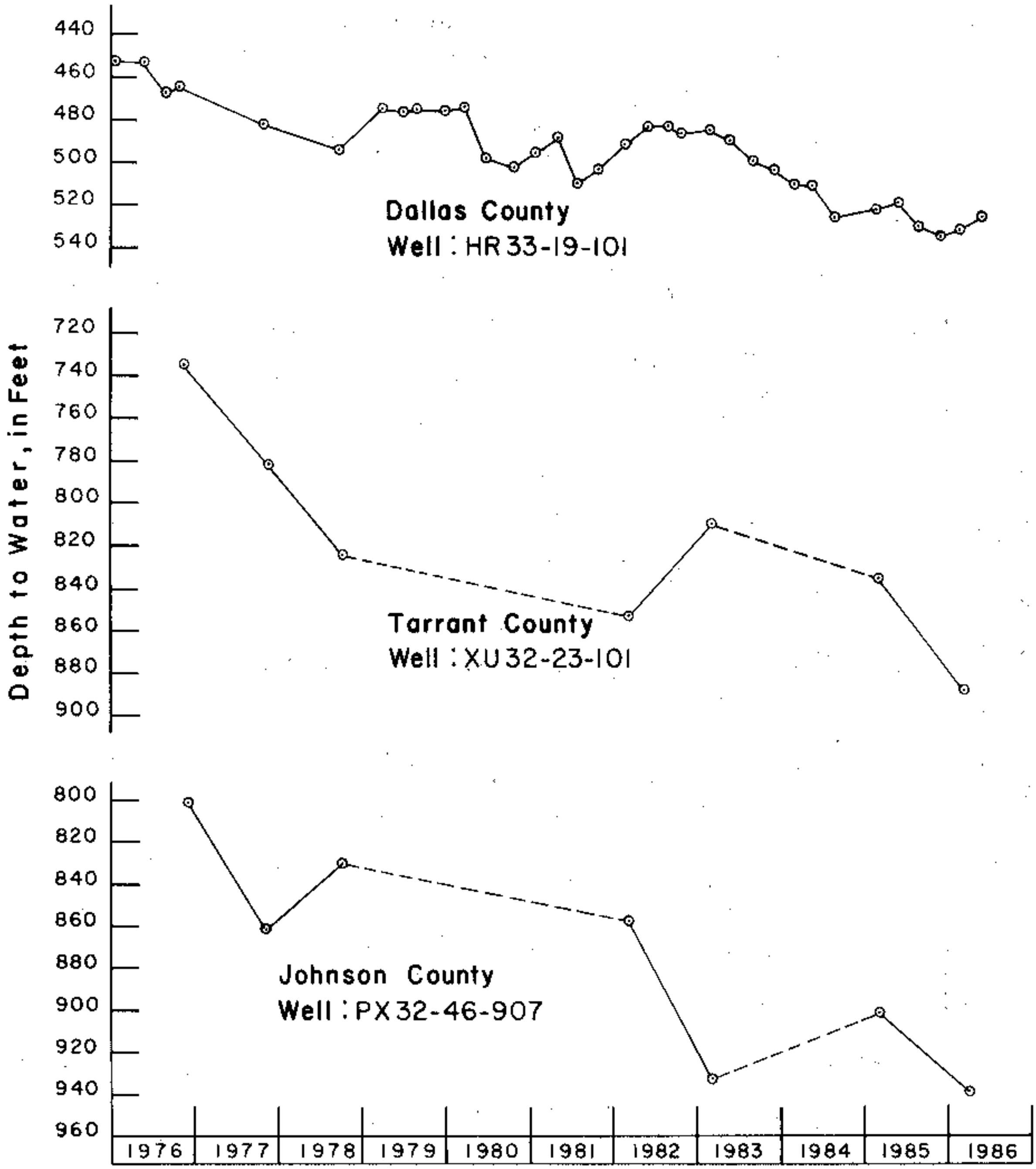


Figure 11

Hydrographs of Selected Wells Completed in the Twin Mountains Formation, Trinity Group Aquifer, in North-Central Texas

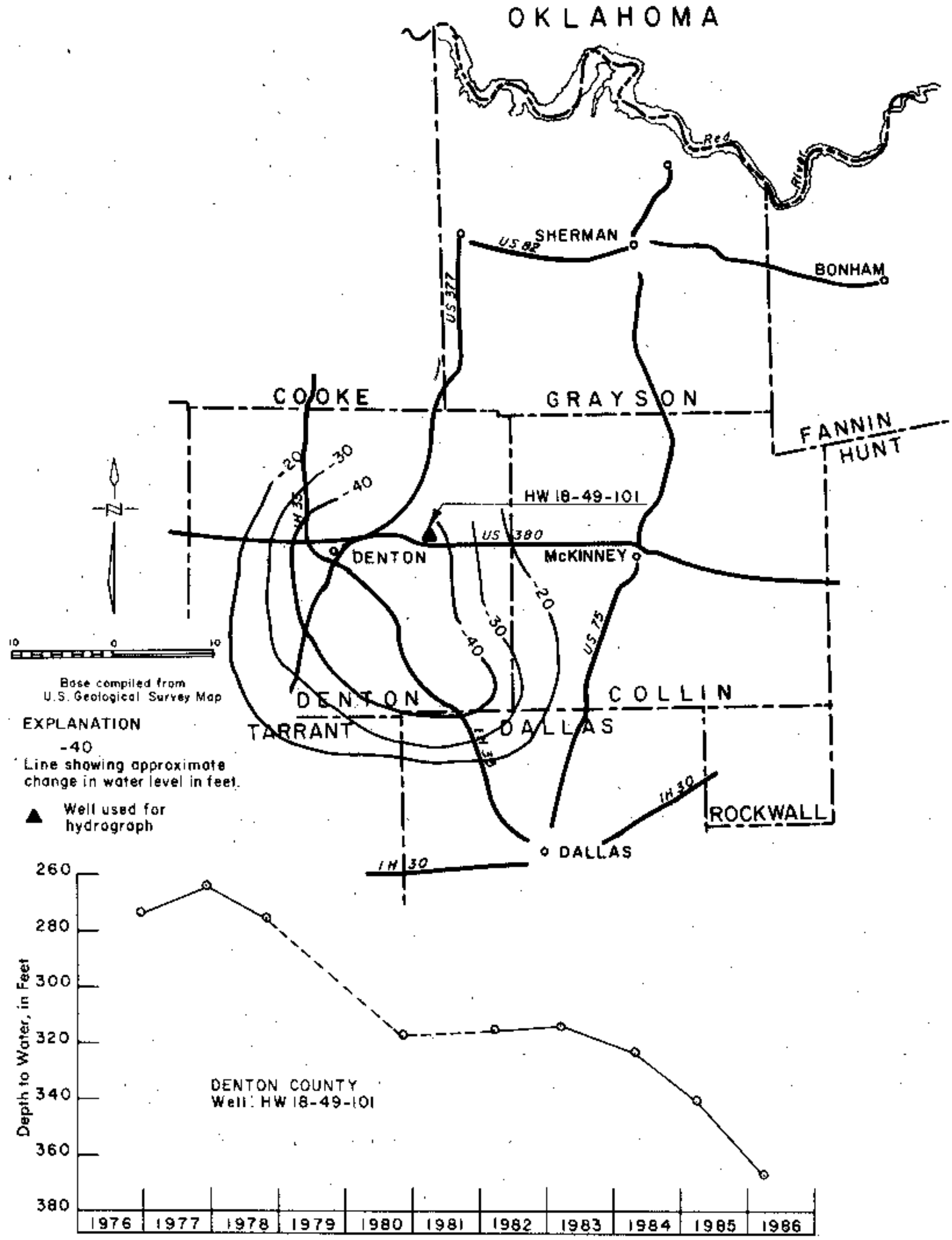


Figure 12

Map Showing Approximate Changes of Water Levels in the Paluxy Formation, Trinity Group Aquifer, in North-Central Texas for the Period 1980-85, and Hydrograph of Well Completed in the Paluxy in Denton County of the fresh-saltwater interface, and increased pumping lift costs will increase as the aquifers' water levels continue to be lowered.

Pumpage from aquifers of the Trinity Group in 1984 amounted to 190,047 acre-feet, a 15 percent increase from that recorded in 1980 (Table 1). Municipal pumpage, which accounted for 63 percent of the total, experienced a seven percent increase over that in 1980, with Dallas, Denton, Grayson, Johnson, Parker, and Tarrant Counties registering the largest increase in municipal use. Irrigation pumpage experienced a 41 percent increase over that in 1980.

Alluvium and Bolson Deposits

Mesilla and Hueco Bolsons

The Mesilla Bolson aquifer is located in the extreme western corner of Texas, west of the Franklin Mountains in El Paso County. Deposits of the Hueco Bolson aquifer lie principally in a north-trending, trough-like depression between the Franklin and Hueco Mountains in north central El Paso County. The Mesilla and Hueco Bolsons are shown on Figure 13. The Rio Grande Alluvium overlies these bolson deposits immediately adjacent to the Rio Grande. Mesilla Bolson deposits have a total thickness of approximately 2,000 feet while the Hueco Bolson deposits have a total thickness of about 9,000 feet. The Rio Grande Alluvium reaches a maximum thickness of about 200 feet.

Wells completed in the Mesilla and Hueco Bolsons usually yield from 1,000 to 2,000 gal/min. Well yields in the Rio Grande Alluvium range from 25 to as large as 3,000 gal/min. The quality of ground water in the Mesilla Bolson varies both areally and with depth and ranges from fresh to moderately saline. Hueco Bolson deposits contain fresh ground water to depths of about 1,200 feet. Water quality in the Rio Grande Alluvium is generally poor.

Water levels in city wells completed in the Mesilla Bolson have risen slightly over the last five years, reflecting that recharge maybe slightly larger than pumpage. Near the center of the City of El Paso, water levels completed in the Hueco Bolson have declined at a rate of up to six to seven feet per year. Further to the northeast, city wells completed in the Hueco Bolson have experienced declines of over one foot per year. These are illustrated in the map showing declines in the Hueco Bolson aquifer during the period 1980 through 1985 and hydrographs of wells completed in the aquifer (Figure 14). As a result of the declining water table, the dissolved mineral content of the water is increasing at a rate of two percent per year. The water table in the alluvium is affected by the level of flow in the river and thereby never varies by more than a few feet.

Bolson deposits of both the Mesilla and Hueco aquifers are the major source of ground water for municipal and industrial needs of the City of El Paso, while the Rio Grande Alluvium is an important source of shallow ground water for supplemental irrigation when the surface-water flow in the Rio Grande is not sufficient to meet the total agricultural water needs of the valley farmers. The City of El Paso presently obtains 16 percent of its water supply from the Mesilla Bolson and 65 percent from the Hueco Bolson. Pumpage from the Hueco and Mesilla Bolsons and Rio Grande Alluvium in 1984 totaled 114,314 acre-feet, a 10 percent increase over that recorded in 1980, with municipal pumpage,

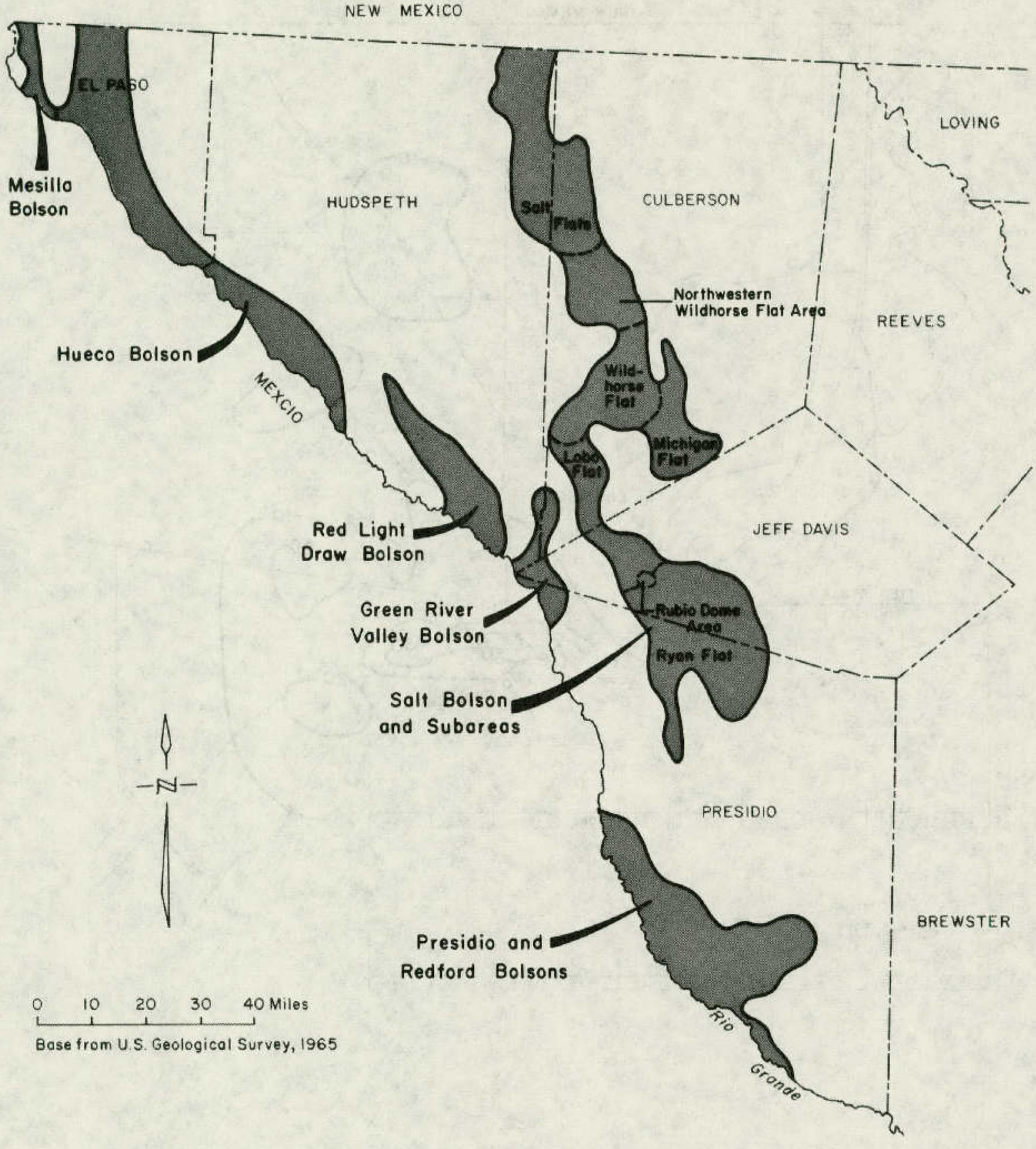


Figure 13

Map Showing the Location of Alluvium and Bolson Aquifers of Westernmost Texas

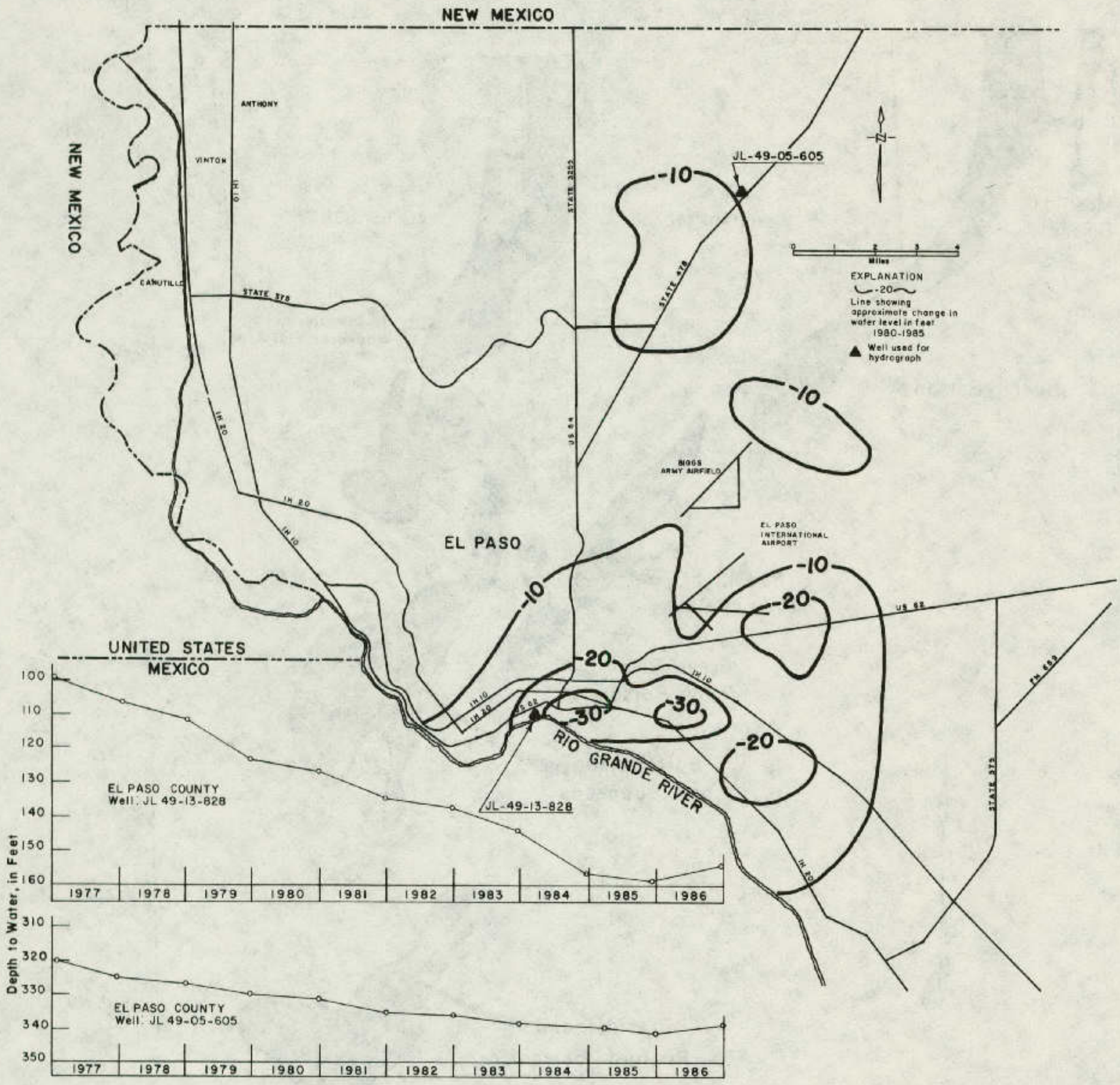


Figure 14
Map Showing Approximate Changes of Water Levels in the Hueco Bolson Aquifer for the Period 1980-85, and Hydrographs of Wells Completed in the Hueco Bolson Aquifer in El Paso County

which represents 82 percent of the total, experiencing an eight percent increase since 1980 (Table 1). Irrigation pumpage increased to 8,222 acre-feet in 1984, an 83 percent increase from the amount in 1980. Pumpage shown as "Alluvium-El Paso" (Table 1) also includes pumpage from the Red Light Draw Bolson.

Salt Bolson

The Salt Bolson extends from northeastern Hudspeth County through western Culberson and Jeff Davis Counties and northern Presidio County (Figure 1). The Bolson is divided into its principal subareas of the Salt Flats, Wild Horse Flat and its northwestern extension, Michigan Flat, Lobo Flat, Ryan Flat, and the Rubio Dome area, all of which are shown in more detail on Figure 13. Deposits in these subareas differ depending on the origin of the fill material.

Sediments in the Salt Flats are composed of lacustrine clay and sand that are saturated with mostly saline ground water with insignificant amounts of fresh to slightly saline water. Consequently, this is the only subarea in the Salt Bolson where irrigation is not possible.

In Wild Horse Flat, the fill material is composed mostly of coarse- to fine-grained alluvial fan deposits, which range in thickness from 1,000 to 1,200 feet. Large-capacity irrigation wells in Wild Horse Flat yield from 400 to 1,500 gal/min. Water quality varies with dissolved solids ranging from 350 to 2,000 mg/l.

The Michigan Flat area contains lacustrine-type deposits of mostly fine-grained sand with clay. The thickness ranges from 400 to over 600 feet. Large-capacity wells may yield over 2,000 gal/min. The quality of the ground water ranges from 1,000 to 2,000 mg/l dissolved solids.

Sediments in the Lobo Flat area are indicative of deposits having a volcanic source as well as lacustrine and alluvial sedimentary history. The thickness ranges from 1,400 to 1,900 feet, and well yields vary from 400 to 1,400 gal/min. The upper part of the fill and volcanics of Lobo Flat contain fresh water that ranges from 300 to 400 mg/l dissolved solids.

The Ryan Flat and Rubio Dome areas lie in the most southern extension of the Salt Bolson and are composed of sediments that indicate volcanic, lacustrine, and alluvial depositional histories. The deposits, which range in thickness from 740 to 4,300 feet, contain fresh ground water, and well yields range from 250 to 1,400 gal/min.

Water levels and water quality in all Salt Bolson subareas have generally remained unchanged during the past five years; and in some areas of previous decline, water levels have risen slightly. Historical records show, however, that these areas are susceptible to rapid water-level declines during times of heavy ground-water pumpage.

Red Light Draw Bolson

The Red Light Draw Bolson (Figure 13) generally consists of coarse-grained alluvial fan deposits. In the southeastern portion, the bolson fill reaches a thickness of at least 1,100 feet. In the northwestern portion, the fill is generally less than 500 feet thick and mostly unsaturated. Most wells in Red Light Draw are livestock wells of small yield; however, irrigation wells located near the Rio Grande in the floodplain alluvium reportedly yield between 1,000 and 1,500 gal/min. The ground water in the bolson fill usually is fresh and has a dissolved-solids content of less than 500 mg/l, but is commonly saline to very saline near the Rio Grande. Pumpage shown as "Alluvium-El Paso" in Table 1 also includes pumpage from the Red Light Draw Bolson.

Green River Valley Bolson

The Green River Valley Bolson (Figure 13) is composed mostly of coarse-grained sediments with considerable amounts of fine-grained lacustrine clay and silt. Thickness of the bolson averages about 750 feet and reaches a maximum of 2,800 feet near the Rio Grande. A few low-yield livestock wells pump from this aquifer, and a limited number of irrigation wells, on the floodplain near the Rio Grande, yield between 1,000 and 1,500 gal/min. The ground water in most of the basin fill is fresh and usually contains less than 500 mg/l dissolved solids. Near the Rio Grande, the water quality is commonly saline to very saline.

Little water has been developed from the Red Light Draw and Green River Valley Bolsons. Water-level data are scarce; however, declines can be expected to be restricted to local areas of concentrated pumpage. It is doubtful that appreciable changes in water level or water quality have occurred during the past five years.

Presidio and Redford Bolsons

The Presidio and Redford Bolsons (Figure 13) deposits vary from conglomerate near the bordering mountains to mudstone near the basin center. Alluvial-fan materials interbedded with gravels near the axis along the Rio Grande unconformably overlie the bolson deposits. Thicknesses of the bolson deposits range from a minimum of 500 feet to a maximum of 5,000 feet along the axis. The Rio Grande Alluvium deposits are usually less than 100 feet thick. Wells located above the floodplain of the Rio Grande have small yields, but those in the proximity of the river generally yield from 300 to 800 gal/min. Ground-water quality above the floodplain of the Rio Grande is usually fresh, but along the river it ranges from fresh to very saline. The overlying alluvium generally contains poor quality water. Ground water along the floodplain of the Rio Grande is used for irrigation purposes while elsewhere, in both bolsons, ground water is withdrawn for livestock and domestic uses. Water-level declines are generally small, especially along the Rio Grande where the aquifer is recharged from the river. No changes in water quality have been observed as a result of ground-water development.

Pumpage for the Salt, Green River Valley, Presidio, and Redford Bolsons in 1984 totaled 25,150 acre-feet, with irrigation pumpage accounting for 85 percent of the total (Table 1). A 78 percent decrease in irrigation pumpage from 1980 to 1984 resulted in a 75 percent decrease in the total pumpage. Pumpage from the Red Light Draw Bolson is included in that shown for the El Paso area (Table 1).

Cenzoic Pecos Alluvium

Deposits of alluvium that occur in the upper part of the Pecos River Valley of West Texas (Figure 1) range up to 1,500 feet or more in thickness and are separated into two basins by a subsurface structural high. Wells producing from the alluvium yield small to large volumes of ground water, used principally for irrigation. Areas that are suitable for withdrawals of fresh to slightly saline ground water are central Winkler and northeastern Ward Counties, the north Coyanosa area of Pecos and Reeves Counties, the area in eastern Reeves and western Pecos Counties, and the southeast Balmorhea and Balmorhea-Toyah areas of Reeves County (Figure 15). In portions of the aquifer, gypseous soils have allowed crop utilization of the aquifer water, even though most of it contains between 1,000 and 4,000 mg/l of dissolved solids. Ground-water quality in the more heavily pumped regions of Reeves, Pecos, and Ward Counties has deteriorated due to saline-water encroachment from irrigation return flow and recharge from the Pecos River. The practice of disposing of oil-field brine through unlined surface pits has been linked to areas of ground-water contamination.

Water levels in wells located in the western basin in central Reeves, western Ward, and northwestern Pecos Counties have declined up to 250 feet or more in the past. In recent years, the water level in much of this area has recovered substantially in response to reduced pumpage and recharge, but in portions of the area as illustrated in Figure 15, water levels declined at a rate of up to three feet per year during the period 1980 to 1985. Water levels in wells in the eastern basin have not been affected as much because of less pumpage. In south central Winkler and central Ward Counties, however, the water table is dropping at a rate of up to 1.5 feet per year. To illustrate the contrasting nature of the ground-water development, Figure 15, which illustrates the areas of decline, also contains a hydrograph of a well located adjacent to an area of decline and it indicates a rise in water level since 1973.

Total pumpage of ground water from the Cenzoic Pecos Alluvium in 1984 amounted to 116,799 acre-feet, with irrigation pumpage accounting for 78 percent of the total (Table 1). A 38 percent decrease in the total resulted from a 44 percent decrease in irrigation pumpage.

Seymour Alluvium

The Seymour Formation consists of isolated areas of alluvium which occur in parts of 22 north central and Panhandle counties (Figure 1). In most areas, the saturated thickness is less than 100 feet and yields of large-capacity wells range from less than 100 gal/min to 1,300 gal/min. The quality of water differs widely from place to place, but generally ranges from less than 500 mg/l to more than 2,500 mg/l of dissolved solids. Water levels fluctuate

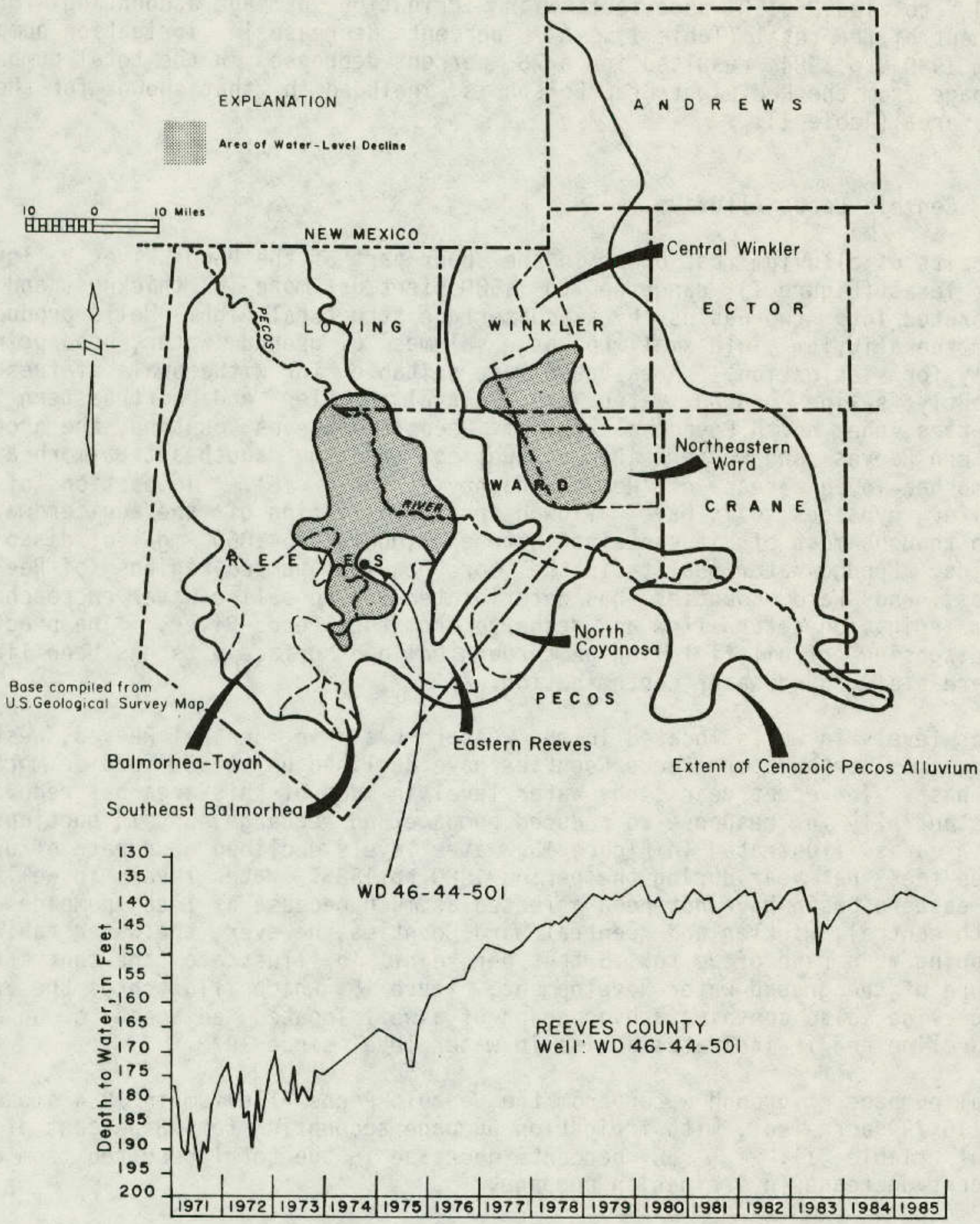


Figure 15

Map Showing the Location of the Cenezoic Pecos Alluvium Aquifer in West Texas; Areas Suitable for Ground-Water Withdrawal from the Aquifer; Approximate Changes of Water Levels in the Aquifer for the Period 1980-85; and Hydrograph of Well Completed in the Aquifer in Reeves County annually in response to precipitation and pumpage. Declines are small and local in extent, with no long-term regional declines having occurred in the last five years. The water quality has deteriorated in many previously heavily pumped areas to the point that the water has become unsuitable for domestic and municipal use; both salinity and relatively high concentrations of nitrate have rendered the water undesirable for human consumption in these areas.

Total pumpage from the Seymour in 1984 was 160,698 acre-feet, an 11 percent decrease from that recorded in 1980, with a 12 percent decrease in irrigation pumpage accounting for most of the decrease.

Leona Alluvium

The Leona alluvial deposits were derived from the same source as the Ogallala Formation and are located in east central Tom Green County (Figure 1). The Leona is composed of discontinuous beds of poorly sorted, round to subangular gravel, conglomerate, sand, silty clay, and caliche. The total thickness of alluvium ranges from a few feet to about 125 feet, and saturated thickness ranges from zero to a maximum of 117 feet. Yields of irrigation wells range from about 100 to nearly 7,000 gal/min. The chemical quality of the ground water is generally suitable for most purposes, ranging from fresh to slightly saline. No changes in quality have been observed as a result of pumpage. Water levels throughout the aquifer have remained relatively unchanged in the last five years; only a small area south of Veribest experienced a four foot per year decline during this time frame. Pumpage shown as "Alluvium-Seymour" in Table 1 also includes some pumpage from the Leona Alluvium.

Brazos River Alluvium

Water-bearing alluvium occurs in the floodplain of the Brazos River of southeast Texas (Figure 1). These deposits cover an area which ranges from less than one mile to about seven miles in width for a distance of approximately 350 miles along the river. Saturated thicknesses of these deposits of up to 85 feet permit wells which yield between 250 and 500 gal/min. The chemical quality of the ground water varies widely, even within short distances. In many areas, concentrations of dissolved solids exceed 1,000 mg/l; however, the valley soils are usually sufficiently permeable to alleviate soil salinity problems.

Historically, water levels in the aquifer decline during the summer pumping season, especially in areas of concentrated well development. Following the pumping season, levels usually recover as the aquifer receives recharge from the river. Levels tend to be higher during periods of precipitation because there is less need for irrigation pumpage, as well as because of increased recharge.

Pumpage for irrigation use accounted for 99 percent of the aquifer's total 1984 pumpage of 40,408 acre-feet.

Gulf Coast

The Gulf Coast aquifer (Figure 1) is composed of sedimentary deposits of gravel, sand, silt and clay which are hydraulically connected and form a large, leaky artesian aquifer system. The system has been subdivided into three major water-producing components, referred to as the Chicot (shallowest) Evangeline, and Jasper (deepest) aquifers.

From the San Antonio River northeastward to Louisiana, usable quality water may be encountered in the Gulf Coast aquifer to a depth of 3,200 feet, of which the total aggregate sand thickness is about 1,300 feet. Well yields average about 1,600 gal/min. Fresh to slightly saline water with a dissolved-solids content of less than 500 mg/l is generally obtained for municipal, industrial, and irrigation use.

From the San Antonio River basin southwestward to Mexico, the maximum depth of the aquifer below land surface is 2,800 feet, of which the maximum total sand thickness is about 700 feet. The dissolved-solids content of the water generally ranges between 1,000 and 1,500 mg/l; however, there are areas where no appreciable amounts of fresh to slightly saline ground water can be found. In addition, in this portion of the aquifer only small amounts of the aquifer's water is acceptable for prolonged irrigation use, due to either high salinity or alkalinity hazard. In the Lower Rio Grande Valley, supplemental ground water is pumped for irrigation as well as for municipal use during times when the flow of the Rio Grande does not meet demands.

Problems related to withdrawal of ground water from the Gulf Coast aquifer are: (a) land-surface subsidence, (b) increased chloride content in the ground water of the southwest portion of the aquifer, and (c) saltwater encroachment along the coast.

Years of heavy pumpage for municipal and manufacturing uses in portions of the Gulf Coast aquifer have resulted in areas of significant water-level decline. Historic declines of 200 to 300 feet have been measured in some areas of eastern and southeastern Harris and northern Galveston Counties. Other areas of significant historical water-level decline include portions of the counties of Jefferson, Orange, and Wharton, and the Kingsville area in Kleberg County. Some of these declines resulted in compaction of dewatered clays, which caused significant subsidence of the land surface and subsequent flooding in many low-lying areas of Baytown, Texas City, and Houston along the ship channel. As a result, the Harris-Galveston Coastal Subsidence District was established by the Texas Legislature in 1975. Its purpose is to attempt to alleviate or at least slow down land-surface subsidence by switching large ground-water users within the area of greatest subsidence over to use of surface water.

Changes in water levels in the deeper artesian portion of the Gulf Coast aquifer (the Evangeline aquifer) are shown on Figure 16 for the periods 1975 to 1985 and 1980 to 1985. These show a recent lessening of water-level declines throughout much of the area, and that significant rises in water levels have occurred in the Houston area and southeastern portion of Harris County during the latter period.

Figure 17 shows water-level changes for the same time periods for the shallow (Chicot) aquifer. These show that rises in water levels are occurring in a

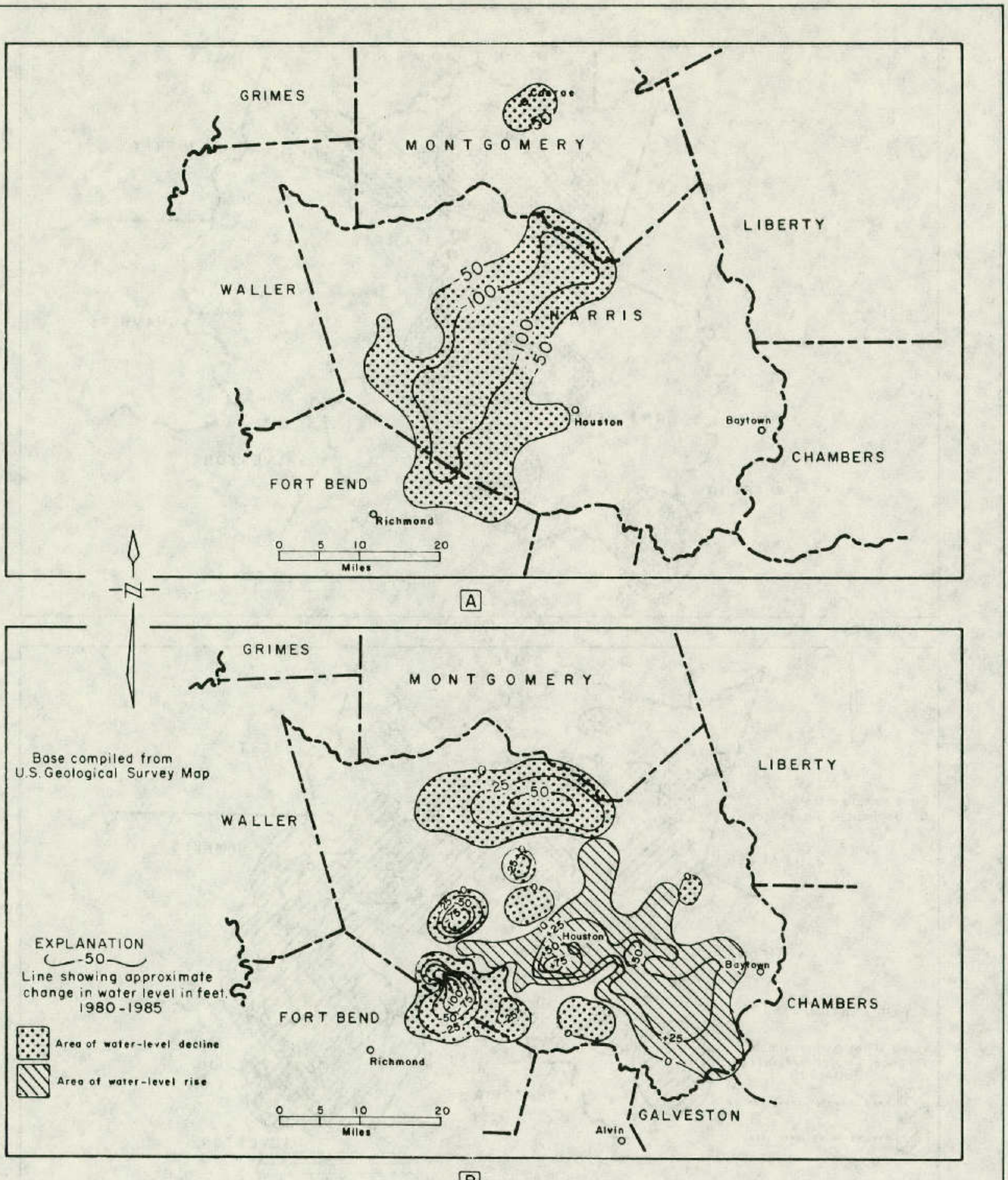


Figure 16

Map Showing Approximate Changes of Water Levels in the Evangeline Aquifer for the Periods 1975-85(A) and 1980-85(B)

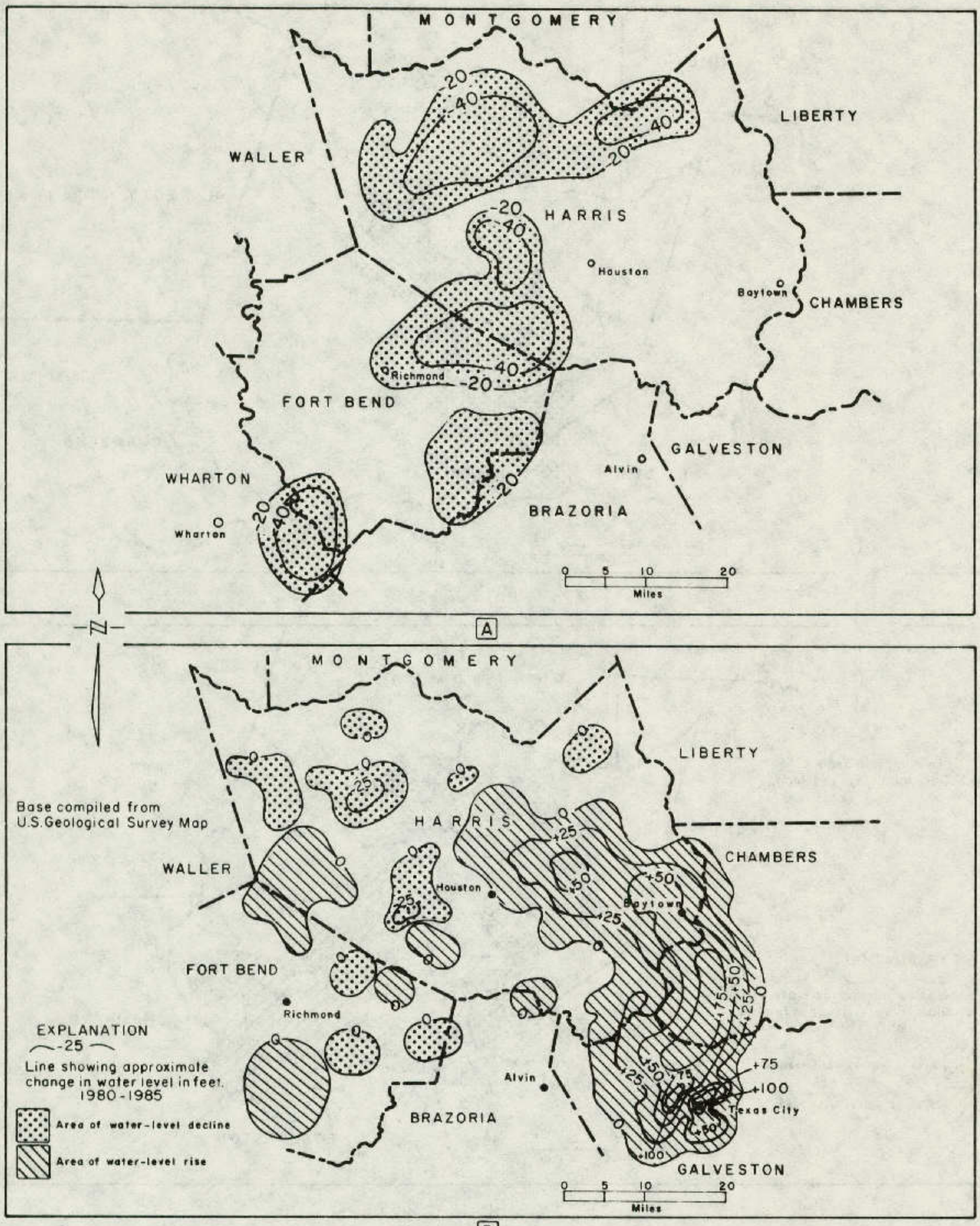


Figure 17

Map Showing Approximate Changes of Water Levels in the Chicot Aquifer for the Periods 1975-85(A) and 1980-85(B) broad region of southeastern Harris, western Chambers, and northwestern Galveston Counties. Both figures also indicate, however, that the heavy pumpage for municipal, manufacturing, and irrigation purposes in western Harris County and adjacent areas is continuing to cause significant water-level declines.

Reductions in rice farming operations in Wharton and surrounding areas and in Jefferson and Orange Counties have caused a slowdown or halt of historic water-level declines in those areas. Changing conditions are also found in several areas at or near the coast where heavy municipal or industrial pumpage had previously caused an updip migration, or "saltwater intrusion," of poor quality water into the wells. These include Galveston Island and the central and southern parts of Orange County. Recent reductions of pumpage in these areas have resulted in a stabilization and in some cases, even improvement of ground-water quality. Recent United States Geological Survey and Harris-Galveston Coastal Subsidence District land-surface leveling measurements also indicate that subsidence has slowed appreciably in these areas.

In the Kingsville area of Kleberg County, historic declines have also reversed, and in the last 10 years, water levels have recovered, as shown on the hydrograph of a well at Kingsville (Figure 18). Water levels will undoubtedly continue to rise in the Kingsville area as the area's dependence on ground water is curtailed by the increased use of surface water from nearby Corpus Christi reservoirs.

The total pumpage from the Gulf Coast aquifer in 1984 was 1,284,758 acre-feet, which represents a seven percent decline from that recorded for 1980. Municipal and irrigation pumpage accounted for 46 and 43 percent of the total, respectively. Pumpage for municipal purposes increased nine percent, while that for irrigation experienced an 18 percent decrease in 1984.

Edwards-Trinity (Plateau)

The Edwards-Trinity (Plateau) aquifer (Figure 1) consists of saturated sediments made up of sand, sandstone, gravel, and conglomerate of the Trinity Group (Antlers Formation); and cherty, gypseous, argillaceous, cavernous limestones and dolomites of the Comanche Peak, Edwards, and Georgetown Formations. The Santa Rosa Sandstone of Triassic age is also included where it underlies and is in hydraulic continuity. The maximum saturated thickness is more than 800 feet, and some large-capacity wells completed in jointed and cavernous limestone yield as much as 3,000 gal/min. The chemical quality of the water ranges from fresh to slightly saline, is generally hard, varies widely in concentrations of dissolved solids, and in certain areas, may have unacceptable levels of fluoride.

There is little pumpage from the aquifer over most of its extent, and water levels have generally remained constant or fluctuate with seasonal precipitation. In some instances, however, water levels have declined as a result of increased pumpage. The hydrograph of a well in eastern Kerr County (Figure 19) shows that the aquifer was essentially in equilibrium prior to 1981, but subsequently has experienced water-level declines as a result of increased development in the area. Declines have also occurred in the northwestern part of the aquifer as a result of agricultural irrigation development. Here, the

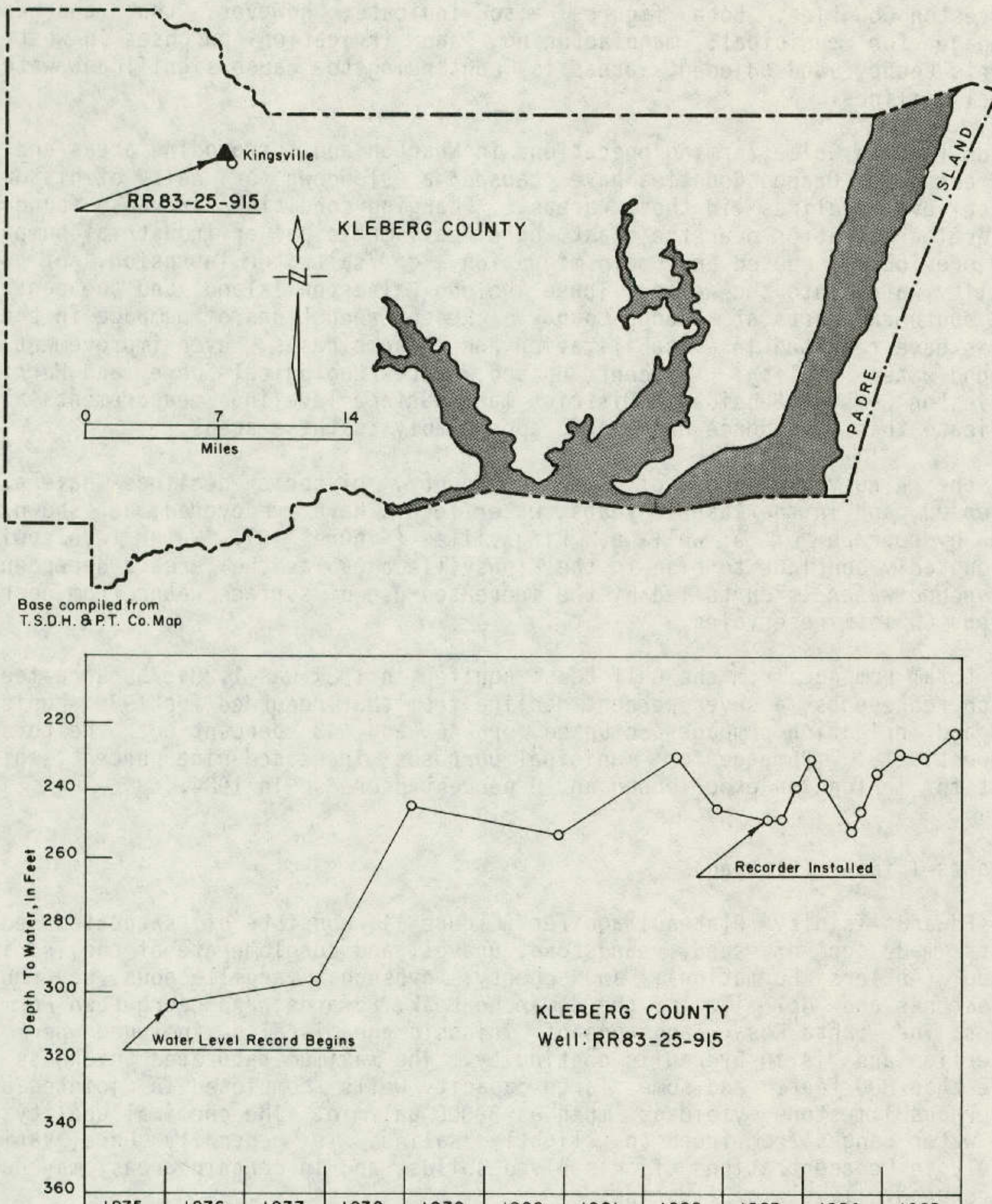


Figure 18

Hydrograph of Well Completed in the Gulf Coast Aquifer in Kingsville in Kleberg County

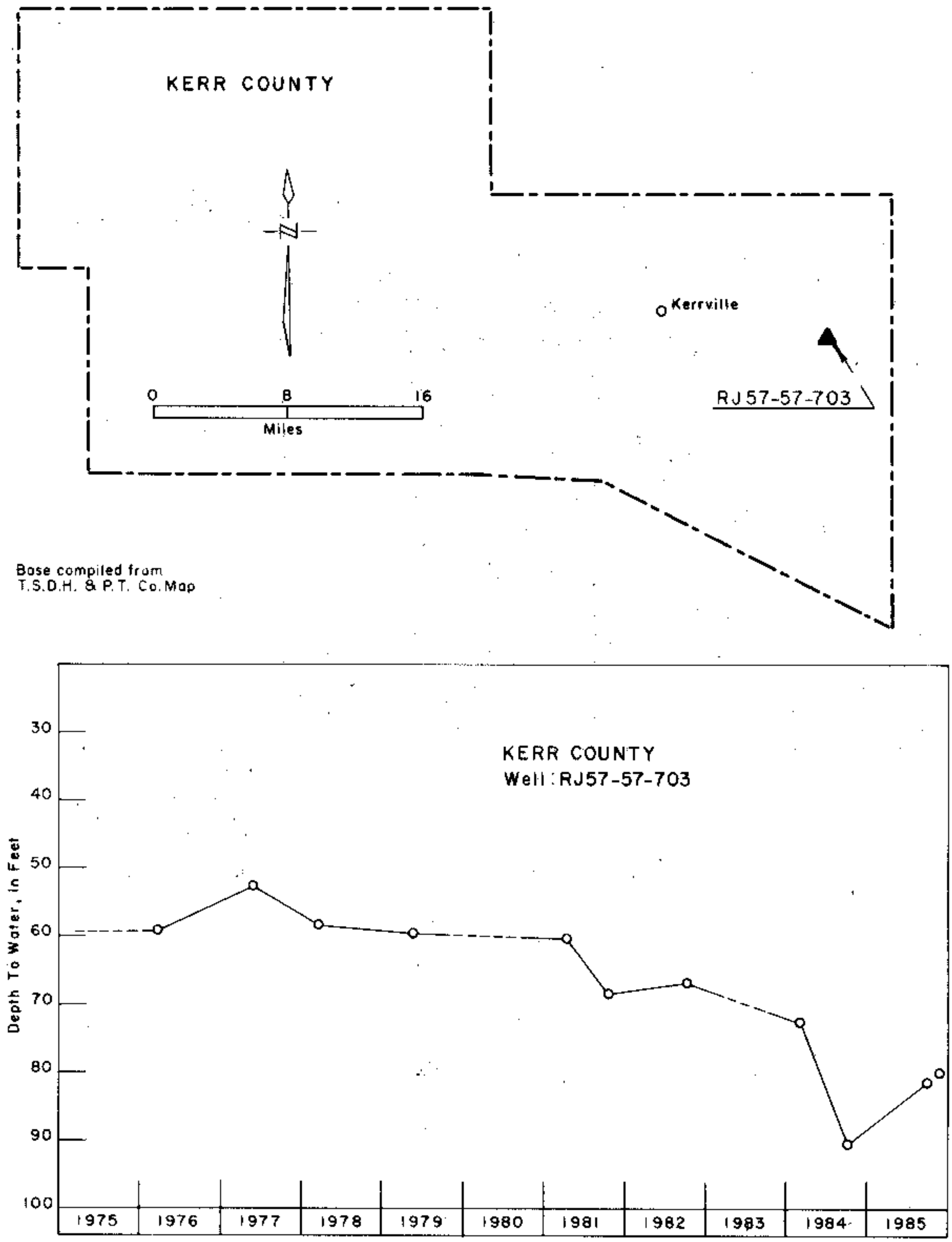


Figure 19

Hydrograph of Well Completed in the Hensel Formation, Trinity Group, in Kerr County

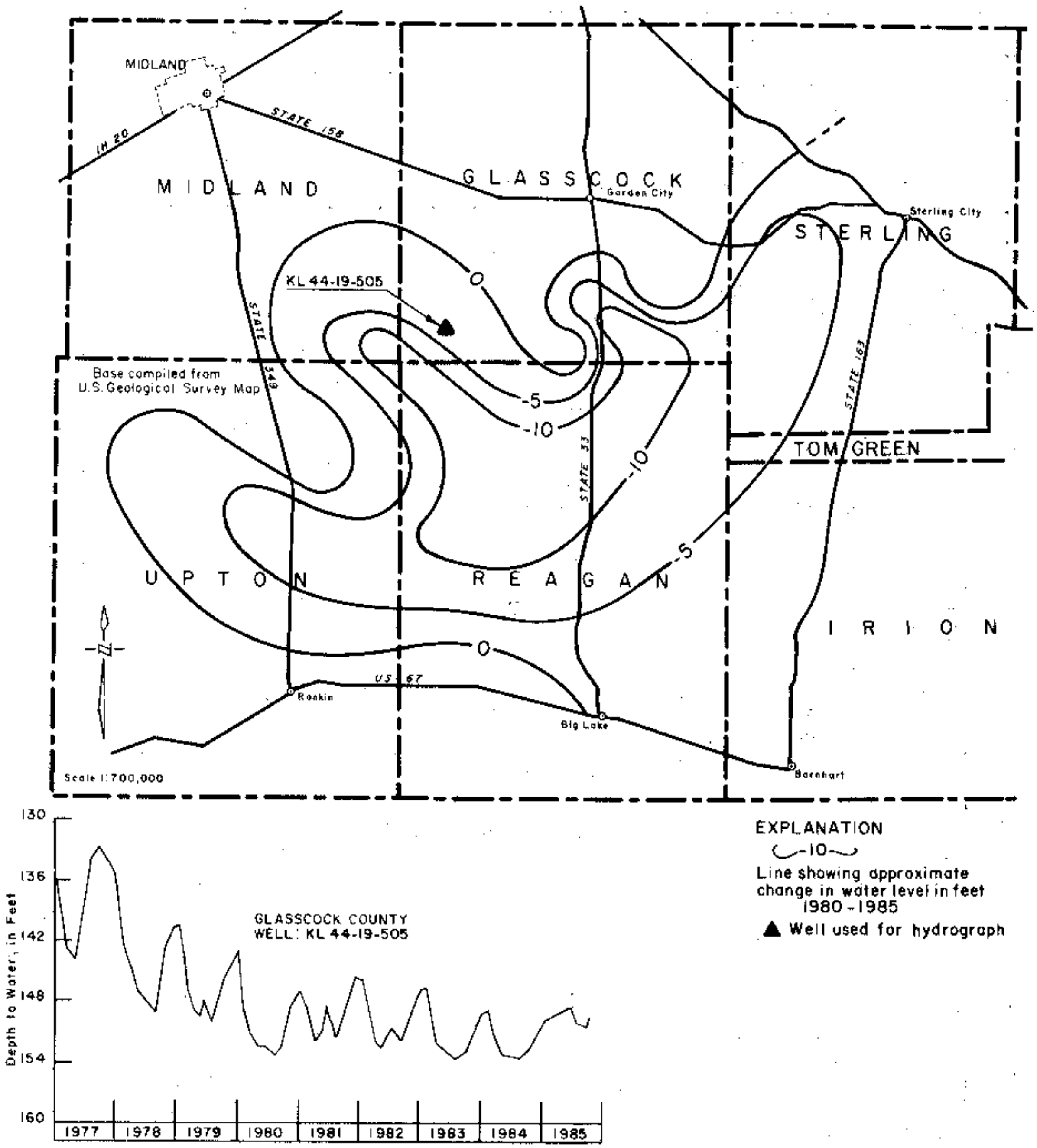
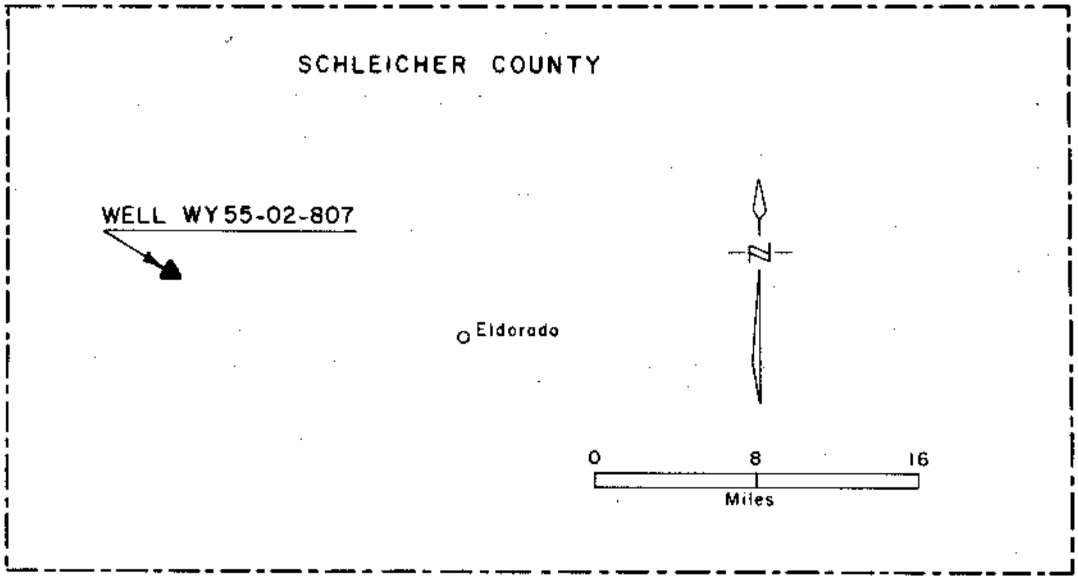


Figure 20

Map Showing Approximate Changes in Water Levels in Edwards-Trinity (Plateau) Aquifer for the Period 1980-85, and Hydrograph of Well Completed in the Antlers Formation in Glasscock County



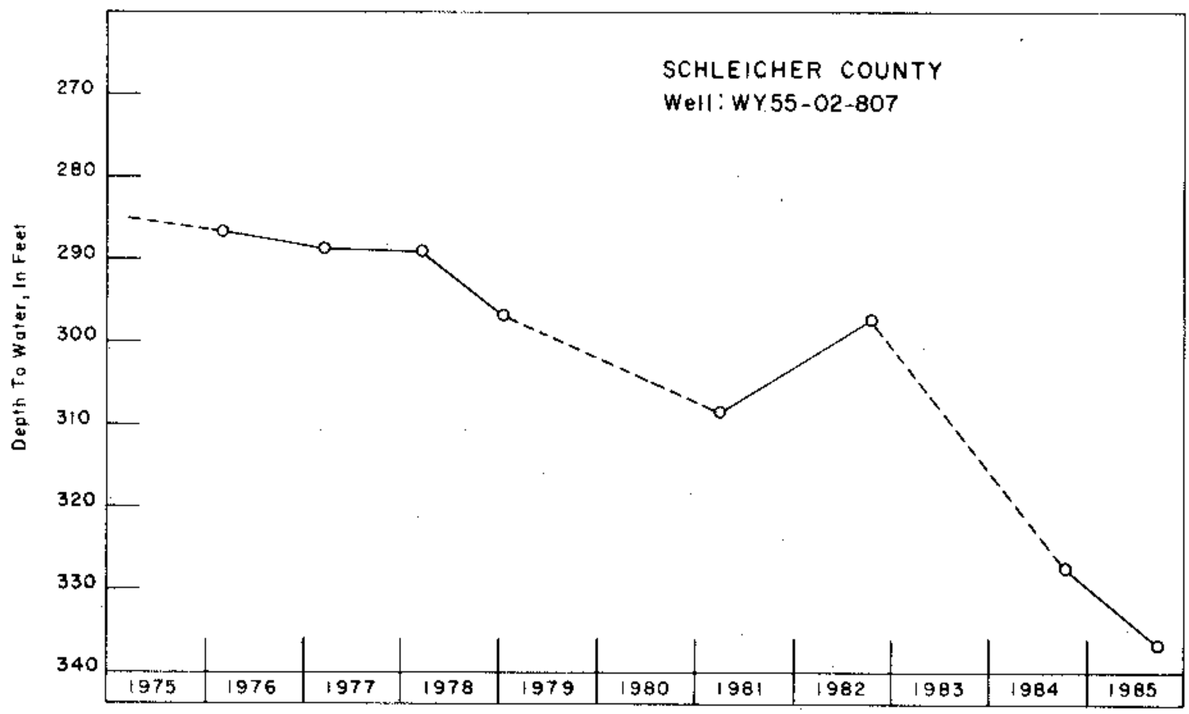


Figure 21
Hydrograph of Well Completed in the
Edwards-Trinity Aquifer in Schleicher County

major area of influence, shown on Figure 20, has moved since 1980 from the southern portion of Glasscock County to northern Reagan County and has also expanded to affect surrounding portions of Midland, Upton, and Sterling Counties. Within this area, water levels have declined two feet per year, as illustrated by the hydrograph (Figure 20) of a well completed in the Antlers Formation in Glasscock County. Southeast of this area, in Schleicher County, water levels have declined about four feet per year as a result of irrigation pumpage as illustrated in the hydrograph of a well west of Eldorado (Figure 21). Irrigation pumpage in Schleicher County has increased about 44 percent since 1980.

The aquifer's total 1984 pumpage of 234,274 acre-feet represents a 13 percent increase over that recorded in 1980 (Table 1), with the largest component increase, 18 percent, being for irrigation use.

MINOR AQUIFERS

Minor aquifers are defined as those which yield large quantities of water in small areas or relatively small quantities of water in large areas of the State. The minor aquifers in Texas are important and in some areas are the only sources of water supply. Their locations and extent are shown on Figure 22 and their water-bearing properties are described below.

Woodbine

The Woodbine aquifer (Figure 22) consists of sand and sandstone beds which reach depths of 2,000 feet below land surface and thickness of up to 600 feet. Yields of wells range from less than 100 gal/min to about 700 gal/min. The water is generally high in dissolved solids, sulfate, fluoride, and in places, chloride. Poorer quality water containing excessive iron concentrations is usually encountered in the upper water-bearing sands.

In most cases, only the lower part of the formation is developed to supply domestic and municipal wells. Figure 23 is a map which exhibits water-level declines of less than 20 feet to over 40 feet in the Woodbine Formation for the period 1980 to 1985 in portions of Grayson, Collin, and Fannin Counties. In Ellis County south of Dallas, limited data indicate declines of 15 feet or more during the period 1980 to 1985. Also shown are hydrographs indicating water-level changes for the period 1976 to 1986 in two Woodbine wells in Fannin and Collin Counties. The average annual decline rates in the two wells were 12 feet and three feet per year, respectively.

Pumpage from the Woodbine aquifer totaled 14,936 acre-feet in 1984, a 39 percent decrease from the 1980 total, most of which was the result of a 50 percent decrease in municipal pumpage (Table 1).

Queen City

The Queen City aquifer (Figure 22) consists principally of sand, loosely cemented sandstone, and interbedded clays and is up to 500 feet thick. Yields of wells are generally low with only a few exceeding 400 gal/min. Concentrations of dissolved solids are generally low. However, in parts of the aquifer in northeast Texas, the ground water has high acidity (low pH) and locally contains excessive concentrations of iron. Ground water containing less than 3,000 mg/l dissolved solids is encountered to depths of approximately 2,000 feet below the land surface.

The Queen City supplies water for rural domestic and livestock purposes on or near the outcrop, for municipal pumpage in central and northeast Texas, and for irrigation purposes in the southern part of the aquifer, especially in Wilson County. Water-level declines have occurred in the immediate vicinity of some individual high-capacity wells and well fields, but there are no indications of any regional declines. Water quality has not changed appreciably as a result of ground-water pumpage.

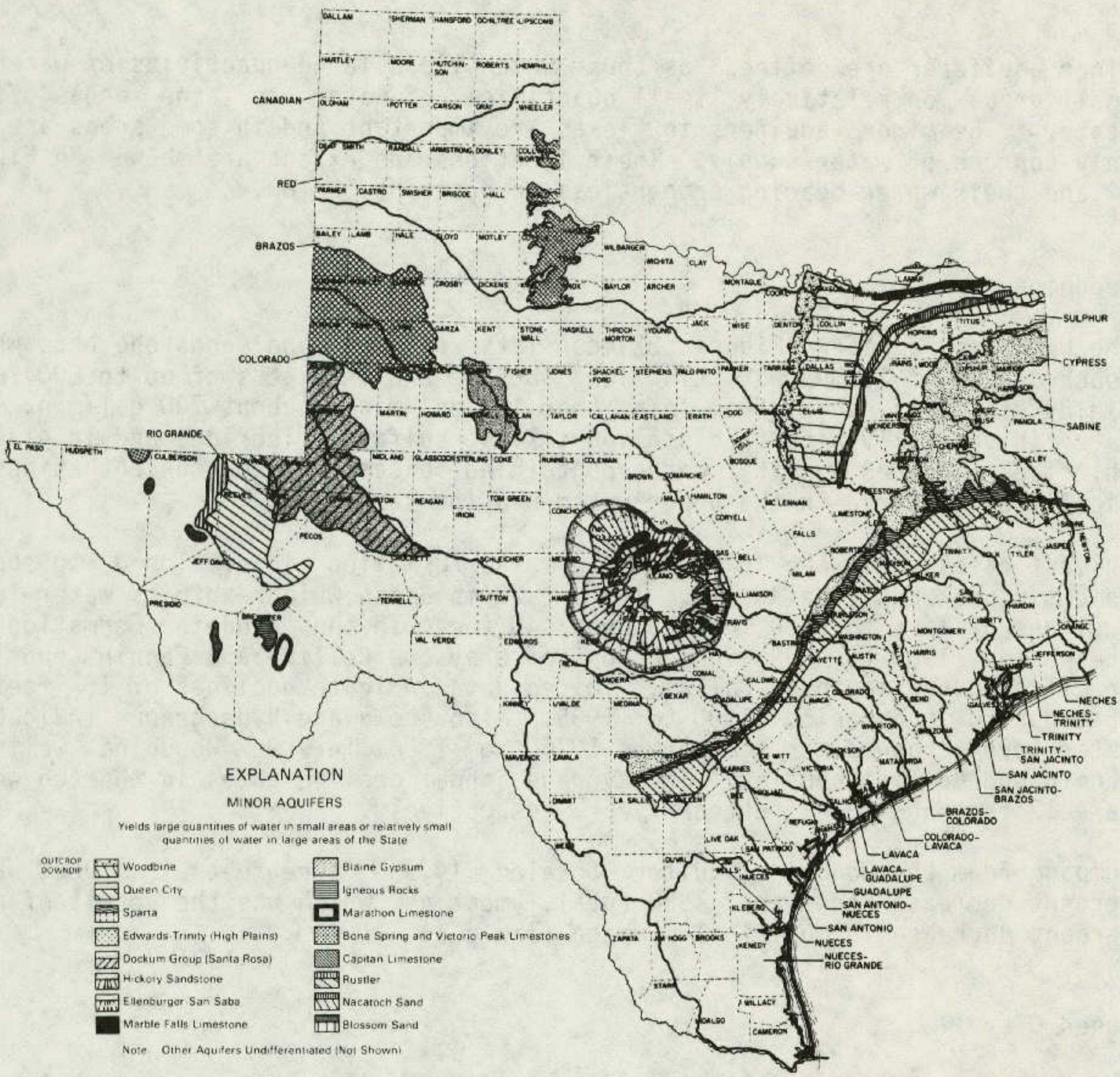


Figure 22
Map of Texas Showing Minor Aquifers, and River and Coastal Basins

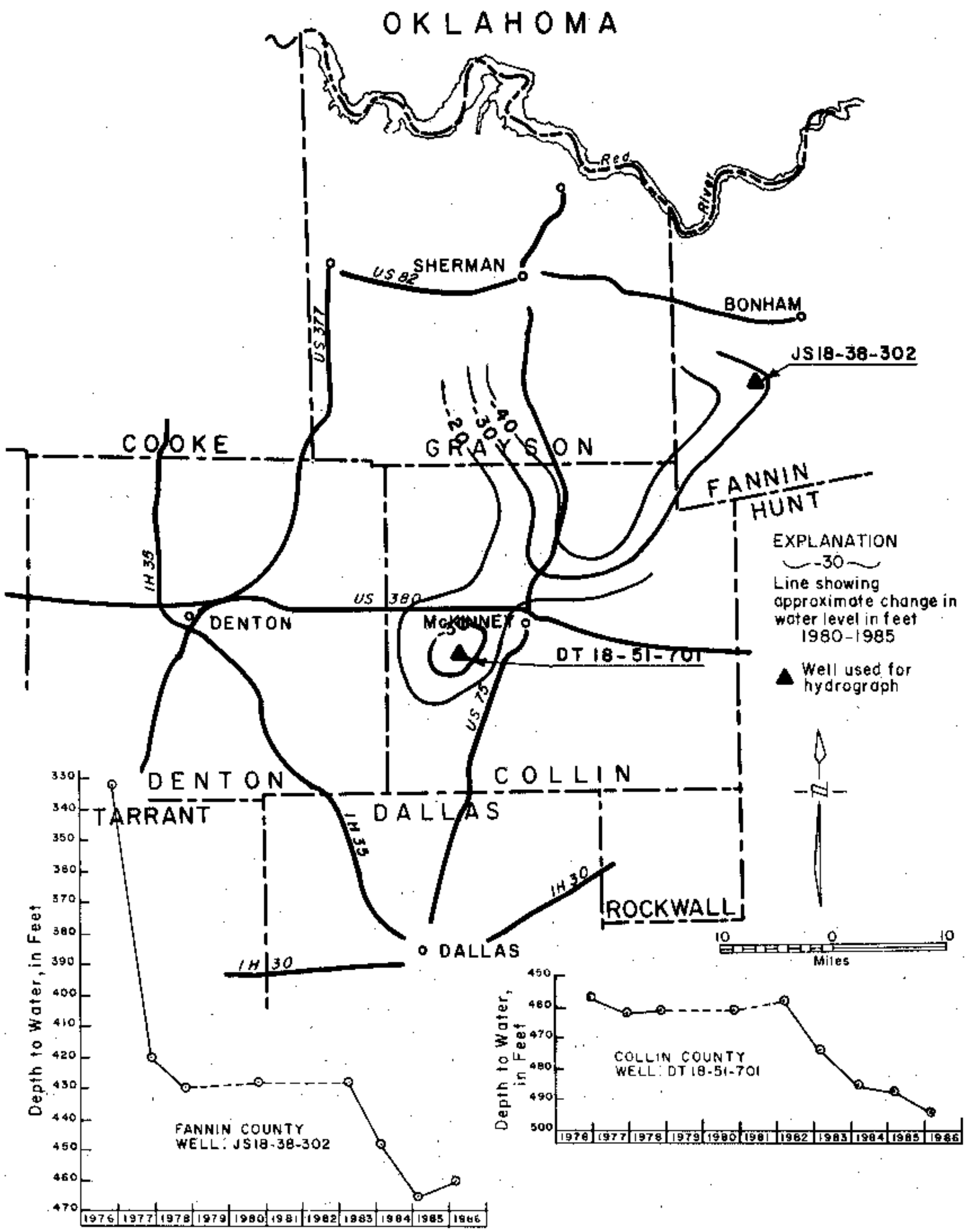


Figure 23

Map Showing Approximate Changes of Water Levels in the Woodbine Aquifer in North-Central Texas for the Period 1980-85, and Hydrographs of Wells Completed in the Woodbine Aquifer in Collin and Fannin Counties

Total pumpage of water from the aquifer amounted to 21,276 acre-feet in 1984, a decline of 21 percent from the total in 1980, with most of the change being a 45 percent decrease in municipal pumpage.

Sparta

The Sparta aquifer (Figure 22) is composed mainly of sands and interbedded clays. Thickness ranges from 100 feet to approximately 300 feet, and large-capacity wells, producing principally from thick sand beds near the base of the formation, generally yield 400 to 500 gal/min. Ground water produced from the aquifer is generally low in concentrations of dissolved solids; however, in many areas the aquifer contains iron in excess of proposed U.S. Environmental Protection Agency secondary standards. Slightly saline water can be found to depths in excess of 2,000 feet along the aquifer's southeast boundary.

Water from the Sparta aquifer is used for domestic and livestock purposes on or near the outcrop throughout its extent. In the central and eastern parts of the aquifer there is significant use for public and industrial supplies. Minor amounts of water from the Sparta are used for irrigation in East Texas. Significant water-level declines have occurred in the immediate vicinity of some individual high-capacity wells and well fields in East Texas, but there are no indications of regional declines.

The total 1984 pumpage amounted to 9,231 acre-feet, a 21 percent decrease from the 1980 total. Irrigation pumpage experienced a 45 percent decrease from 1980.

Edwards-Trinity (High Plains)

The Edwards-Trinity aquifer (Figure 22) is composed of sands and sandstones of the Trinity Group and limestones of the Fredericksburg Group. In much of the southern High Plains, it underlies and is generally in hydraulic contact with the Ogallala Formation. The aquifer reaches a total thickness of 300 feet. Well yields are generally small except where water is present in the limestone, in which case, yields range up to 600 gal/min. Water quality is usually slightly to moderately saline, with the poorest qualities concentrated below saltwater ponds. Because most wells drilled into the aquifer are dually completed in both the Cretaceous and Ogallala Formations, changes in water levels are more indicative of the prevailing conditions in the overlying Ogallala. Since little water is produced from the aquifer, declines are of local extent, restricted to the immediate areas of water use. No long-term regional declines have been observed.

Small quantities of water are produced from the aquifer for irrigation and secondary oil recovery. The total 1984 pumpage from the aquifer amounted to 16,393 acre-feet, with irrigation accounting for 91 percent of the total.

Dockum Group (Santa Rosa)

The Dockum Group aquifer in Texas (Figure 22) consists primarily of interbedded shale, sand, sandstone, and conglomerate of the Santa Rosa Formation. Saturated thickness of the aquifer may be as much as 700 feet, and well yields vary and do not normally exceed 300 gal/min. Dissolved solids in the ground water range from less than 100 mg/l to more than 4,000 mg/l. The sodium content is high, thus limiting regional use of the water for irrigation. Only small quantities of water are produced from the aquifer; consequently, water-level declines are restricted to locales of development. No regional declines have been observed.

Pumpage from the aquifer in 1984 amounted to 35,680 acre-feet, a 17 percent decrease from the total recorded in 1980. Pumpage for irrigation and mining purposes accounted for 27 and 28 percent of the total, respectively, with both experiencing decreases in 1984, of 36 and 25 percent, respectively.

Hickory Sandstone

The Hickory Sandstone aquifer (Figure 22) underlies the Ellenburger-San Saba aquifer in the Llano Uplift region of central Texas and is made up principally of sand and sandstone. The maximum thickness of the Hickory is about 500 feet, and well yields generally range between 200 and 500 gal/min. Dissolved solids commonly range from about 300 to 500 mg/l. However, ground water containing less than 3,000 mg/l dissolved solids extends to maximum depths of about 5,000 feet below the land surface as far west as the Concho-Tom Green County line.

The declining trend of water levels in the Hickory Sandstone aquifer is shown on the hydrograph of an irrigation well located in the Camp San Saba/Katemcy area (Figure 24). The hydrograph indicates that declines of about two feet per year have occurred since 1977. Declines are generally restricted to the immediate area of development. No regional declines have been observed.

Pumpage totaled 26,183 acre-feet in 1984, which was essentially unchanged from that reported in 1980. Irrigation pumpage, which experienced an eight percent decrease from 1980, accounted for 68 percent of the total in 1984.

Ellenburger-San Saba

The Ellenburger-San Saba aquifer (Figure 22) is composed of limestone and dolomite and reaches a thickness of about 2,000 feet. Water in the aquifer is commonly under artesian pressure and issues through springs and wells which yield as much as 1,000 gal/min. The water is generally hard, but comparatively low in dissolved solids, usually containing less than 3,000 mg/l downdip to depths of approximately 3,000 feet below the surface. Little water is produced from the aquifer, so water-level declines are restricted to the immediate areas of development. Levels recover quickly through recharge from

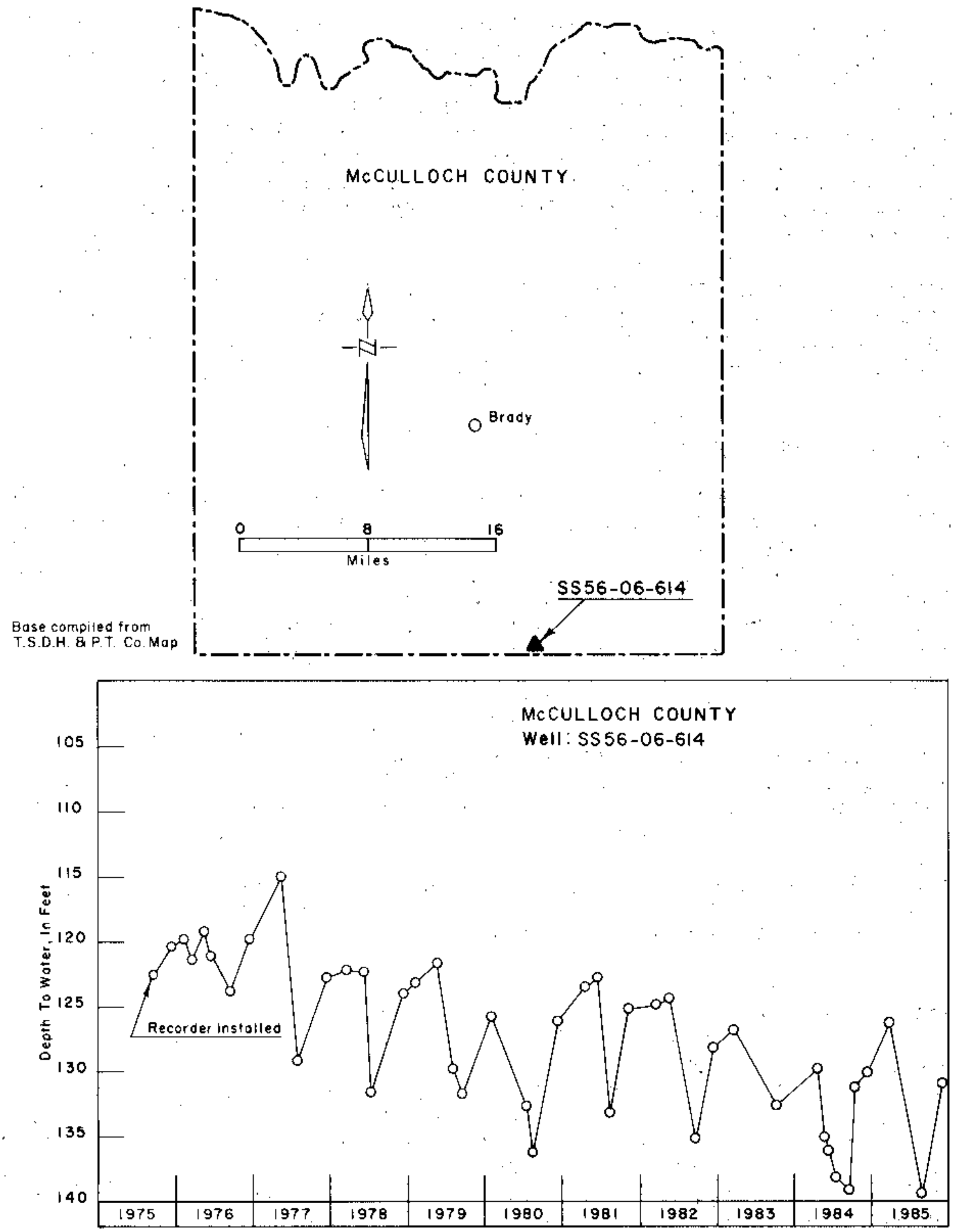


Figure 24

Hydrograph of Well Completed in the Hickory Sandstone Aquifer in McCulloch County seasonal precipitation and streams crossing the outcrop. No regional declines have been observed.

Pumpage from the Ellenburger-San Saba aquifer in 1984 totaled 7,205 acre-feet, a 79 percent increase from that in 1980. Pumpage for municipal purposes accounted for 50 percent of the 1984 total.

Marble Falls Limestone

The Marble Falls Limestone aquifer (Figure 22) reaches a maximum thickness of 600 feet. Ground water occurs in cavities and fractures in the limestone, and wells completed in the aquifer may yield as much as 2,000 gal/min. The quality of water produced from the aquifer is usually suitable for most purposes in and near the outcrop area. Little water is produced from the aquifer, consequently water-level declines are generally limited to the locale of development. The levels recover quickly through recharge from seasonal precipitation. No regional declines have been observed.

Pumpage from the Marble Falls Limestone aquifer in 1984 totaled 1,141 acre-feet, a 10 percent increase from that in 1980.

Blaine Gypsum

The Blaine Gypsum aquifer (Figure 22) comprises zones in the Blaine Formation containing usable quality water, which occurs principally in the fractured and cavernous gypsum and associated dolomite beds. The maximum thickness of the aquifer is about 300 feet, and yields of wells vary from a few gallons per minute to more than 1,500 gal/min. The water generally contains between 2,000 and 5,000 mg/l dissolved solids. Salinity of the water sometimes increases during sustained pumpage as saline waters underlying the fresh water-bearing sections are drawn into wells through the extensive fractures and solution channels. Use of the water for irrigation is generally restricted to salt-tolerant crops and to areas where soils are permeable and drainage is adequate. Since most of the water is used for agricultural purposes, water-level declines can be expected to be limited to the irrigated areas. Levels recover quickly through recharge from seasonal precipitation. No regional declines are occurring.

Pumpage from the aquifer in 1984 totaled 15,330 acre-feet, a 25 percent decrease from the 1980 total. Irrigation pumpage accounted for 97 percent of the 1984 total. A 25 percent decrease in irrigation pumpage from that recorded in 1980 accounted for the bulk of the total 1984 decrease.

Igneous Rocks

Igneous rocks in west Texas (Figure 22) contain small to large amounts of good quality water in fractures and fissures which is used by the area residents for municipal, domestic, and other purposes. Towns such as Alpine, Fort Davis, and Marfa derive all or part of their municipal water supply from such igneous rocks. Wells drilled into the aquifer generally yield small to moderate quantities of fresh water. Water levels decline during the summer pumping period, but recover rapidly when pumpage decreases. No long-term declines have been observed.

Pumpage from these igneous rocks in 1984 totaled 4,550 acre-feet, a 39 percent increase from the 1980 total. Municipal pumpage accounts for 61 percent of the 1984 total, and irrigation 29 percent. Irrigation pumpage in 1984 amounted to 1,301 acre-feet, a 217 percent increase over that in 1980.

Marathon Limestone

The Marathon Limestone (Figure 22) is an upfolded limestone formation found at or near land surface in north central Brewster County in West Texas. The aquifer ranges in thickness from 350 feet to about 900 feet, and well yields range from less than 10 gal/min to more than 300 gal/min. The water is generally very hard, and dissolved solids usually range from 500 to 1,000 mg/l.

Only a small amount of water is pumped from the aquifer (85 acre-feet in 1984), primarily for municipal and domestic use in the town of Marathon. The water table has remained relatively unchanged as the aquifer is recharged quickly through seasonal precipitation.

Bone Spring and Victorio Peak Limestones

The Bone Spring and Victorio Peak Limestones (Figure 22) contain water which has collected in the joints, fractures, and solution cavities of these limestone beds. The thickness of this aquifer may be as much as 2,000 feet, and yields of wells vary widely from about 150 gal/min to more than 2,200 gal/min. Ground water from this aquifer generally contains between 1,000 and 8,000 mg/l of dissolved solids. Although the water is generally suitable for irrigation, treatment is desirable prior to its use for municipal and domestic purposes. Water quality has continued to deteriorate as illustrated in Figure 25 which shows the concentrations of total dissolved solids in ground water in the Dell City area. The chloride content of the water is expected to continue to increase as salts are leached from the surface soils by irrigation return flow. There has been no indication of saline-water encroachment from the nearby salt flats located to the east, however. Dell City continues to treat its municipal water supply, although problems with the treatment process have been experienced periodically.

Ground water is used principally for irrigation in the Dell City area. Subsequent to the beginning of ground-water development in this area, water levels declined. However, in the last 10 years the level has remained relatively constant, as illustrated in the hydrograph of a well in Dell City (Figure 25). This indicates that the aquifer is in equilibrium and that recharge through seasonal precipitation and irrigation return flow has kept pace with the water withdrawn annually.

Pumpage in 1984 totaled 100,787 acre-feet, a decrease of 24 percent from that recorded for 1980. Since 99 percent of the 1984 total pumpage was for irrigation purposes, it follows that the reduction in total pumpage was the result

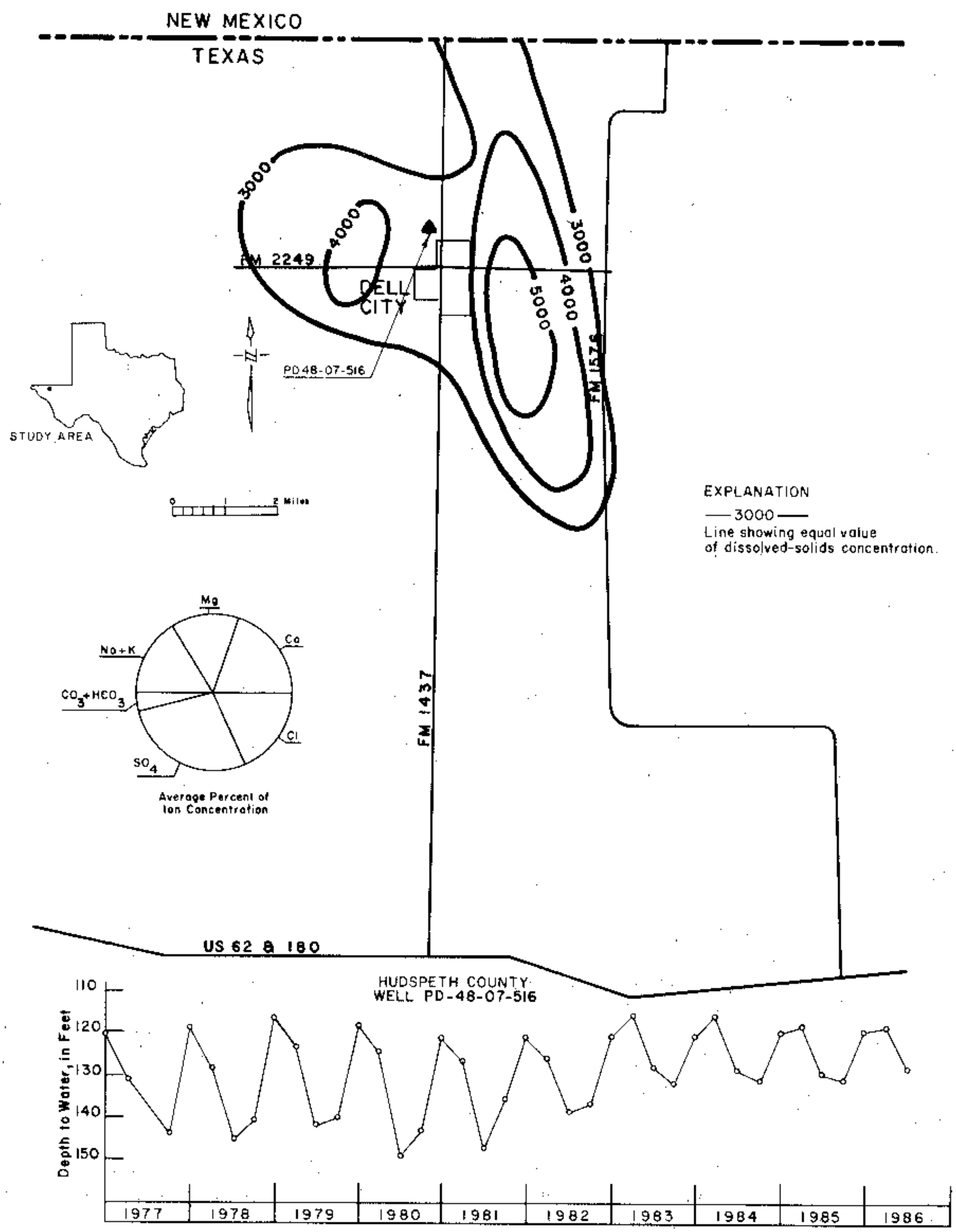


Figure 25

Map Showing Total Dissolved-Solids Content in Ground Water in the Bone Spring and Victorio Peak Limestones Aquifer in Dell City; Pie Diagram Showing the Average Percent of Ion Concentration; and Hydrograph of Well Completed in the Aquifer in Dell City of decreased agricultural activity in the Dell City area, a trend reflected throughout West Texas.

Capitan Limestone

The Capitan Limestone covered here (Figure 22) is primarily that portion of the Capitan reef which underlies the Salt Bolson deposits where ground water is available for development, primarily in the old "Diablo Farms" area along the northern Culberson-Hudspeth County line. Additionally, the limestone crops out in the Apache Mountains of southeastern Culberson County and the Glass Mountains in northern Brewster and southern Pecos Counties. In the northern Salt Bolson (old "Diablo Farms" area), the reef has been penetrated by wells to depths greater than 1,000 feet and well yields are commonly more than 1,000 gal/min. The chemical quality of the ground water in this vicinity ranges from 850 to 1,500 mg/l dissolved solids. In the Apache Mountains area, wells range in depth from 350 to 1,722 feet and yields of wells are as high as 400 gal/min. In the Apache Mountains area, dissolved solids in the water range from about 1,000 to 2,500 mg/l.

Water levels in wells in the northern Salt Bolson (old "Diablo Farms") area of Hudspeth and Culberson Counties have risen slightly in recent years as a result of a decrease in irrigation pumpage. Water levels in the other areas of occurrence have been little affected due to the minor amount of pumpage from the aquifer.

Pumpage from the Capitan totaled 303 acre-feet in 1984, with 39 percent of the total being for irrigation purposes. This represents a substantial decrease from the total pumpage of 4,600 acre-feet recorded in 1980. This again reflects the general trend of reduced irrigation pumpage resulting from decreased agricultural activity in 1984.

Rustler

The Rustler aquifer (Figure 22) consists mainly of dolomite, limestone, and gypsum with a basal zone of sand, conglomerate, shale, and minor amounts of salt. The dolomite, limestone, and gypsum are vugular and cavernous. The aquifer reaches a maximum thickness of 500 feet, and acidizing the wells usually results in yields from 300 to 1,000 gal/min. Ground water from the Rustler aquifer generally contains from 2,000 to 6,000 mg/l dissolved solids and is unsuitable for human consumption. Since little water is produced from the aquifer, water levels have remained relatively unchanged.

Pumpage from the Rustler totaled 360 acre-feet in 1984, an 83 percent increase over that in 1980, mostly as a result of 124 acre-feet of irrigation pumpage not previously experienced.

Nacatoch Sand

The Nacatoch Sand (Figure 22) is made up of light gray, unconsolidated to indurated, massive, glauconitic, calcareous sand and marl. The aquifer ranges in thickness from 350 to 500 feet, and well yields can be as much as 500 gal/min. The dissolved-solids content of the water generally ranges from 400 to 1,000 mg/l. Small quantities of water are produced from the aquifer; therefore, water-level declines are generally restricted to locales of development. A significant area of decline occurs in the vicinity of the City of Commerce, which is the aquifer's largest water producer. No other regional declines have been observed.

Pumpage from the aquifer totaled 4,967 acre-feet in 1984, an 11 percent increase over the 1980 total. Municipal pumpage experienced an 11 percent decrease, while irrigation pumpage increased by 267 percent in 1984.

Blossom Sand

The Blossom Sand aquifer (Figure 22) consists of brownish to light grayish, unconsolidated, ferruginous, glauconitic, fine- to medium-grained sand interbedded with light to dark, sandy and chalky marl. It reaches thickness of up to 400 feet, and yields from wells may be as much as 650 gal/min or more. Water from the aquifer has a dissolved-solids content of 500 to 2,000 mg/l and is soft. Little water is produced from the aquifer, and water-level declines are generally limited to the locale of development. A significant area of decline occurs in the vicinity of the city of Clarksville, which is the aquifer's largest water producer. No other regional declines have been observed.

Pumpage in 1984 totaled 1,337 acre-feet, a 19 percent decrease from that in 1980. Most of the water, 88 percent, is used for municipal purposes, which experienced a 14 percent decrease from that pumped in 1980.

Purgatoire-Dakota

The Purgatoire-Dakota aquifer, located in northwest Dallam County, is composed of white and yellow to brown sandstone and gray shale. Its thickness ranges to more than 250 feet, and well yields are sufficient to support irrigation. A City of Texline well completed in the aquifer has a dissolved-solids content of 283 mg/l. Water-level declines in the aquifer are expected to be limited to the immediate area of development. Prior to the 1978 study which resulted in redefinition of the Ogallala aquifer to what is now referred to as High Plains (Ogallala) aquifer, the Purgatoire-Dakota was treated as a separate aquifer. Now, however, it is considered to be a part of the High Plains (Ogallala), and its pumpage is included in the total for that aquifer in Table 1.

Other Undifferentiated

Additional aquifers, which in many local areas may represent the only source of ground water available, are considered here. These include deposits of Quaternary, Tertiary, Cretaceous, Permian, and Pennsylvanian age which in places provide small to moderate quantities of fresh to slightly saline ground water. These aquifers, which provide water that is utilized for all purposes, vary in extent from very small to several hundred square miles. Well yields are generally small, but some isolated wells completed in alluvial deposits or highly permeable carbonate deposits may yield several hundred gallons per minute. Water-level declines are restricted to the immediate areas of development, and no extensive water-quality deterioration has been observed.

Pumpage from this group of aquifers totaled 124,667 acre-feet in 1984, a 12 percent decrease from that in 1980. This pumpage occurred in 13 of the State's 22 river basins. Irrigation and municipal pumpage accounted for 68 and 17 percent of the total, respectively. Irrigation pumpage from the Quaternary and Tertiary deposits of the Nueces River Basin accounted for 40 percent of the total pumpage and 58 percent of the irrigation pumpage in 1984.

PUMPAGE - STATE PERSPECTIVE

The Texas Water Development Board (TWDB) conducts a program to collect and maintain a comprehensive basic data base on the occurrence and use of water in the State. These data are utilized by the Board and others to evaluate current resources and to develop future water-supply requirements. This program includes water use data collection activities for municipal and manufacturing uses, for mining and steam-electric generation uses, and for agricultural uses. Information from users of municipal, manufacturing, steam-electric power, and selected users of water for mining purposes, is collected through the TWDB's annual water use survey. Irrigated agriculture water use data are collected through cooperation with the Texas State Soil and Water Conservation Board and the U.S. Soil Conservation Service. In addition, estimates of water use are made when water use data are not available. These include estimates of: (1) individual self-supplied use, in rural areas not served by public systems, (2) mining use, based on survey data of various mining operations and data from the U.S. Bureau of Mines, (3) "water-flood" use, from data reported to the Railroad Commission of Texas, and (4) livestock water use, estimated from information collected by the Texas Crop and Livestock Reporting Service.

Ground-water pumpage (Table 1) is presented by aquifer in the county in which pumpage occurred, rather than where the water was used. Two additional illustrations are included to emphasize the distribution of ground-water pumpage in Texas in 1984 (Figures 26 and 27). These dramatically illustrate that the heaviest concentration of pumpage occurred on the Texas High Plains. This pumpage, from the High Plains (Ogallala) aquifer and primarily for irrigation purposes, accounted for 60 percent of the 1984 statewide total. Other particularly significant ground-water pumpage areas shown include: (1) municipal and industrial use in the Houston area (Gulf Coast aquifer), and (2) municipal use in the San Antonio area (Edwards-Balcones Fault Zone aquifer).

The following discussion is based on pumpage information shown in Table 1 of this report. The total ground-water pumpage in 1984 was 8,854,470 acre-feet. This is 1,992,511 acre-feet or 18 percent less than the 1980 total. Irrigation pumpage accounts for 78 percent of the 1984 total. The decrease in total pumpage between 1980 and 1984 is due essentially to a 23 percent decrease in irrigation pumpage of 2,057,142 acre-feet. Although the 1984 irrigation pumpage was essentially lower throughout the State compared to the 1980 pumpage, a reduction of 1,886,132 acre-feet of water pumped from the High Plains (Ogallala) aquifer accounted for 95 percent of the total irrigation pumpage decrease. Other large declines in 1984 irrigation pumpage compared to 1980 were recorded in the Gulf Coast aquifer (down 18 percent), Bone Spring and Victorio Peak Limestones aquifer (down 24 percent), and a 39 percent decrease in the alluvial and bolson aquifers of north and west Texas (Seymour, Salt Bolson, and Cenozoic Pecos Alluvium). Between 1980 and 1984, minor increases in irrigation pumpage were recorded in several aquifers, the largest being a 45 percent increase in the Edwards (Balcones Fault Zone) aquifer. The decline in water use for irrigated agriculture between 1980 and 1984 can primarily be attributed to a decline in irrigated acreage, an above average rainfall and soil moisture content during the last part of the growing season, and a more efficient application of irrigation water.

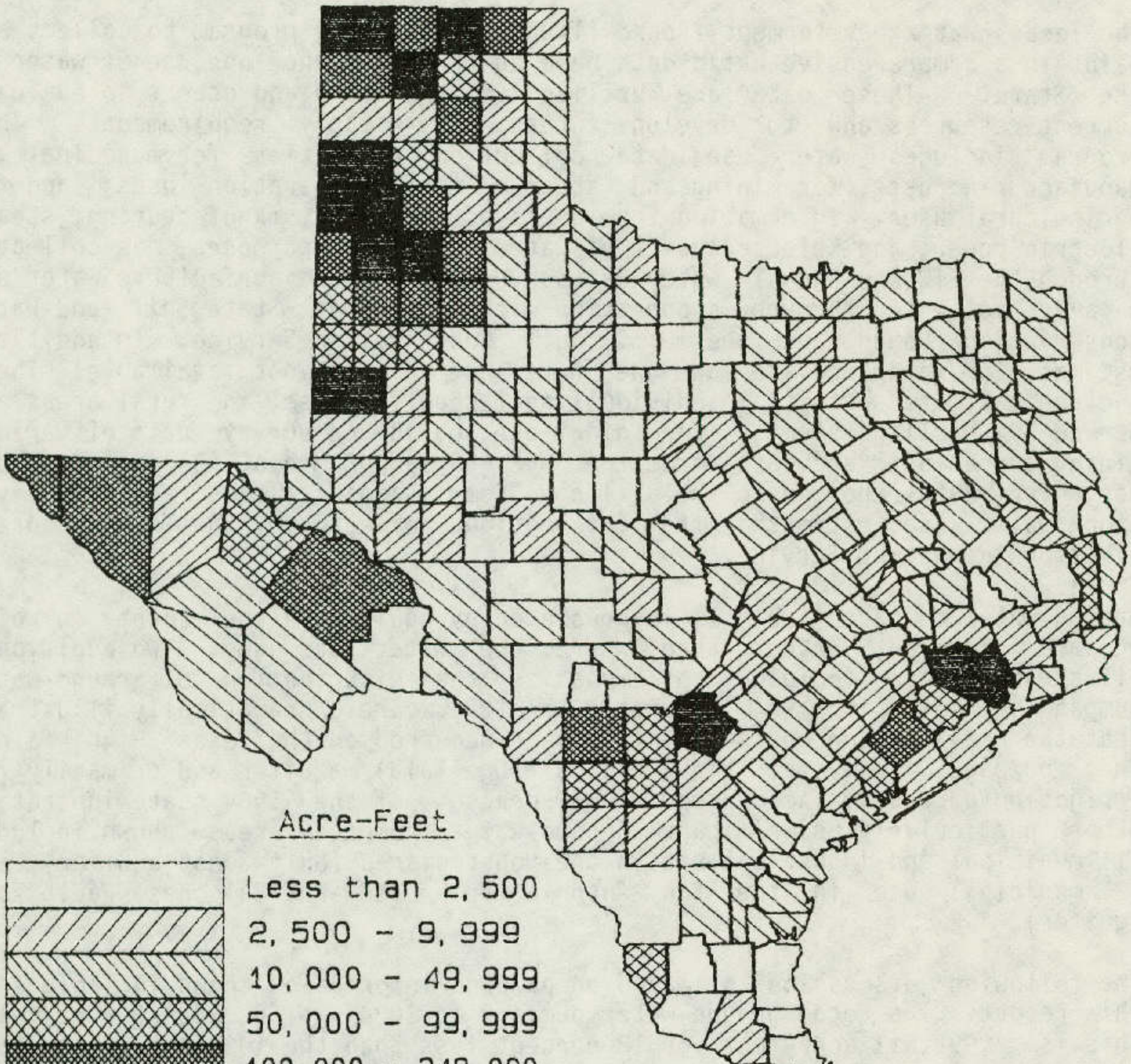


Figure 26
Map of Texas Showing 1984 Ground-Water Pumpage, by County, in Acre-Feet

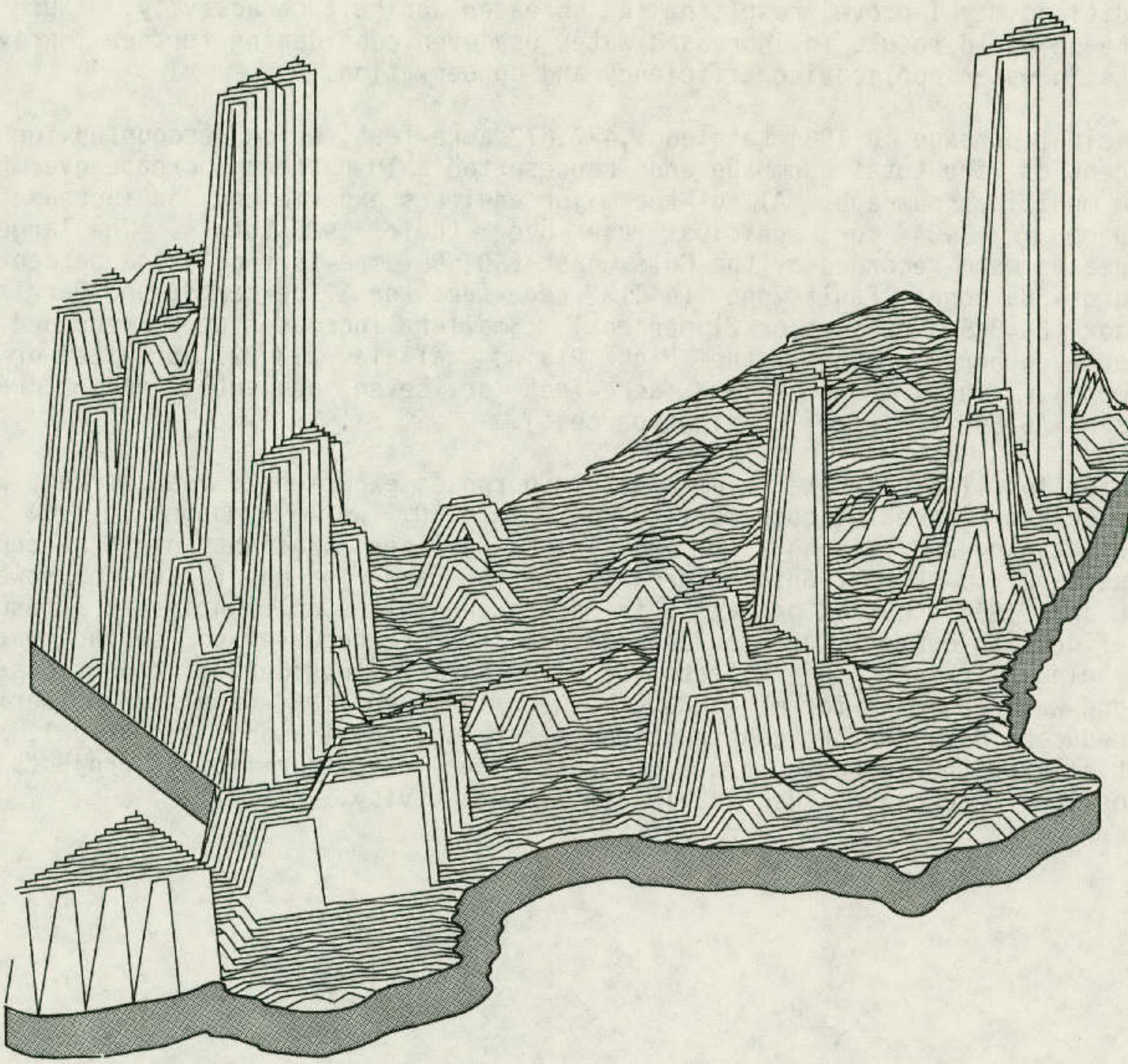


Figure 27
Graphic Illustration of 1984 Pumpage by County

This trend of reduced water use for irrigation may not continue as economic conditions may improve, resulting in increased agriculture activity. Such an increase would result in increased water use even considering further improvements in water application efficiency and conservation.

Municipal pumpage in 1984 totaled 1,477,672 acre-feet, which accounted for 17 percent of the total pumpage and represented a 10 percent increase over the 1980 municipal pumpage. All of the major aquifers experienced an increase in pumpage in 1984 for municipal use over their 1980 totals. The largest increases were recorded by the Gulf Coast (50,698 acre-feet or nine percent), Edwards- Balcones Fault Zone (44,132 acre-feet or 17 percent), and Carrizo-Wilcox (24,825 acre-feet or 21 percent). Smaller increases were recorded by several others, notably the High Plains-Ogallala (13,221 acre-feet or 14 percent), Trinity Group (8,333 acre-feet or seven percent), and El Paso Bolsons (6,698 acre-feet or eight percent).

Pumpage for livestock and steam-electric purposes experienced four percent and one percent increases compared to that in 1980, while pumpage in 1984 for manufacturing and mining uses experienced declines of eight and 35 percent, respectively. Reductions in ground-water pumpage for manufacturing between 1980 and 1984 occurred primarily in Harris and Galveston Counties as a result of efforts to convert the area's water use from ground water to surface water to help alleviate the effects of land surface subsidence. Reductions in ground-water pumpage for mining use between 1980 and 1984 were due primarily to reduced demands for construction materials, mainly sand and gravel, and partially to the decrease in use of fresh water for "water flood" projects as a result of the general decline in oil field activity.

SUMMARY

Of the total quantity of water used in Texas in 1984 (15,552,222 acre-feet), 60 percent (8,854,470 acre-feet) was ground water from the State's aquifers. The amount of ground water projected to be pumped from State's aquifers has been previously determined to range from approximately 12.1 million acre-feet in 1980 to 9.4 million acre-feet through 2030. Countless municipalities, households, and industrial users obtain their water supply from nearly aquifers. Most of the ground water pumped was used for irrigation purposes. Texas is indeed fortunate to have this ground water as a major natural resource.

Irrigation pumpage accounted for 78 percent of the 1984 total and the High Plains (Ogallala) aquifer accounted for 74 percent of this total. Despite this, over half of the southern High Plains area experienced water-level rises.

Reduced agricultural activity resulted in a 23 percent reduction in irrigation pumpage from that recorded in 1980. The areas primarily affected by these reductions were the High Plains, irrigated areas of West Texas, and the Gulf Coast.

Municipal and industrial pumpage from the Trinity Group aquifers has resulted in water-level declines of over six feet per year in the Dallas-Fort Worth area and 18 feet per year in the Waco area. Decreased industrial pumpage plus the efforts of the Harris-Galveston Coastal Subsidence District have resulted in water-level rises occurring in areas of the upper Gulf Coast which had previously experienced declines.

Small changes in water quality may be occurring in individual wells, but no areas of regional deterioration of native ground-water quality have been identified except in the Dell City area. Here, recirculated recharge from the use of slightly saline ground water for irrigation purposes continues to result in a cumulative increase in the total mineral content of the water.