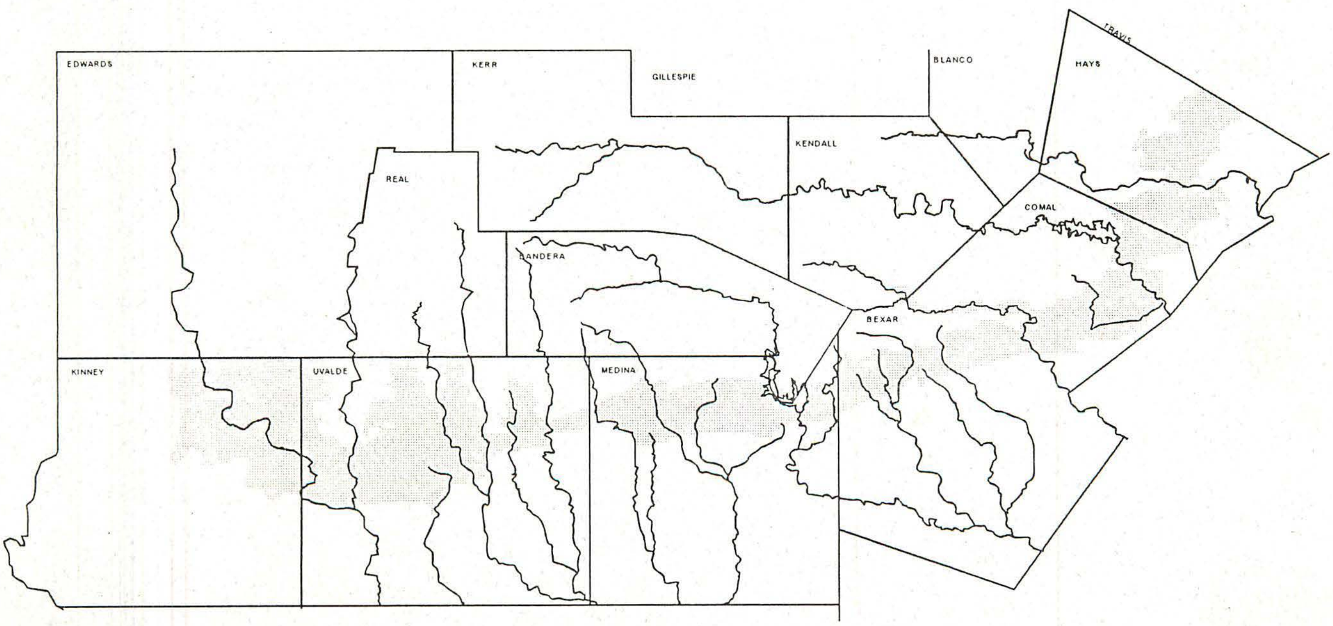
EDWARDS UNDERGROUND
WATER DISTRICT

Report 93-05

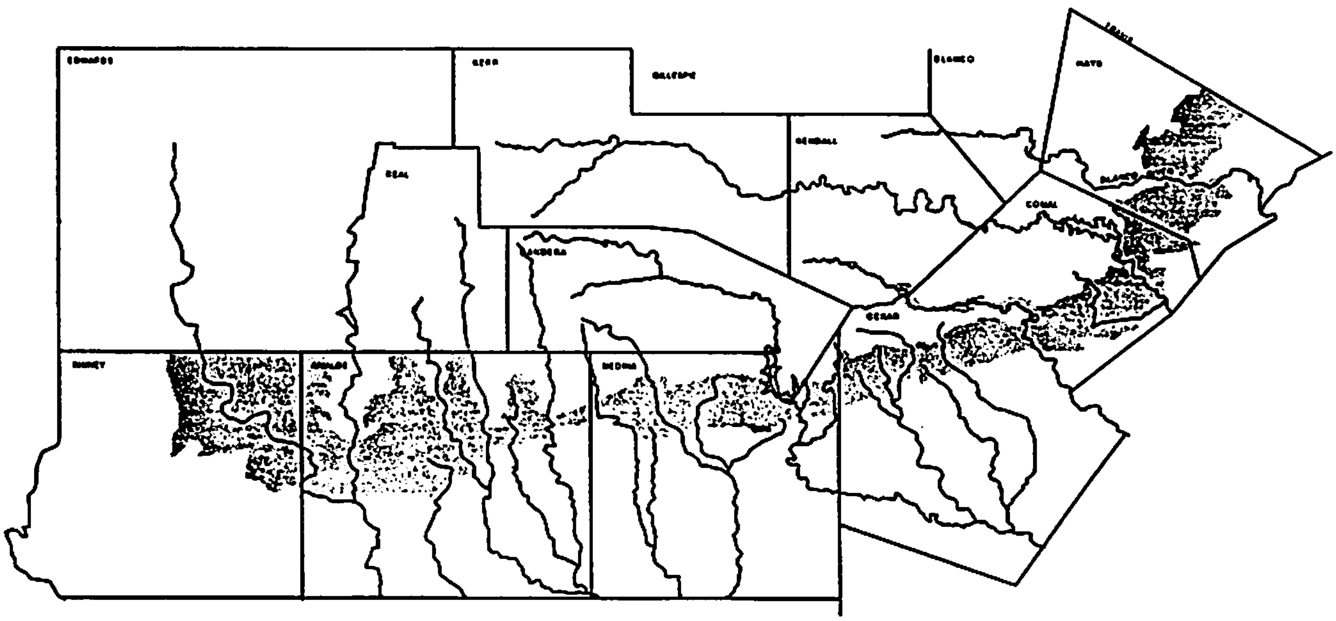
EDWARDS AQUIFER HYDROGEOLOGIC STATUS REPORT FOR 1992



Prepared by: Field Operations Division

EDWARDS UNDERGROUND WATER DISTRICT

EDWARDS AQUIFER HYDROGEOLOGIC STATUS REPORT FOR 1992



Prepared by: Field Operations Division

EDWARDS UNDERGROUND WATER DISTRICT

1615 N. St. Marys
San Antonio, Texas 78215

EDWARDS AQUIFER HYDROGEOLOGIC STATUS REPORT FOR 1992

Compiled by

Robert W. Bader, Steven D. Walthour, and John R. Waugh
Edwards Underground Water District

Prepared by the Edwards Underground Water District

August 1993

Table of Contents

List of Figures

List of Tables

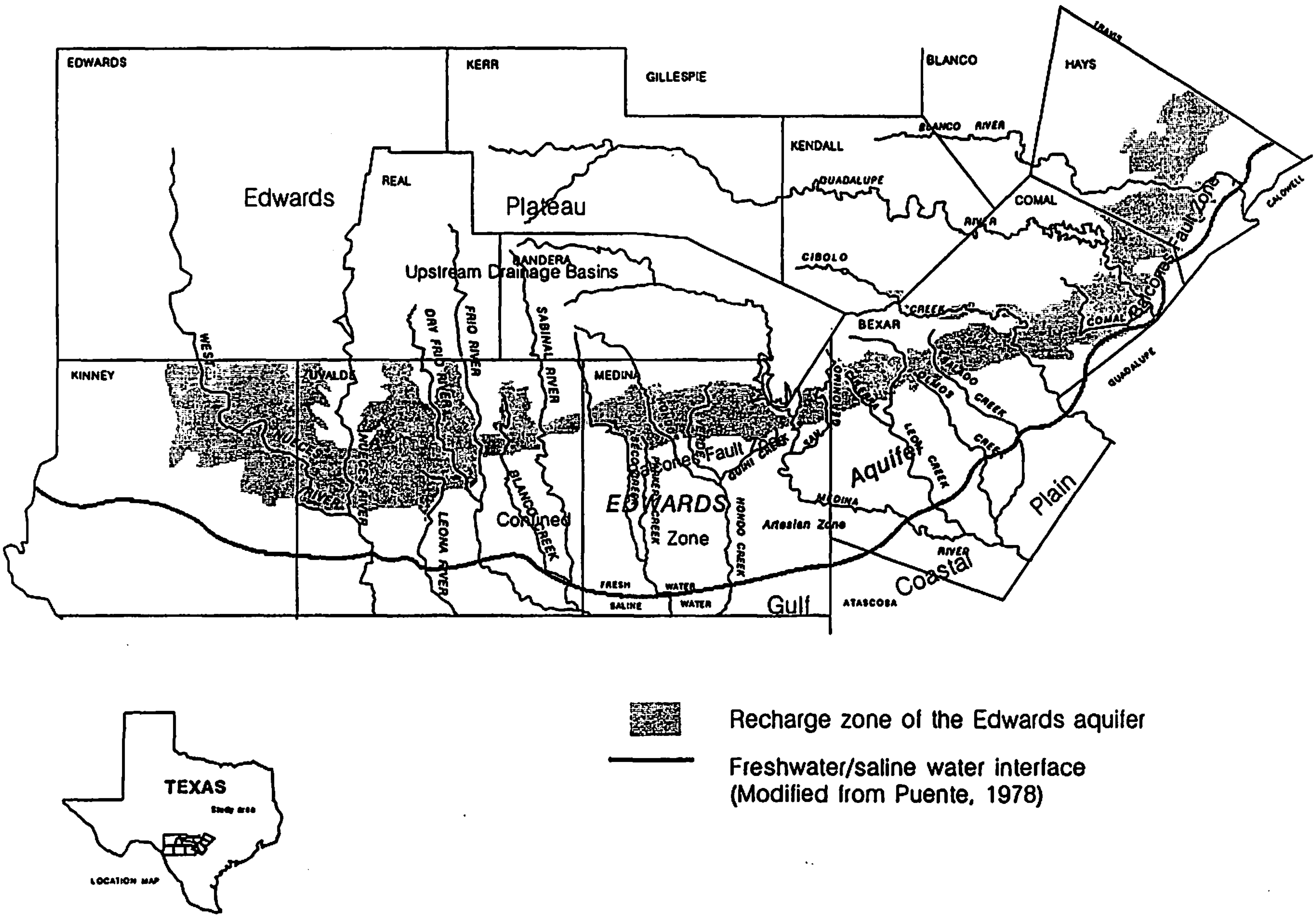
1.0 Introduction

The Edwards Underground Water District (District), created by the Texas Legislature in 1959, is charged with conserving, protecting, recharging and preventing pollution of the groundwater in the Edwards aquifer. The District conducts investigations of groundwater resources, develops regional usage plans as well as informs and educates the public about the aquifer to accomplish its mandate.

In keeping with the District's statutory charge, District staff have prepared this report of technical data collected by the District for calendar year 1992, and present this information with a historical perspective for the public and for officials responsible for establishing policies regarding the use of this unique resource.

The San Antonio area of the Edwards aquifer extends through six counties in central Texas from the groundwater divide near Brackettville in Kinney County to the groundwater divide near Kyle in central Hays County. Though the Edwards aquifer is not limited to this six county area, this report will present information only on this portion of the aquifer. **Figure 1.1** is a regional map showing primary physiographic features of the Edwards aquifer within the report area.

Figure 1.1 - Edwards aquifer and other physiographic features in the San Antonio area.



2.0 Water Levels

Periodic water level measurements from a variety of wells have been compiled in the San Antonio area of the Edwards aquifer region since 1929. These periodic measurements were enhanced with the introduction of continuous water level recorders in some of the observation wells in the 1930's by the United States Geological Survey (USGS). The District has since added numerous continuous digital recorders to develop a groundwater data collection network from eastern Kinney County to central Hays County.

The wells in the data network are located in the water table portion as well as the artesian portion of the Edwards aquifer. Since January 1991, the District has been collecting water level data in northern Bexar County from the Glen Rose formation. Water level monitoring assists in research and management of these aquifers.

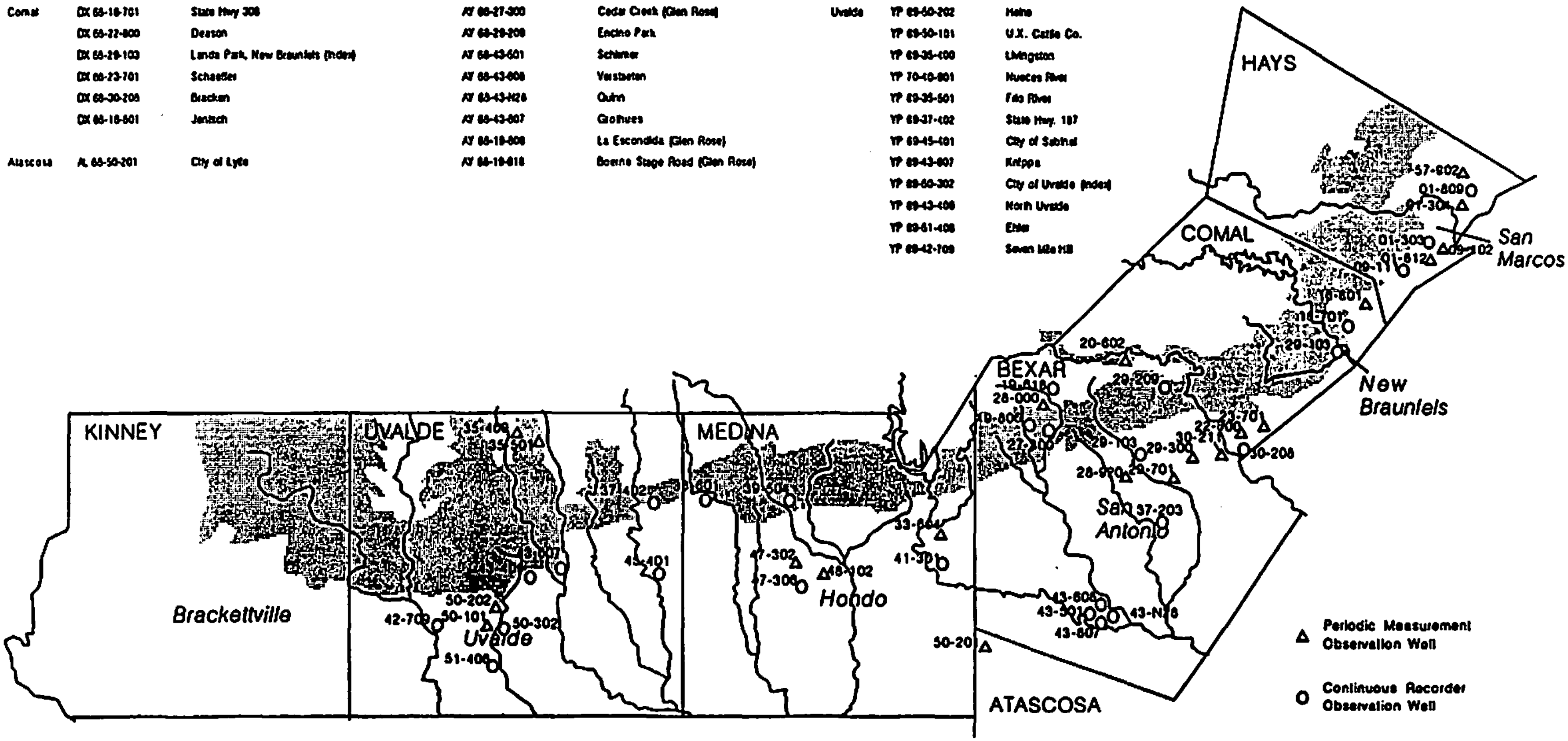
2.1 Groundwater Level Data Collection Methods

Over 800,000 water level measurements from twenty-five digital recorder equipped observation wells and monthly measurements from 20 periodic observation wells were performed in 1992 as part of the District's water level data collection activities. **Figure 2.1** shows the locations of the observation wells within the network.

The digital recorder network measures water levels across the aquifer every fifteen minutes, 365 days a year. These wells are equipped with a float device, or a pressure transducer, for water level readings. Data are recorded on digital storage cards and then downloaded during site inspection, or by modem to the District's central data collection facility in San Antonio.

Figure 2.1 - Edwards Underground Water District water level observation well network.

County	Well I.D. Number	Name (Location)
Hays	LR 67-01-303	City of Kyle (Index)
	LR 67-01-809	Knispel (Index)
	LR 67-09-102	Hichelson
	LR 67-09-111	Southwest Texas
	LR 58-57-902	Gregg
	LR 67-01-304	City of Kyle (Index)
	LR 67-01-812	San Marcos BWL
Comal	DX 68-16-701	State Hwy 306
	DX 68-22-800	Deason
	DX 68-29-103	Landa Park, New Braunfels (Index)
	DX 68-23-701	Schaefer
	DX 68-30-208	Bracken
	DX 68-16-801	Jentsch
Atascosa	AL 68-50-201	City of Lytle
Bexar	AY 68-30-211	Cibolo Creek
	AY 68-29-300	Judson Road
	AY 68-29-701	Airport
	AY 68-20-602	Blanco Road (Glen Rose, Cow Creek)
	AY 68-28-920	West Avenue
	AY 68-28-000	Chulan Pass (Glen Rose)
	AY 68-29-100	Hill Country
	AY 68-37-203	Dodd Field-J 17 (Index)
	AY 68-27-300	Cedar Creek (Glen Rose)
	AY 68-29-208	Encino Park
	AY 68-43-601	Schirmer
	AY 68-43-608	Verstuyft
	AY 68-43-N26	Quinn
	AY 68-43-807	Grothues
	AY 68-19-808	La Escondida (Glen Rose)
	AY 68-19-818	Boerne Stage Road (Glen Rose)
Medina	TD 68-33-804	Stinson
	TD 69-48-102	Muennink
	TD 69-47-302	Hondo Pool
	TD 69-39-504	Tarply Road
	TD 69-47-306	City of Hondo (Index)
	TD 69-38-601	Seco Creek
	TD 68-41-301	City of Castroville (Index)
Uvalde	YP 69-50-202	Heine
	YP 69-50-101	U.X. Cattle Co.
	YP 69-35-400	Livingston
	YP 70-40-801	Nueces River
	YP 69-35-501	Frio River
	YP 69-37-402	State Hwy. 187
	YP 69-45-401	City of Sabinal
	YP 69-43-807	Knippa
	YP 69-50-302	City of Uvalde (Index)
	YP 69-43-408	North Uvalde
	YP 69-51-408	Ebler
	YP 69-42-709	Seven Mile Hill



To augment the digital recorder network, District personnel measure water levels monthly at various wells across the region. These periodic measurements are performed by tape and chalk method and occasionally by conductivity meter. Water level data collected by the District are forwarded to the Texas Water Development Board and the U.S.G.S.

2.2 Historical Water Level Trends

Historical water level trends in observation wells along with corresponding precipitation and discharge information are necessary to determine the quantity of groundwater stored in the aquifer during any given period. Water level increases generally indicate that greater quantities of water are recharging the aquifer than are being discharged. During periods where groundwater recharge is greater than discharge, springflow increases in proportion to groundwater level increases. Likewise, during drought conditions water levels and springflow generally decline, reflecting greater groundwater discharge than groundwater recharge.

Historical annual water level highs and lows for selected index wells for the period of record in the Edwards aquifer are shown in **Figure 2.2** and in **Table 2.1**.

Since 1929, four extended periods of significantly lower than normal water levels were recorded throughout the region. These time periods were: 1952 to 1957, 1967, 1984, and 1989 to 1990. It was also during the drought of the 1950s that the lowest recorded water levels for the period of record were measured. Comal Springs in New Braunfels ceased to flow for about five months in 1956. Lower than normal rainfall was also recorded for San Antonio from 1951 to 1956.

Figure 2.3 is a hydrograph comparing the Bexar County index well in San Antonio to springflow at Comal Springs from 1949

Figure 2.2 - Yearly water level highs and lows for five selected Edwards aquifer index wells, 1934-1992.

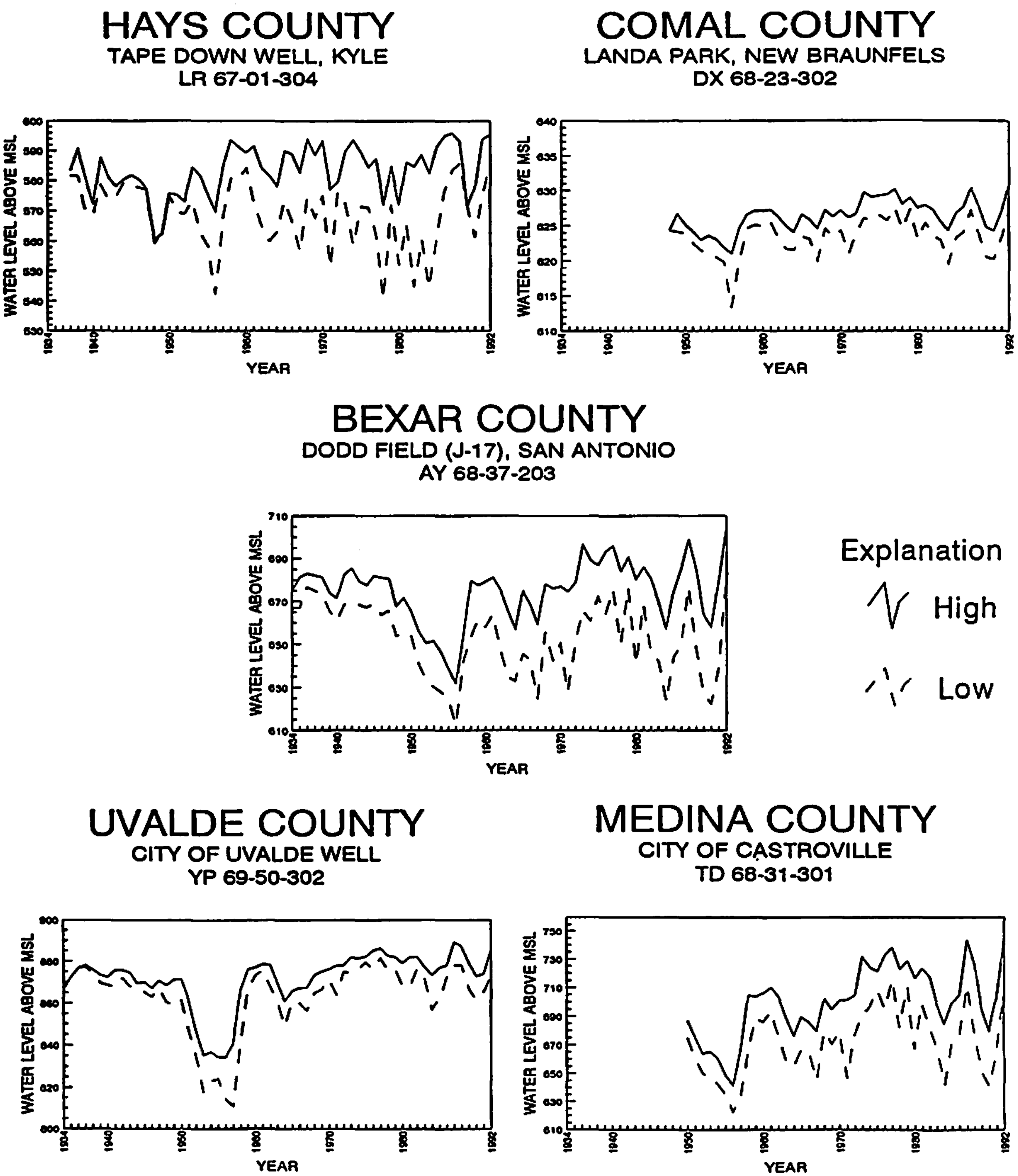
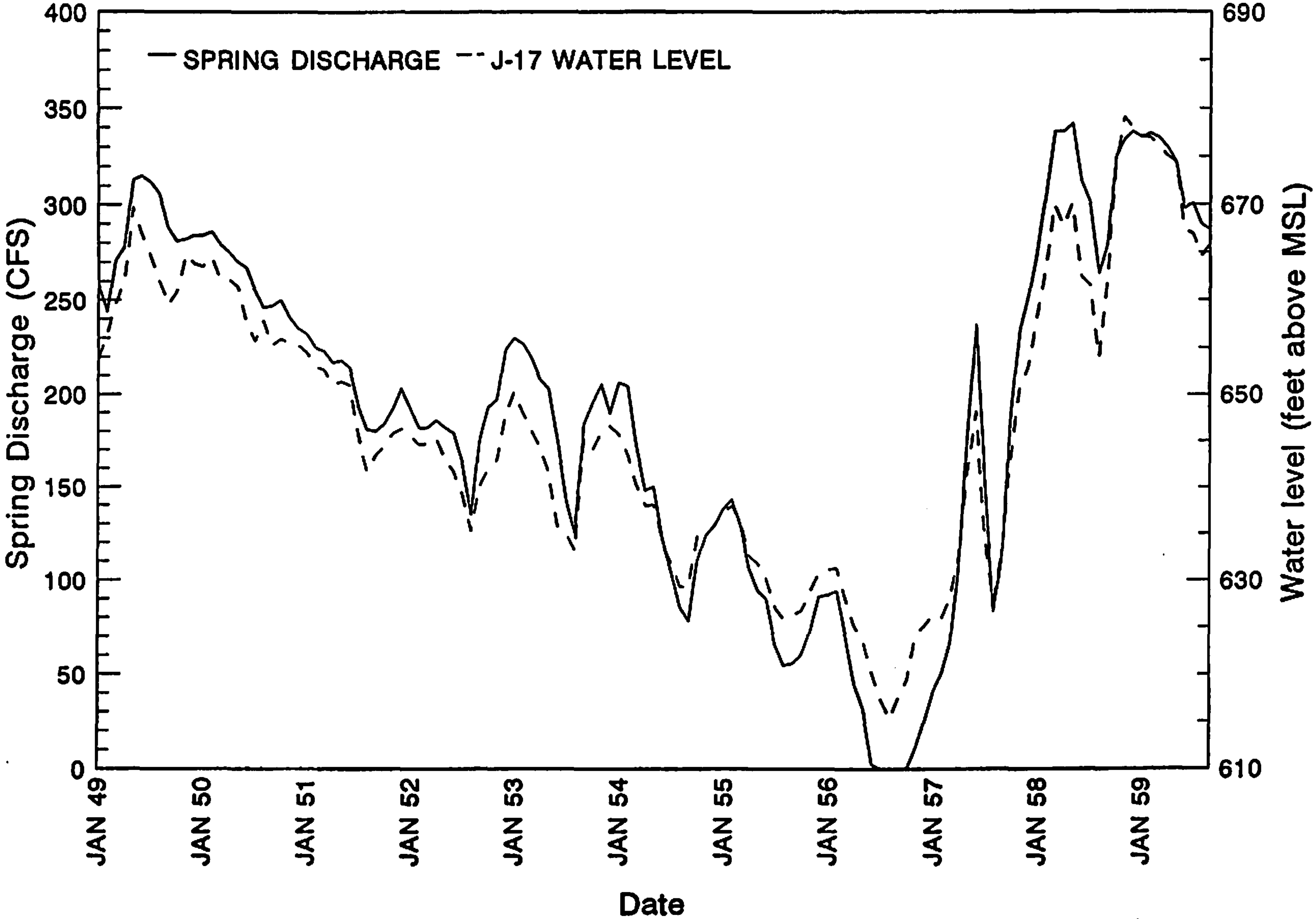


Table 2.1 - Annual and period of record high and low water levels measured in selected observation wells completed in the Edwards aquifer, 1934-1992. Water levels are measured in feet above mean sea level (msl).

Year	City of Uvalde Uvalde County YP-69-50-302 HIGH	 LOW	Castroville Medina County TD-68-41-301 HIGH	 LOW	San Antonio Bexar County AY-68-37-203 HIGH	 LOW	New Braunfels Comal County DX-68-23-302 HIGH	 LOW	Kyle Hays County LR-61-01-304 HIGH	 LOW
1934	866.61	—	—	—	675.20	666.81	—	—	—	—
1935	872.12	—	—	—	681.31	666.80	—	—	—	—
1936	876.63	876.51	—	—	683.02	676.62	—	—	—	—
1937	878.11	877.08	—	—	682.08	674.92	—	—	583.4	581.6
1938	875.79	873.95	—	—	681.39	673.58	—	—	590.6	581.5
1939	873.35	869.58	—	—	674.10	665.69	—	—	580.6	569.6
1940	872.33	868.53	—	—	671.43	660.96	—	—	572.2	568.7
1941	875.70	867.74	—	—	682.46	668.26	—	—	587.7	578.6
1942	875.75	871.87	—	—	685.36	669.74	—	—	580.8	573.7
1943	874.53	867.98	—	—	679.58	668.51	—	—	578.2	574.6
1944	869.30	866.80	—	—	677.62	667.13	—	—	580.5	579.3
1945	870.08	865.17	—	—	681.91	668.81	—	—	581.8	—
1946	867.06	862.87	—	—	681.15	663.61	—	—	580.3	—
1947	870.73	867.08	—	—	680.70	665.81	—	—	577.3	577.0
1948	868.37	860.49	—	—	667.74	653.68	624.4	624.3	560.5	559.4
1949	871.15	859.09	—	—	671.59	655.55	626.7	624.1	562.3	561.8
1950	871.24	861.79	686.97	674.86	665.38	653.76	625.2	624.0	575.8	575.2
1951	861.78	846.84	675.17	659.91	656.01	640.63	624.2	622.5	575.3	569.4
1952	846.80	834.87	663.77	649.92	650.49	633.44	623.0	621.5	573.0	569.1
1953	835.21	817.79	665.12	647.69	651.52	630.53	623.6	621.1	584.5	573.2
1954	836.71	823.14	660.34	642.44	646.34	628.09	623.1	620.5	581.8	562.8
1955	834.30	824.05	649.13	635.59	638.49	624.24	621.9	619.8	575.7	558.4
1956	834.20	814.20	641.58	622.31	632.22	612.51	621.0	613.3	569.8	542.2
1957	840.85	810.95	666.11	632.99	653.77	624.36	624.7	620.1	584.9	568.3
1958	866.09	840.82	704.35	665.74	679.56	653.26	626.6	624.6	593.6	580.8
1959	876.06	866.20	703.82	688.95	677.66	661.47	627.1	625.1	591.4	580.5
1960	876.92	873.09	706.29	686.00	679.39	657.86	627.1	624.9	589.4	584.3
1961	878.48	875.60	710.31	693.38	681.16	663.90	627.3	625.7	591.6	573.2
1962	878.26	867.72	703.59	676.34	675.51	646.94	626.3	623.2	584.1	565.0
1963	869.69	860.93	689.12	659.19	665.80	635.02	625.0	621.7	581.6	560.0
1964	860.93	848.97	676.28	654.78	657.05	632.83	624.1	621.6	578.2	562.8
1965	865.82	860.33	689.63	666.77	674.99	645.64	626.6	623.5	590.1	573.4
1966	867.23	860.16	686.06	665.00	668.79	642.74	625.9	623.1	589.0	566.6
1967	867.38	856.44	679.44	645.19	659.69	624.91	624.6	620.0	582.8	556.6
1968	873.31	864.83	701.95	679.19	678.33	655.87	627.2	624.6	593.8	574.4
1969	874.98	866.51	694.76	670.49	676.10	642.77	626.3	623.4	588.7	567.7
1970	876.11	871.32	700.74	678.83	677.08	650.41	627.2	624.3	593.2	575.0
1971	877.65	863.95	701.30	646.43	674.58	627.89	626.2	621.0	577.1	551.3
1972	877.78	874.56	704.59	676.71	678.99	651.17	626.7	624.1	579.7	576.3
1973	881.63	874.50	731.23	690.06	696.52	665.92	629.8	626.1	589.9	572.3
1974	881.35	875.97	723.84	695.96	689.22	660.88	629.1	625.8	593.6	558.5
1975	882.10	879.41	720.99	708.15	686.92	671.99	629.3	626.5	589.8	571.4
1976	884.93	875.97	732.35	694.88	693.11	663.76	629.4	625.8	584.6	571.2
1977	886.21	881.31	737.82	715.27	695.95	675.63	630.2	627.6	587.4	562.1
1978	882.56	875.62	722.40	681.66	684.11	650.13	628.1	624.5	572.0	540.4
1979	881.95	876.06	728.22	710.29	690.52	676.40	629.0	627.3	584.9	572.0
1980	879.07	868.00	716.09	666.76	680.29	640.76	627.5	623.0	572.0	551.8
1981	881.80	867.90	723.17	698.77	685.99	668.57	628.0	625.5	586.2	565.5
1982	881.83	876.35	717.12	682.77	680.45	645.33	627.3	623.6	584.7	544.7
1983	877.05	871.25	698.16	667.69	669.92	642.11	625.6	623.0	588.7	560.4
1984	873.26	856.91	684.52	642.03	656.97	623.29	624.4	619.6	582.5	544.3
1985	876.85	862.24	698.98	670.68	674.50	644.05	626.8	623.3	591.4	561.8
1986	877.82	872.20	704.64	674.19	685.59	649.81	627.7	624.1	595.0	576.3
1987	889.08	877.86	743.48	711.12	699.23	676.88	630.4	627.2	595.9	583.5
1988	887.03	877.99	725.34	679.89	684.87	647.74	627.9	623.9	593.2	585.9
1989	879.02	866.64	695.30	650.52	663.90	626.98	624.9	620.5	571.7	571.5
1990	872.91	861.58	679.47	640.79	658.11	622.66	624.3	620.3	577.6	561.2
1991	873.80	865.41	703.77	666.08	680.32	640.54	627.0	623.3	593.8	575.1
1992	885.15	872.87	743.60	704.33	703.31	680.74	630.9	627.0	595.4	586.2
Average	High 871.54	Low 862.73	High 699.79	Low 671.41	High 674.84	Low 652.22	High 626.44	Low 623.33	High 583.42	Low 568.30
Record Level	High 889.08	Low 811.00	High 743.60	Low 622.27	High 703.31	Low 612.51	High 630.92	Low 613.34	High 595.90	Low 540.40
Month Year	June 1987	April 1957	June 1992	Aug 1956	June 1992	Aug 1956	June 1992	Aug 1956	Sept 1987	July 1978

Figure 2.3 - Comparison of average monthly water levels in the Bexar County index well, to groundwater discharge at Comal Springs from January 1949 to September 1959.



to 1959. This period was selected to contrast normal water levels in the Bexar County index well and springflow at Comal Springs before and after the 1951 to 1956 drought.

In contrast to the periods of low water level, six extended periods of significantly higher than normal water levels were recorded throughout the region since 1929. These periods were; 1934 to 1938, 1941 to 1947, 1958 to 1961, 1972 to 1982, 1986 to 1988, and 1991 to 1992. The record water levels for the period of record in each of the five county primary index wells were set in 1987 or 1992.

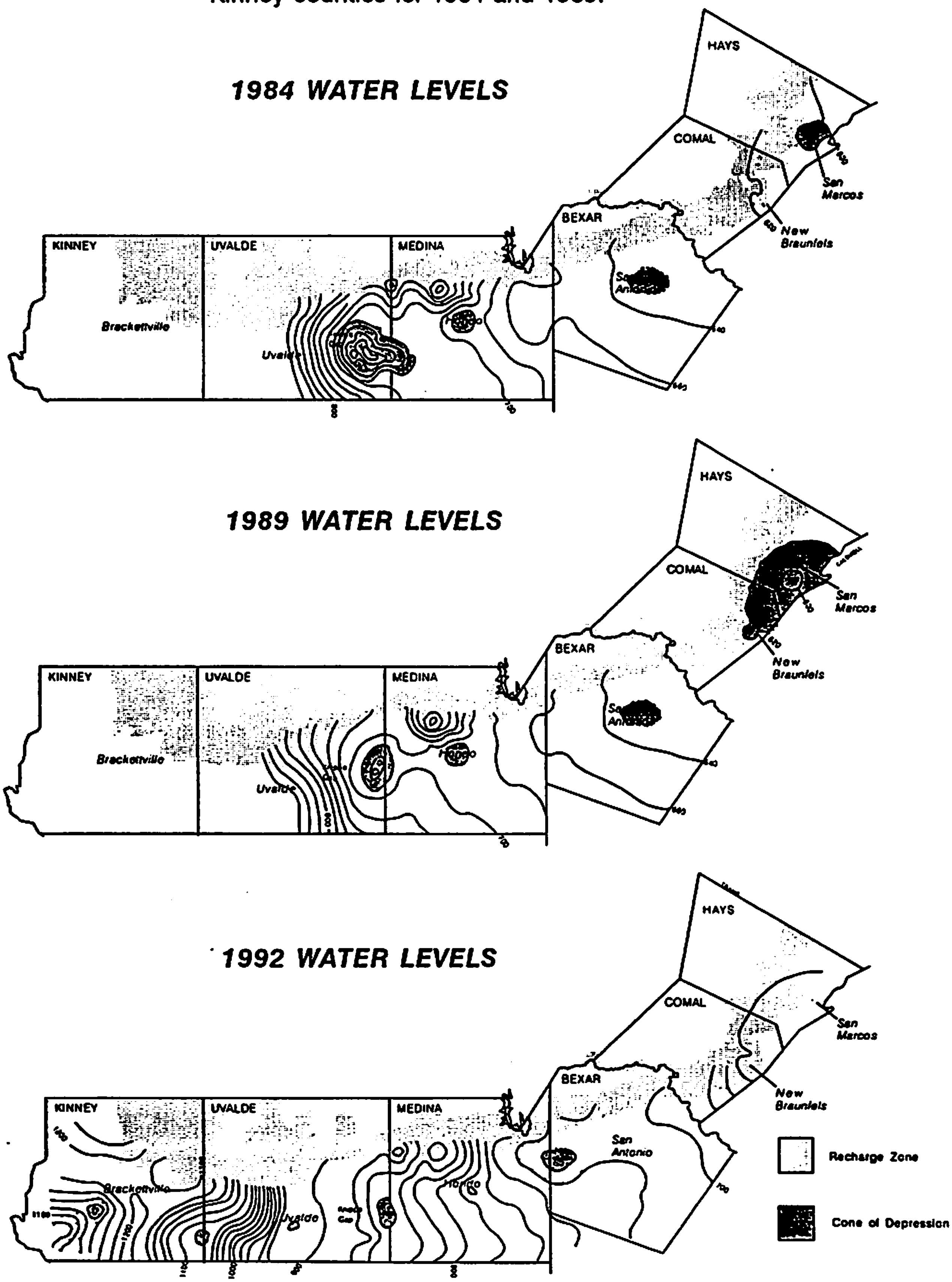
2.3 Regional Water Levels for 1992

In 1992, water levels in the Edwards aquifer increased to record elevations reflecting greater groundwater recharge than groundwater discharge for the year. Water level data indicated that groundwater storage increased during the year in various proportions throughout the aquifer.

Regional potentiometric surface maps for 1984 and 1989 which were relatively dry years and for 1992 were plotted by the District staff. In 1992, the amplitude of cones of depression which formed around pumping and spring discharge centers were significantly decreased compared to the two dry years. The cone of depression surrounding groundwater discharge in San Antonio was markedly smaller during the year. **Figure 2.4** shows potentiometric surface maps for 1984, 1989, and 1992.

Two cones of depression were present in areas of relatively low groundwater discharge. These two depressions occurred at Knippa in Uvalde County and southeast of Medina Lake on the Bexar County/Medina County line. The cone of depression at Knippa has been referred to as the Knippa Gap by groundwater researchers. The second cone of depression was located near the Bexar County/Medina County line.

Figure 2.4 - Potentiometric surface maps for selected periods in 1984, 1989, and 1992. No data was available for the western Uvalde and Kinney counties for 1984 and 1989.



2.4 Groundwater Levels at Selected Observation Wells for 1992

During 1992, Edwards aquifer water levels generally crested in Hays County in February and March; and in Bexar, Comal, Medina and Uvalde Counties in June. Water levels continued to rise through December in the Glen Rose.

Hydrographs for selected Edwards aquifer index wells in each county are shown in **Figure 2.5**. Observation well water levels, discussed in this report, are recorded in feet above mean sea level (msl). The following is a summary of water level conditions in each of the five counties with discussion of selected index wells and primary observation wells throughout the region.

2.4.1 Bexar County

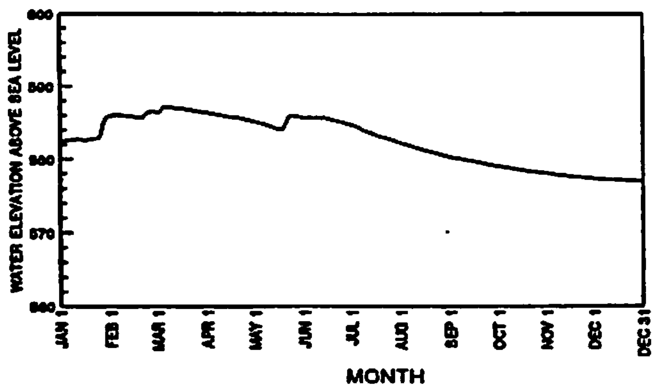
Groundwater data from the Bexar County index well are available for the period of record from 1932 to present.

Water levels in this key index well of the Edwards aquifer reached a record high of 703.3′ above msl on June 14, 1992, then progressively declined to 691.7′ above msl on December 31, 1992. In comparison, the water level for the end of December, 1991 (an above average precipitation year) was 680.3′ above msl, and for December 31, 1956 (longest drought for the period of record) the water level was 626.9′ above msl. The normal (or average) annual water level high and low for this well for the period of record is 674.8′ above msl and 652.2′ above msl, respectively.

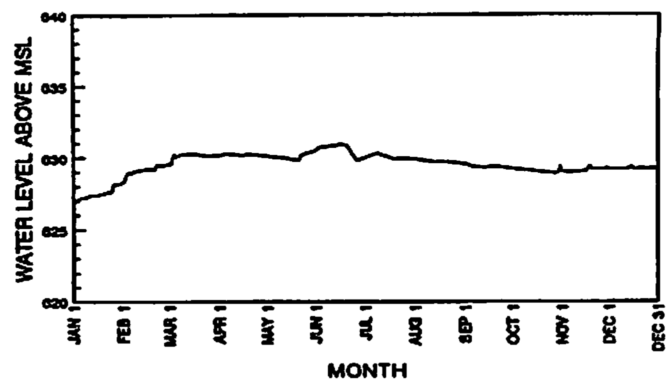
An observation well was established at La Escondida in northern Bexar County January 29, 1991 to continuously monitor the Lower Glen Rose aquifer. The Glen Rose formation is located stratigraphically below the Edwards aquifer throughout the region. Water levels associated with the Glen Rose aquifer consistently increased from 1013.1′

Figure 2.5 - 1992 hydrographs for selected Edwards aquifer index wells.

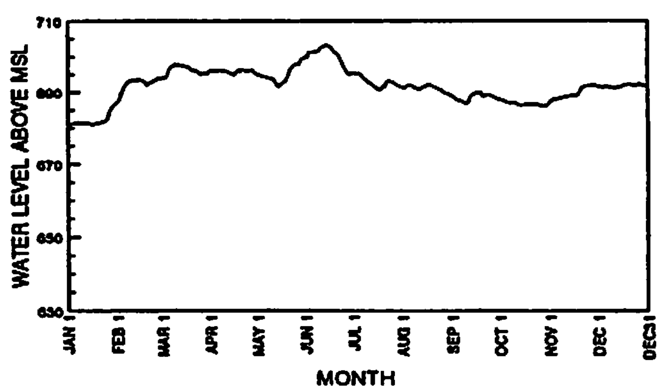
HAYS COUNTY INDEX WELL
KNISPEL
67-01-809



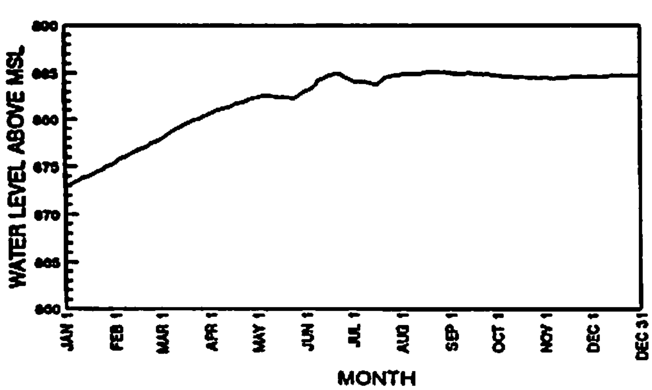
COMAL COUNTY INDEX WELL
NEW BRAUNFELS
68-23-302



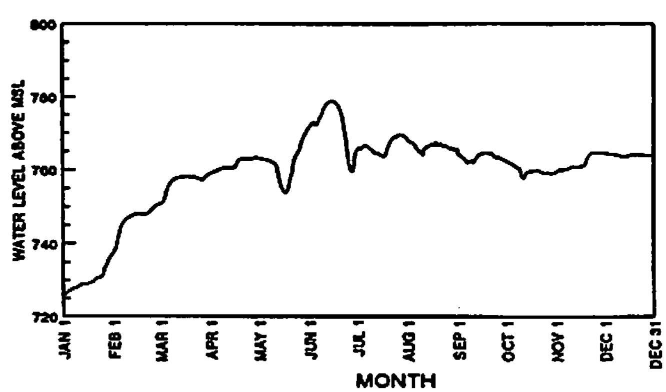
BEXAR COUNTY INDEX WELL
SAN ANTONIO
68-37-203



UVALDE COUNTY INDEX WELL
CITY OF UVALDE
69-50-302



MEDINA COUNTY
HONDO CITY YARD
69-47-306



above msl on January 1, 1992 to 1055.4′ above msl on December 31, 1992, setting a new record high.

Though Bexar County water levels in both the Edwards and the Glen Rose aquifers increased in response to higher than normal precipitation, Glen Rose water levels increased through the year while most Edwards water levels crested mid year. A hydrograph comparing the La Escondida index well to the Bexar County index well for the Edwards aquifer for the 1992 calendar year is shown in **Figure 2.6**.

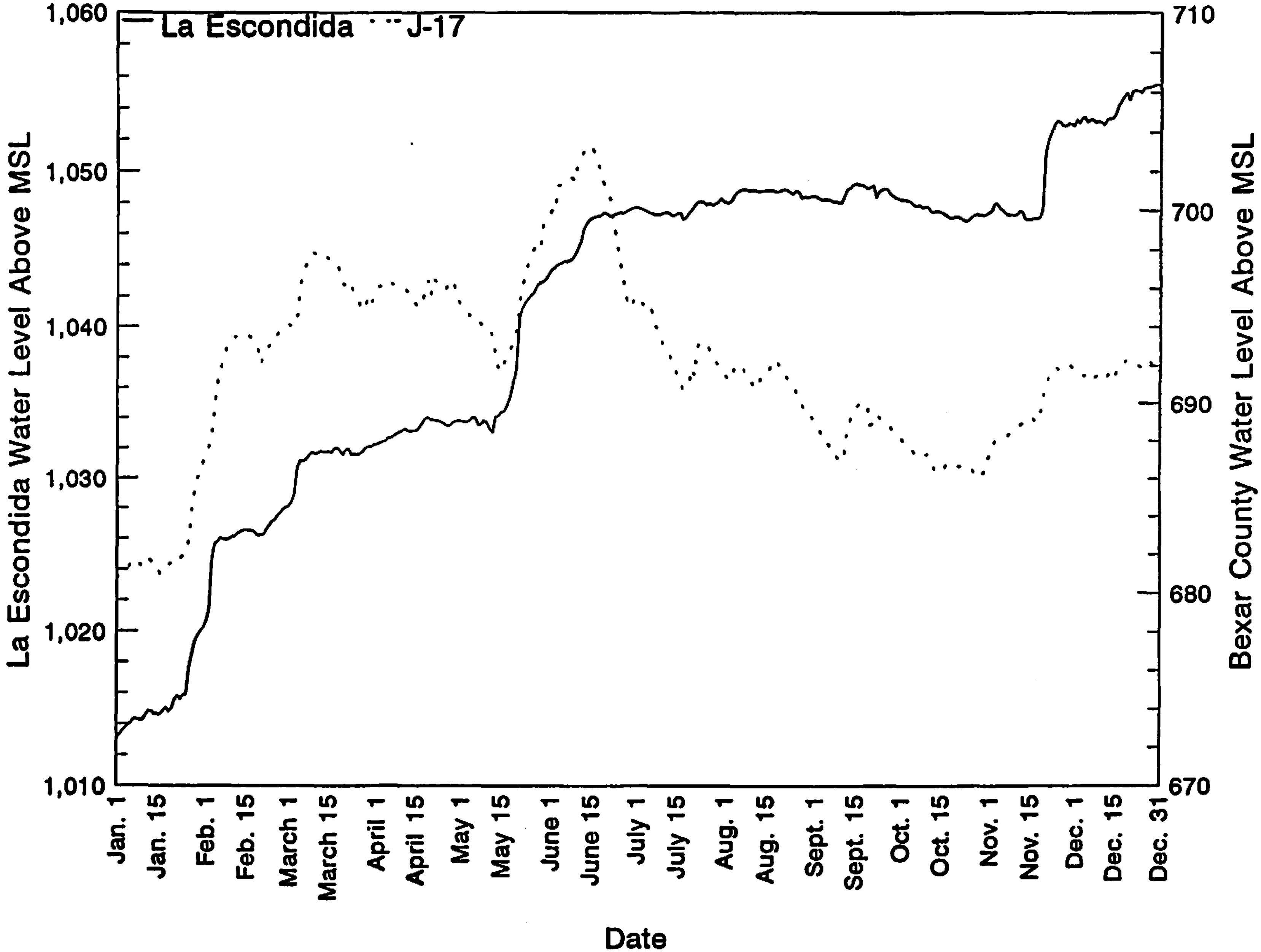
2.4.2 Comal County

The Comal County index well, located in Landa Park, New Braunfels, approximately 100 yards from Comal Springs, was established as an observation well in November 1948 and has provided a continuous water level record for its period of record spanning over 44 years. Water levels at this location peaked on June 14 through 15, 1992, setting a record water level high at 630.9′ above msl for the period of record. Water levels declined to 629.2′ above msl by December 31, 1992. The water level for this well was 629.2′ above msl on December 31, 1991 and was 625.5′ above msl on December 31, 1956.

A second observation well for Comal County, located at Bracken approximately 20 miles southwest of New Braunfels, was established in July 1955. In 1992, water levels crested at this well at 694.7′ above msl on June 13, and then receded to 680.2′ above msl by December 31. In comparison, the groundwater high recorded on December 31, 1991, was 667.4′ above msl, and 625.1′ above msl on December 31, 1956.

Generally, water levels at the Bracken observation well and the Comal County index well consistently have similar hydrographs to that of the Bexar County index well. Though all three wells have similar hydrographs, the Comal County

Figure 2.6 - Hydrograph comparing La Escondida index well for the Glen Rose formation to the Bexar County index well (J-17, Dodd Field) for the Edwards aquifer, 1992.



index well is greatly influenced by Comal Springs groundwater discharge. Water level fluctuations in this well are partially buffered by springflow. When water levels increase at this location, spring discharge increases. This close association of water levels in the Comal County index well with Comal Springs is used periodically to estimate groundwater discharge from the springs.

Figure 2.7 shows a hydrograph comparing the similarities of the Comal County index well to the Bexar County index well. Note the similarities in the hydrographic curves and the differences in water level elevation. As a result of this close similarity, the water level in Bexar County index well may be used as an indicator of groundwater discharge conditions at Comal Springs.

2.4.3 Hays County

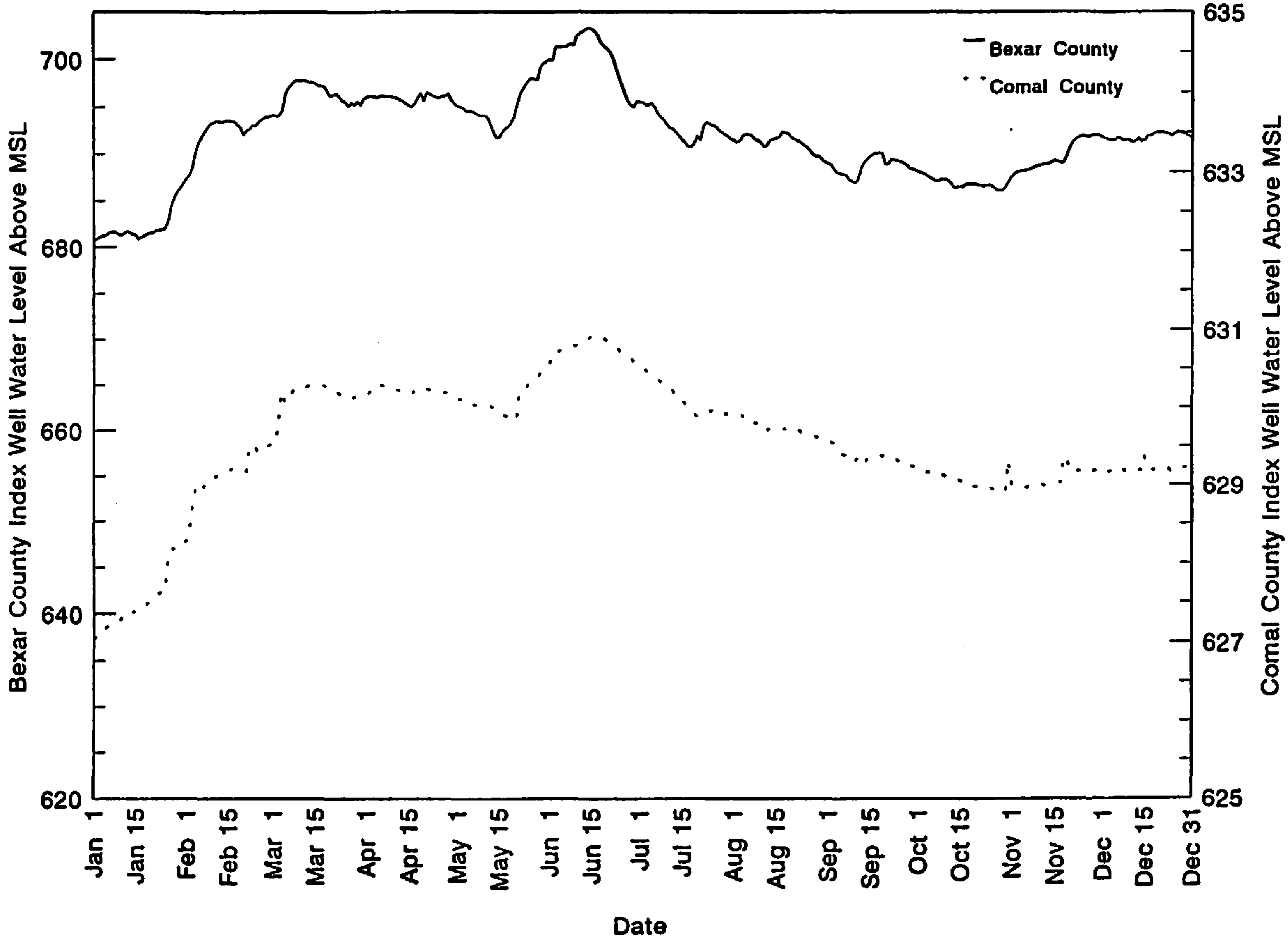
The Hays County index well, located in Kyle, was established as a periodic water level observation well in 1937. This well, which is measured monthly, posted a record high of 596.0' above msl on February 5, 1992 then declined to 588.8' on December 10, 1992. In comparison, this well registered water levels of 589.3' above msl in December 1991, and 570.4' above msl in January 1957.

The water level at the Knipsel observation well was 587.2' above msl on March 1, 1992 and steadily declined to a low of 577.1' above msl on December 31, 1992. The water level on December 31, 1991 was 582.4' above msl.

2.4.4 Medina County

The District operates two key observation wells in Medina County. These wells are located in Hondo, Texas and Castroville, Texas.

Figure 2.7 - Hydrograph comparing water levels in the Bexar County index well (J-17, Dodd Field, San Antonio) to the Comal County index well (Landa Park, New Braunfels) for 1992.



Water levels at the Hondo well crested at 778.9′ above msl on June 14, 1992 and declined to 763.6′ above msl by December 31, 1992. In comparison, this same well recorded a water level of 725.2′ above msl on December 31, 1991.

The observation well at Castroville, Texas, set a new water level record of 743.6′ above msl on June 10, 1992 and declined to 730.4′ above msl by December 31, 1992. On December 31, 1991, the water level was measured at 703.8′ above msl and for December 31, 1956 the water level was at 634.2′ above msl.

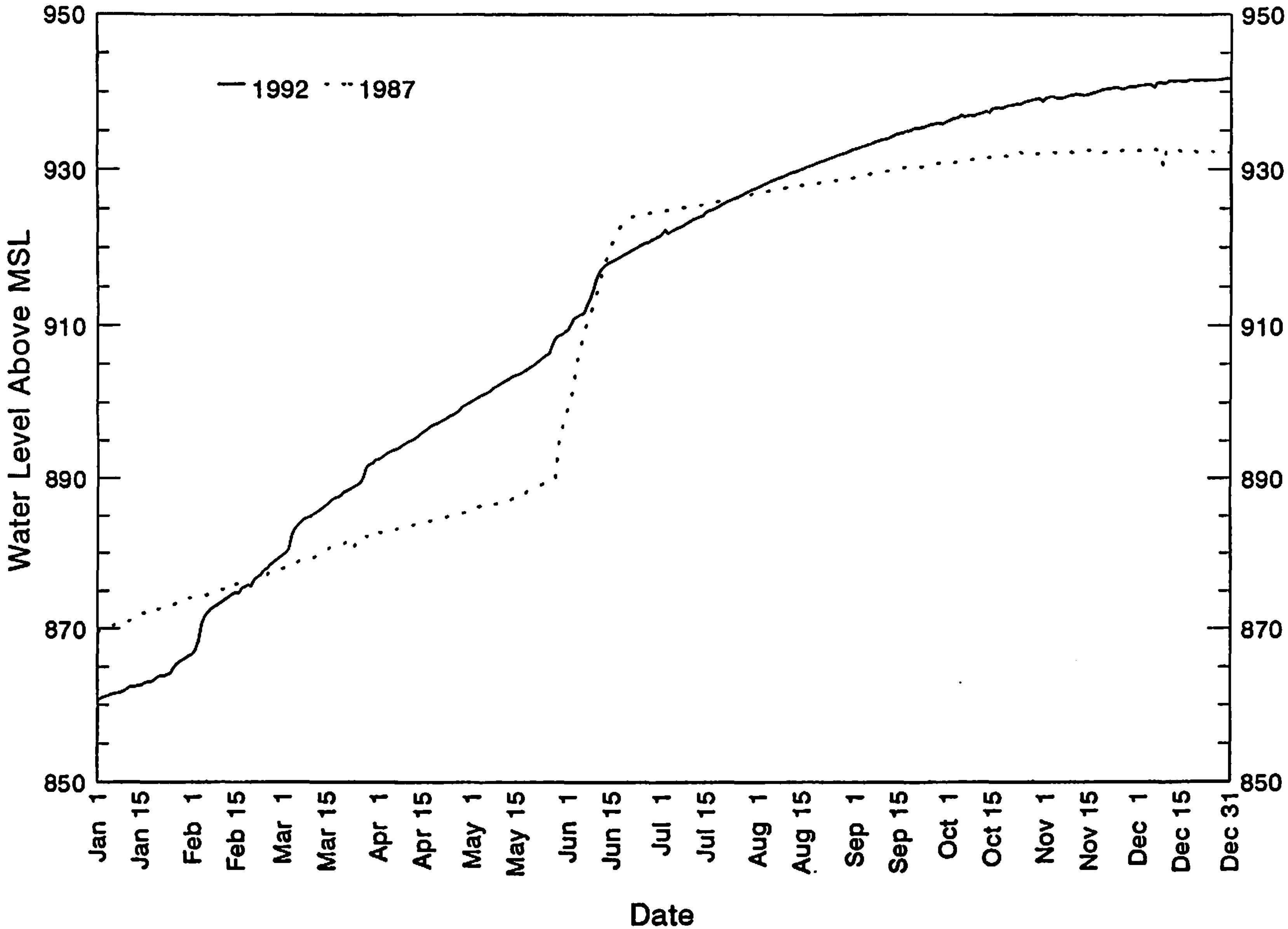
In contrast to the observation wells in Hondo and Castroville, the Seco Creek observation well in northwestern Medina County continued to post progressively higher groundwater levels from January 1992, through the end of the year. On December 31, 1992, a record groundwater high was set at 941.7′. The hydrograph of this observation well for 1992 is very similar to the hydrograph for the same period in 1987, when the area received higher than normal precipitation. Hydrographs comparing water level measurements in 1992 to 1987 data for the Seco Creek observation well are provided in **Figure 2.8**.

2.4.5 Uvalde County

The observation well located in the City of Uvalde peaked at 885.2′ above msl in August, 1992, while the observation well on Highway 187 near Sabinal, Texas, reached its yearly high of 900.6′ above msl in October.

Observation wells located within the City of Sabinal and the City of Knippa set record high groundwater levels of 839.4′ above msl and 869.0′, above msl respectively, in June, 1992. These measurements were consistent with water level highs in key observation wells for Medina, Bexar and Comal Counties.

Figure 2.8 - Hydrograph comparing 1992 to 1987 water levels in the Seco Creek observation well, Medina County.



3.0 Precipitation

Precipitation provides the primary water source for recharge to the Edwards aquifer. Water levels monitored in the District's network of observation wells across the artesian zone have risen within hours of a heavy rainfall event on the recharge zone and associated upstream drainage basin.

Annual precipitation for the Edwards aquifer region is monitored by the District to determine the volume of groundwater recharge to the aquifer. Precipitation data are gathered from District rain gauge stations, National Oceanic and Atmospheric Administration (NOAA) weather stations and USGS rain gauge stations located across the recharge zone and upstream drainage basins.

A map showing the location of the precipitation gauging stations utilized by the District to track area rainfall is shown in **Figure 3.1**.

3.1 Precipitation Data Collection Methods

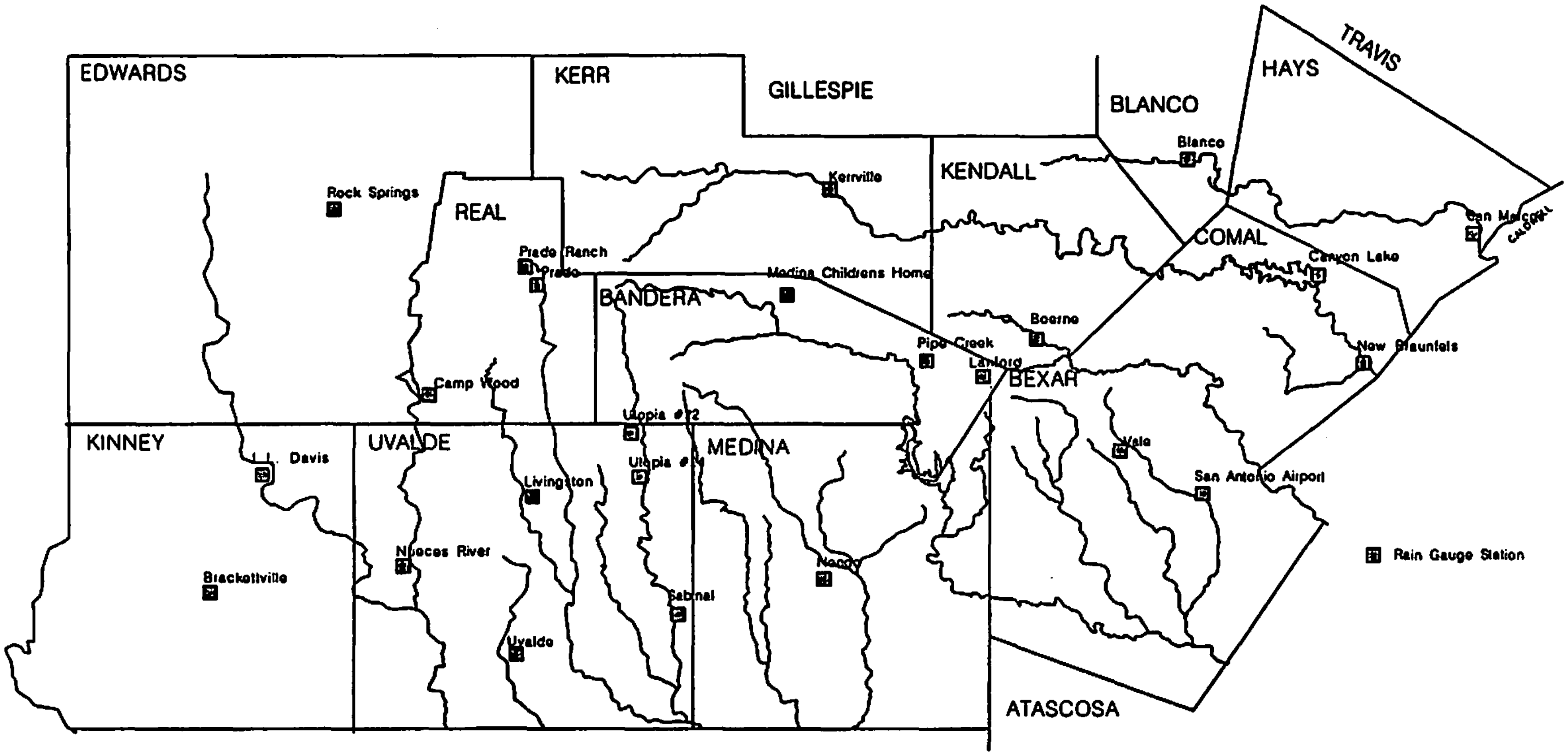
Daily precipitation data are forwarded every month to the District from ten rain-gauge observation sites located on the recharge zone. This information is augmented with data from 14 weather and rain gauge stations maintained by NOAA and the USGS.

The precipitation data are tabulated and utilized to calculate recharge as well as to monitor any precipitation trends that may affect recharge to the aquifer.

3.2 Historical Precipitation Trends

Precipitation data from San Antonio have been kept since 1871. Historical trends in aquifer water levels, recharge

Figure 3.1 - Regional rain gauge network utilized by the Edwards Underground Water District to monitor precipitation.



and springflow are closely related to precipitation. Water levels, recharge and springflow decrease during periods of low precipitation.

Table 3.1 shows historical precipitation for selected rain gauges. **Figure 3.2** is a graph of precipitation for San Antonio from 1871 to present.

3.2.1 Extended Periods of Lower than Normal Precipitation

Records from 1932 to present indicate that seven extended periods of significantly lower than normal precipitation were recorded throughout the region. These were: 1933 to 1934, 1937 to 1939, 1947 to 1948, 1951 to 1956, 1961 to 1963, 1982 to 1984, and 1988 to 1989.

The six year period from 1951 to 1956 of lower than normal rainfall resulted in the worst drought during the period of record. During that period, water levels in the aquifer and springflow declined. It should be noted that normal pumpage levels from the aquifer which average 459.6 thousand acre-feet. per year during the period from 1983 through 1992, causes water levels to fall, even when precipitation is near normal conditions.

A hydrograph comparing precipitation in San Antonio to the Bexar County index well and springflow at Comal Springs from 1949 to 1962 is shown in **Figure 3.3**.

3.2.2 Extended Periods of Higher than Normal Precipitation

Since 1932, there have been nine extended periods of significantly higher than normal rainfall in the San Antonio area. These were: 1935 to 1936, 1944 to 1946, 1957 to 1958, 1964 to 1965, 1967 to 1969, 1973 to 1974, 1976 to 1979, 1985 to 1987, and 1990 to 1992.

Table 3.1 - Annual precipitation for 1934-92 (a/), historical average and 30 year floating average at selected stations. Measurement in inches.

Calendar year	Brackettville	Uvalde	Sabinal	Hondo	San Antonio	Boerne	New Braunfels	San Marcos
1934	—	16.70	18.07	23.97	27.65	26.78	30.80	35.67
1935	—	41.17	48.21	58.73	42.93	52.93	41.67	41.09
1936	22.34	24.53	26.53	35.27	34.11	47.59	30.41	33.48
1937	16.85	17.88	b/ 9.57	22.93	26.07	32.81	29.19	b/26.03
1938	19.97	13.12	15.39	27.56	23.26	24.14	28.32	28.17
1939	18.38	25.30	c/13.98	23.14	18.83	26.20	13.35	18.59
1940	22.43	27.66	27.51	28.13	30.79	32.29	38.11	43.57
1941	21.52	31.79	b/33.74	44.07	26.34	41.60	42.99	48.41
1942	21.01	19.01	b/11.37	34.83	38.46	31.12	42.08	44.65
1943	c/23.39	20.63	17.21	31.43	20.51	26.33	29.93	25.45
1944	24.76	32.76	b/27.62	32.46	33.19	42.98	43.14	47.42
1945	15.69	22.37	26.60	29.57	30.46	33.50	39.38	c/31.74
1946	19.10	26.41	b/14.16	29.65	45.17	45.62	61.60	52.24
1947	c/22.92	22.67	—	18.98	17.32	21.89	27.52	27.53
1948	b/20.02	18.31	—	28.82	23.64	23.77	c/19.88	b/21.27
1949	31.32	34.41	—	39.90	40.81	41.15	43.21	36.22
1950	17.70	18.27	b/15.28	24.91	19.86	24.94	21.13	21.10
1951	14.71	16.07	15.63	b/24.05	24.44	18.76	24.84	30.88
1952	12.26	18.24	23.16	25.56	26.24	37.54	33.87	39.91
1953	10.12	18.34	21.44	20.61	17.56	21.42	30.06	33.39
1954	19.38	15.60	·14.72	11.92	13.70	10.29	10.12	13.42
1955	26.55	18.36	20.87	21.21	18.18	19.27	23.12	26.44
1956	7.58	9.29	11.29	15.54	14.31	12.05	18.41	18.37
1957	34.21	39.30	40.03	35.09	48.83	52.55	51.88	46.51
1958	45.37	39.03	41.18	41.60	39.69	40.94	36.40	39.08
1959	27.51	31.51	27.02	30.68	24.50	35.64	40.45	43.47
1960	19.12	23.98	26.24	32.37	29.76	32.55	34.28	45.48
1961	17.91	26.26	27.24	27.36	26.47	25.45	b/15.7	30.02
1962	10.87	14.12	13.58	17.85	23.90	25.26	27.40	28.47
1963	15.07	16.70	18.99	18.90	18.65	20.66	23.41	19.90
1964	20.75	22.30	23.78	28.29	31.88	27.36	30.65	30.27
1965	21.48	26.21	29.41	30.80	36.65	42.41	45.16	45.00
1966	21.63	20.87	21.54	29.46	21.44	29.05	25.98	27.12
1967	21.95	20.10	23.89	30.33	29.26	26.75	31.74	26.41
1968	17.26	25.20	c/29.88	31.91	30.40	35.14	35.97	37.13
1969	28.53	33.38	33.05	32.30	31.42	38.07	33.01	36.59
1970	16.50	13.59	22.13	30.96	22.74	27.79	35.23	32.30
1971	29.46	31.01	31.00	32.96	31.80	45.24	29.43	31.10
1972	21.21	15.49	21.10	25.43	31.49	35.09	42.02	31.90
1973	30.61	30.85	c/35.14	47.82	52.28	50.93	51.66	47.91
1974	18.25	30.94	c/20.93	c/36.41	37.00	41.80	42.85	b/37.28
1975	26.62	24.92	23.65	b/25.84	25.67	33.49	35.82	48.64
1976	34.40	46.04	40.82	45.21	39.13	45.24	49.06	47.46
1977	15.06	19.90	17.06	19.40	29.64	32.43	24.83	29.69
1978	19.04	18.48	21.28	24.64	35.99	35.17	c/36.35	33.08
1979	16.34	32.35	31.44	28.83	36.64	39.97	36.72	38.74
1980	18.33	23.05	22.67	21.27	24.23	39.02	33.69	29.56
1981	28.73	26.24	30.19	27.40	36.37	41.05	43.23	49.62
1982	19.10	23.35	18.44	21.99	22.96	27.64	21.04	c/22.47
1983	19.35	b/24.45	23.33	c/20.92	26.11	34.60	34.13	36.95
1984	16.24	c/15.33	20.67	b/21.19	25.95	26.97	20.90	b/ 8.26
1985	18.93	b/ 5.76	23.67	21.94	41.43	37.77	37.26	33.54
1986	27.44	c/29.86	c/29.62	c/36.01	42.73	43.52	47.14	42.20
1987	39.45	36.39	38.36	40.09	37.96	39.86	b/37.33	37.94
1988	12.08	15.20	13.52	c/ 9.81	19.01	19.49	c/16.27	21.50
1989	16.98	18.65	17.26	16.10	22.14	25.14	20.99	25.46
1990	c/38.24	24.73	30.06	27.01	38.31	42.51	b/24.58	c/35.14
1991	23.11	21.77	31.12	34.55	42.76	48.22	56.55	51.07
1992	22.22	b/27.85	37.73	45.34	46.49	64.17	c/38.84	c/40.33
Years of Record	94	91	75	90	109	90	96	91
Yearly Average (period of record)	21.19	24.12	25.38	28.52	28.48	33.35	32.33	33.79
30 Year (1963-1992)	21.94	24.71	25.62	29.71	32.28	36.55	35.54	35.64

a/ Precipitation data from the U.S. Department of Commerce (1934-1992)
b/ Partial record not included in long-term average; missing one month.
c/ Partial record not included in long-term average; missing more than one month.

Figure 3.2 - Precipitation trends for San Antonio from 1871 to 1992.

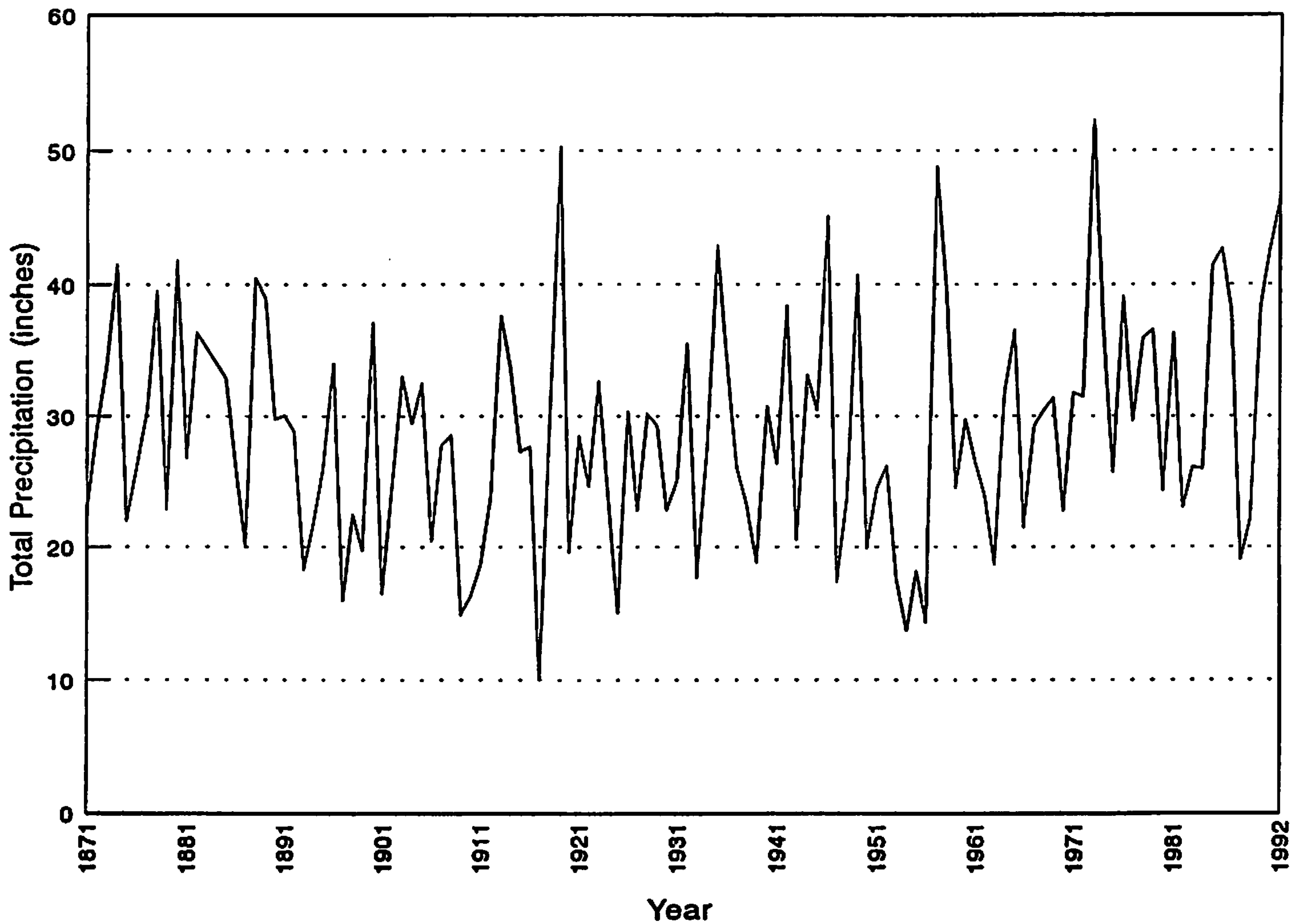
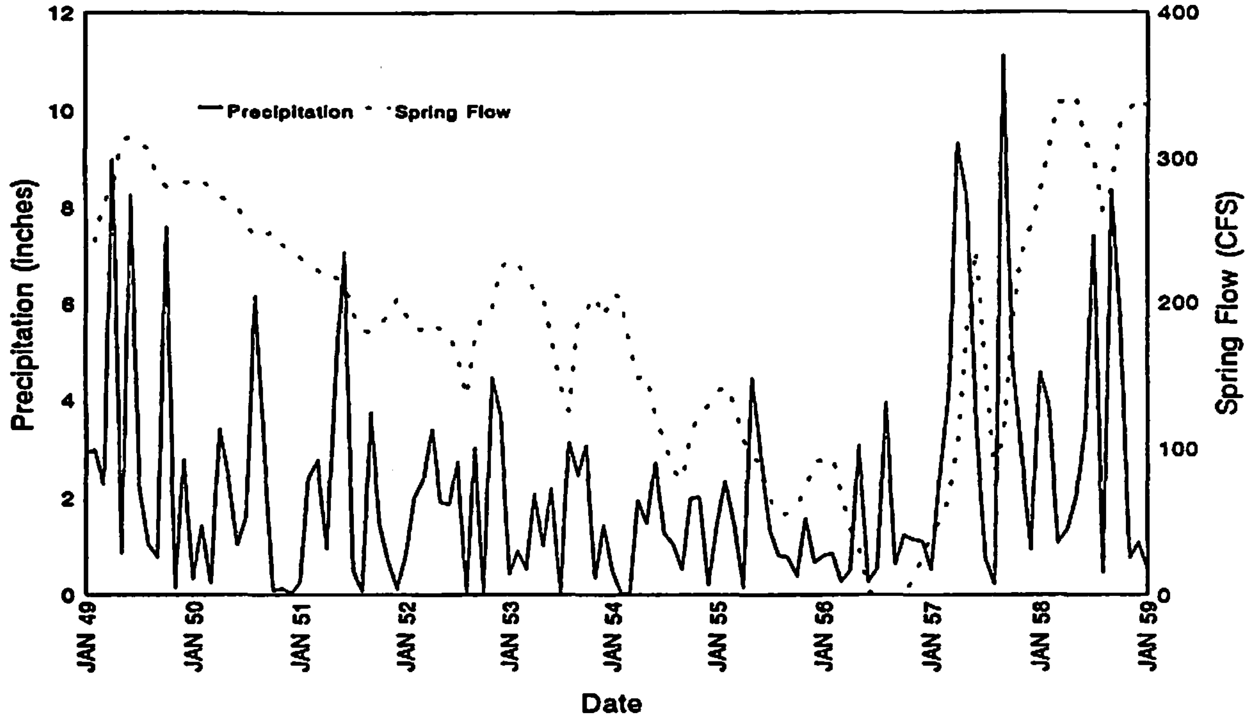
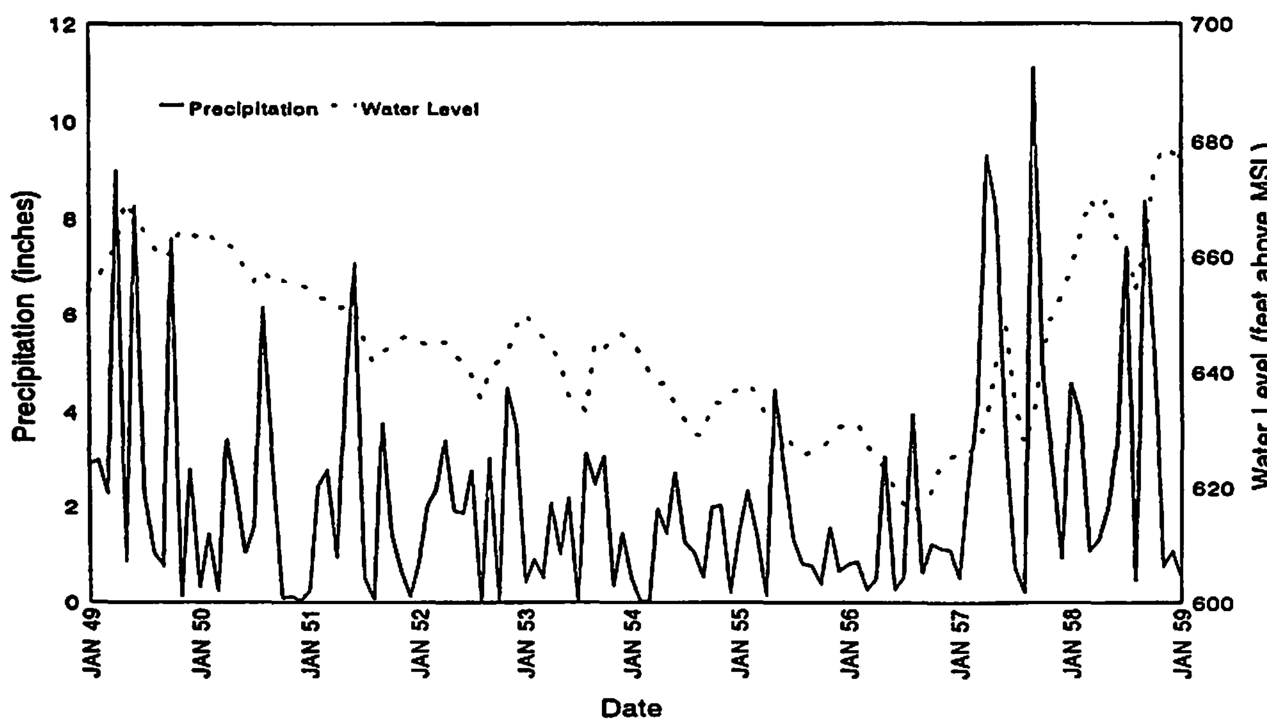


Figure 3.3 - Graphs comparing precipitation in San Antonio to Comal Springs discharge and Bexar County index well (J-17) water levels.

Precipitation in San Antonio compared to Comal Springs discharge from 1949-1959



Precipitation in San Antonio compared to water levels in the Bexar County index well from 1949-1959



3.3 1992 Regional Precipitation Measurements

Precipitation during 1992 was measured at 46.5 inches for San Antonio, which was the fourth wettest year during the period of record. Data from the 22 rain gauge stations indicated an average 38 inches of precipitation on the recharge zone and upstream drainage basins for 1992. Considering that the recharge zone and upstream drainage basins cover about 6,000 square miles and assuming uniform precipitation of 38 inches across these areas, approximately 12 million acre-feet of rain fell across these areas during 1992.

Table 3.2 shows the monthly measurements for 1992 of selected rain gauge stations.

Table 3.2 - Monthly precipitation data from Edwards Underground Water District rain-gauge network and National Oceanic and Atmospheric Administration precipitation gauging stations for 1992. Measurement in inches.

Gauge	County	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pipe Creek (a/b/)	Bandera	—	—	—	3.40	12.50	8.75	1.95	0.17	0.85	2.10	4.50	2.10
Childrens Home(b/)	Bandera	3.30	4.65	4.45	1.95	8.75	4.05	1.75	1.30	0.55	0.95	4.15	1.75
Medina (c/)	Bandera	3.96	5.48	7.82	2.60	6.80	6.92	1.27	1.62	2.30	—	6.70	2.32
Vale (b/)	Bexar	—	6.05	4.75	2.95	8.75	5.40	1.20	1.05	0.95	2.05	4.80	2.05
Blanco (c/)	Blanco	4.56	6.06	5.94	1.81	10.27	4.07	3.41	0.90	0.72	0.11	4.89	—
Canyon Lake (c/)	Comal	4.82	5.18	5.10	2.61	4.13	6.35	2.43	2.31	0.87	0.51	3.57	—
New Braunfels (c/)	Comal	6.40	6.17	5.24	2.02	8.65	4.85	1.70	—	1.30	0.45	—	2.06
Rock Springs (c/)	Edwards	1.92	4.27	2.08	1.40	2.99	3.92	1.55	2.49	1.00	1.39	1.21	1.65
San Marcos (c/)	Hays	5.86	7.55	4.84	2.77	8.80	5.97	0.98	0.88	2.11	0.57	—	—
Boerne (c/)	Kendall	4.67	7.81	5.93	1.77	12.61	7.20	4.88	4.54	3.69	1.40	7.13	2.54
Kerrville (c/)	Kerr	3.15	6.36	4.37	2.53	6.16	4.77	1.84	1.68	2.34	0.19	3.06	2.59
Bracketville (c/)	Kinney	2.50	0.60	1.30	0.57	6.28	0.30	3.10	2.46	2.72	0.00	1.31	1.08
Davis Ranch (b/)	Kinney	2.40	2.80	3.00	1.55	4.65	3.40	4.15	1.20	1.15	0.00	—	—
Hondo (c/)	Medina	3.48	5.00	3.64	3.41	9.68	5.90	2.95	1.90	2.68	0.32	5.08	1.30
Camp Wood (c/)	Real	2.82	2.91	3.73	1.68	4.82	3.19	1.69	2.52	0.28	1.02	0.99	1.36
Prade (c/)	Real	3.19	3.87	4.11	2.41	4.43	4.31	1.78	4.04	1.00	0.33	—	—
Prade Ranch (b/)	Real	3 .00	2.80	3.90	2.20	3.55	4.7	1.95	3.72	0.10	0.6	1.75	1.65
Livingston (b/)	Uvalde	4 .00	3.35	4.50	2.20	4.30	5.4	2.15	1.75	0.20	0.75	1.90	0.70
Sabinal (c/)	Uvalde	3.80	5.64	2.93	2.35	4.60	2.66	3.08	2.17	2.10	0.09	6.42	1.89
Utopia 22 (b/)	Uvalde	3.15	4.60	6.05	2.55	2.70	6.10	1.35	0.20	0.90	0.80	3.90	1.70
Utopia 24 (b/)	Uvalde	3.30	4.20	5.10	2.40	8.00	6.30	1.20	2.40	0.60	1.15	3.95	1.70
Uvalde (c/)	Uvalde	3.87	3.67	2.15	3.51	—	6.13	2.98	2.26	0.87	0.28	0.37	1.76

a/ Rain-gauge station installed March 1992
b/ Edwards Underground Water District rain-gauge observation station.
c/ National Oceanic and Atmospheric Administration precipitation station.
— Incomplete or no data available.

4.0 Groundwater Recharge

The segment of the recharge zone that supplies groundwater to the San Antonio area of the Edwards aquifer extends from central Kinney County to central Hays County. Eight drainage basins cross the recharge zone of the aquifer (**Figure 4.1**). These basins are:

Nueces-West Nueces River Basin
Frio-Dry Frio River Basin
Sabinal River Basin
Medina River Basin
Comal Creek Basin
Cibolo Creek and Dry Comal Creek Basin
Guadalupe River Basin
Blanco River Basin

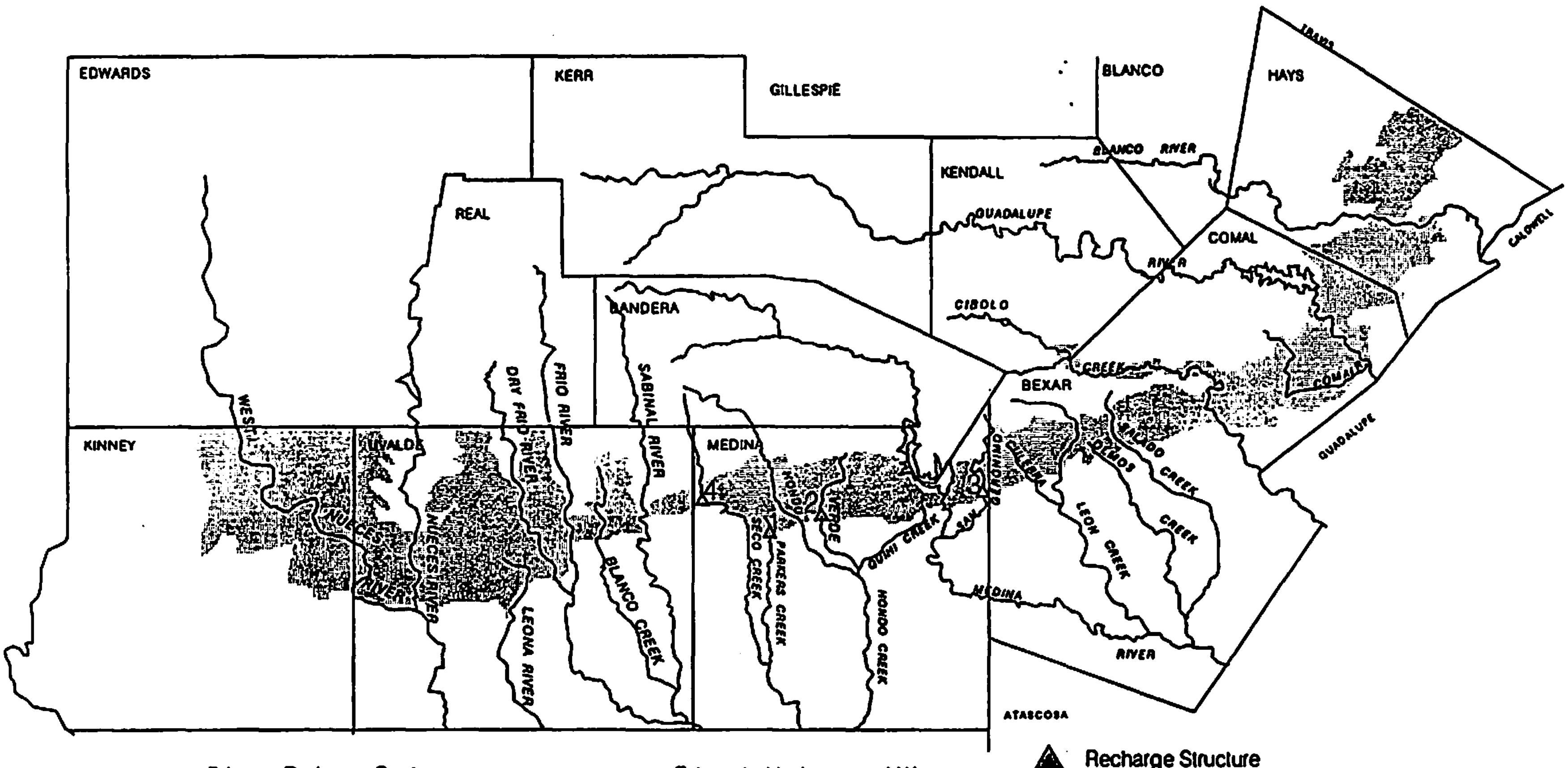
4.1 Recharge Calculation Methods

Although some recharge to the Edwards aquifer is provided by other hydraulically connected aquifers, the amount of groundwater recharge from these aquifers has not been quantified. Only surface water data from precipitation and streamflow are utilized to calculate total recharge.

The USGS has been calculating groundwater recharge for the Edwards aquifer since 1934. Their calculation method modified by Puente (1978) utilizes data from seven of the drainage basins and two interbasin areas. Puente (1978) indicates that the net recharge to the Edwards aquifer from the Guadalupe River basin is negligible and has not been included in his calculations.

Table 4.1 shows annual recharge by river basin for 1934-1992 based on the USGS method. HDR Engineering, Inc., is developing a recharge calculation method for Edwards

Figure 4.1 - Eight primary drainage basins and Edwards Underground Water District recharge structures in the San Antonio area of the Edwards aquifer.



Primary Drainage Basins

Nueces - West Nueces River Basin
Frio-Dry Frio River Basin
Sabinal River Basin
Medina River Basin
Comal Creek Basin
Cibolo Creek and Dry Comal Creek Basin
Guadalupe River Basin
Blanco River Basin

Edwards Underground Water District Recharge Structures

Site Number	Name (Location)
1	Parker
2	Verde
3	San Geronimo
4	Seco

Table 4.1 - Estimated annual groundwater recharge to the Edwards aquifer by river basin, 1934-1992 (Data from USGS). Measurement in thousands of acre-feet.

Year	Nueces-West Nueces River basin	Frio-Dry Frio River basin	Sabinal River basin	Area between Sabinal River & Medina River basins	Medina River basin	Area between Medina River & Cibolo-Dry Comal Creek basin	Cibolo- Dry Comal Creek basin	Blanco River basin	Total
1934	8.6	27.9	7.5	19.9	46.5	21.0	28.4	19.8	179.6
1935	411.3	192.3	56.6	166.2	71.1	138.2	182.7	39.8	1258.2
1936	176.5	157.4	43.5	142.9	91.6	108.9	146.1	42.7	909.6
1937	28.8	75.7	21.5	61.3	80.5	47.8	63.9	21.2	400.7
1938	63.5	69.3	20.9	54.1	65.5	46.2	76.8	36.4	432.7
1939	227.0	49.5	17.0	33.1	42.4	9.3	9.6	11.1	399.0
1940	50.4	60.3	23.8	56.6	38.8	29.3	30.8	18.9	308.8
1941	89.9	151.8	50.6	139.0	54.1	116.3	191.2	57.8	850.7
1942	103.5	95.1	34.0	84.4	51.7	66.9	93.6	28.6	557.8
1943	36.5	42.3	11.1	33.8	41.5	29.5	58.3	20.1	273.1
1944	64.1	76.0	24.8	74.3	50.5	72.5	152.5	46.2	560.9
1945	47.3	71.1	30.8	78.6	54.8	79.6	129.9	35.7	527.8
1946	80.9	64.2	16.5	62.0	51.4	105.1	155.3	40.7	556.1
1947	72.4	77.7	16.7	45.2	44.0	55.5	79.5	31.6	422.6
1948	41.1	25.6	26.0	20.2	14.8	17.5	19.9	13.2	178.3
1949	166.0	86.1	31.5	70.3	33.0	41.8	55.9	23.5	508.1
1950	41.5	35.5	13.3	27.0	23.6	17.3	24.6	17.4	200.2
1951	18.3	28.4	7.3	26.4	21.1	15.3	12.5	10.6	139.9
1952	27.9	15.7	3.2	30.2	25.4	50.1	102.3	20.7	275.5
1953	21.4	15.1	3.2	4.4	36.2	20.1	42.3	24.9	167.6
1954	61.3	31.6	7.1	11.9	25.3	4.2	10.0	10.7	162.1
1955	126.0	22.1	0.6	7.7	16.5	4.3	3.3	9.5	192.0
1956	15.6	4.2	1.6	3.6	6.3	2.0	2.2	8.2	43.7
1957	108.6	133.6	65.4	129.5	55.6	175.6	397.9	76.4	1142.6
1958	266.7	300.0	223.8	294.9	95.5	190.9	268.7	70.7	1711.2
1959	109.6	158.9	61.6	96.7	84.7	57.4	77.9	33.6	690.4
1960	88.7	128.1	64.9	127.0	104.0	89.7	160.0	62.4	824.8
1961	85.2	151.3	57.4	105.4	88.3	69.3	110.8	49.4	717.1
1962	47.4	46.6	4.3	23.5	57.3	16.7	24.7	18.9	239.4
1963	39.7	27.0	5.0	10.3	41.9	9.3	21.3	16.2	170.7
1964	126.1	57.1	16.3	61.3	43.3	35.8	51.1	22.2	413.2
1965	97.9	83.0	23.2	104.0	54.6	78.8	115.3	66.7	623.5
1966	169.2	134.0	37.7	78.2	50.5	44.5	66.5	34.6	615.2
1967	82.2	137.9	30.4	64.8	44.7	30.2	57.3	19.0	466.5
1968	130.8	176.0	66.4	198.7	59.9	83.1	120.5	49.3	884.7
1969	119.7	113.8	30.7	84.2	55.4	60.2	99.9	46.6	610.5
1970	112.6	141.9	35.4	81.6	68.0	68.8	113.8	39.5	661.6
1971	263.4	212.4	39.2	155.6	68.7	81.4	82.4	22.2	925.3
1972	108.4	144.6	49.0	154.6	87.9	74.3	104.2	33.4	756.4
1973	190.6	256.9	123.9	286.4	97.6	237.2	211.7	82.2	1486.5
1974	91.1	135.7	36.1	115.3	96.2	68.1	76.9	39.1	658.5
1975	71.8	143.6	47.9	195.9	93.4	138.8	195.7	85.9	973.0
1976	150.7	238.6	68.2	182.0	94.5	47.9	54.3	57.9	894.1
1977	102.9	193.0	62.7	159.5	77.7	97.9	191.6	66.7	952.0
1978	69.8	73.1	30.9	103.7	76.7	49.6	72.4	26.3	502.5
1979	128.4	201.4	68.6	203.1	89.4	85.4	266.3	75.2	1117.8
1980	58.6	85.6	42.6	25.3	88.3	18.8	55.4	31.8	406.4
1981	205.0	365.2	105.6	252.1	91.3	165.0	196.8	67.3	1448.3
1982	19.4	123.4	21.0	90.9	76.8	22.6	44.8	23.5	422.4
1983	79.2	65.9	20.1	42.9	74.4	31.9	82.5	23.2	420.1
1984	32.4	40.4	8.8	18.1	43.9	11.3	16.9	25.9	197.7
1985	105.9	186.9	50.7	148.5	64.7	136.7	259.2	50.7	1003.3
1986	188.4	192.8	42.2	173.6	74.7	170.2	267.4	44.5	1153.8
1987	308.5	473.3	110.7	405.5	90.4	229.3	270.9	114.9	2003.5
1988	59.2	117.9	17.0	24.9	69.9	12.6	28.5	25.5	355.5
1989	52.6	52.6	8.4	13.5	46.9	4.6	12.3	23.6	214.5
1990	479.3	255.0	54.6	131.2	54.0	35.9	71.8	41.3	1123.1
1991	325.2	421.0	103.1	315.2	52.8	84.5	109.7	96.9	1508.4
1992	234.1	586.9	201.1	566.1	91.4	290.6	286.6	226.9	2486.0
Average	116.8	132.9	42.4	109.6	61.0	71.2	106.7	42.0	682.8
10 yr aver. (1983-92)	186.5	241.3	61.7	184.0	66.3	100.8	138.6	67.3	1046.6
30 yr. aver. (1963-92)	140.1	181.9	51.9	148.2	70.7	83.5	119.5	52.6	848.5

aquifer. Their method shows generally lower recharge in the counties west, and higher recharge for the counties in the northeast. The HDR method indicates that recharge is being provided by the Guadalupe River Basin. The net difference in the USGS method and the HDR method is only two to three percent for the San Antonio area of the Edwards aquifer. The HDR model is still being calibrated and evaluated for the San Antonio area of the Edwards Aquifer.

4.2 Historical Recharge Trends

The USGS estimated that annual recharge for the period of record extending from 1934 to 1992 ranges from 43,700 acre-feet during the drought in 1956, to 2,486,000 acre-feet in 1992. For the entire period from 1934 to 1992 average annual recharge was 682,800 acre-feet however, since 1983, the ten year average annual recharge was estimated to be slightly over a million acre-feet per year. **Figure 4.2** is a graph of yearly recharge and the ten year floating average recharge estimate for the San Antonio area of the Edwards aquifer from 1934 to 1992.

Recharge directly affects groundwater levels in the aquifer. Water levels rise during years of higher than normal recharge, and generally decline during normal to below normal recharge. Since recharge is a direct result of precipitation, water levels in the aquifer are greatly affected by precipitation. **Figure 4.3** compares annual recharge to annual groundwater level highs at the Bexar County index well and total annual precipitation in San Antonio from 1934 to 1992.

4.3 1992 Recharge Levels

A new record high of 2,486,000 acre-feet was established for recharge in 1992. Recharge for the year exceeded the old record of 2,003,600 set in 1987 by almost 25%.

Figure 4.2 - Yearly recharge and ten year floating average recharge for San Antonio area of the Edwards aquifer, 1934-1992.

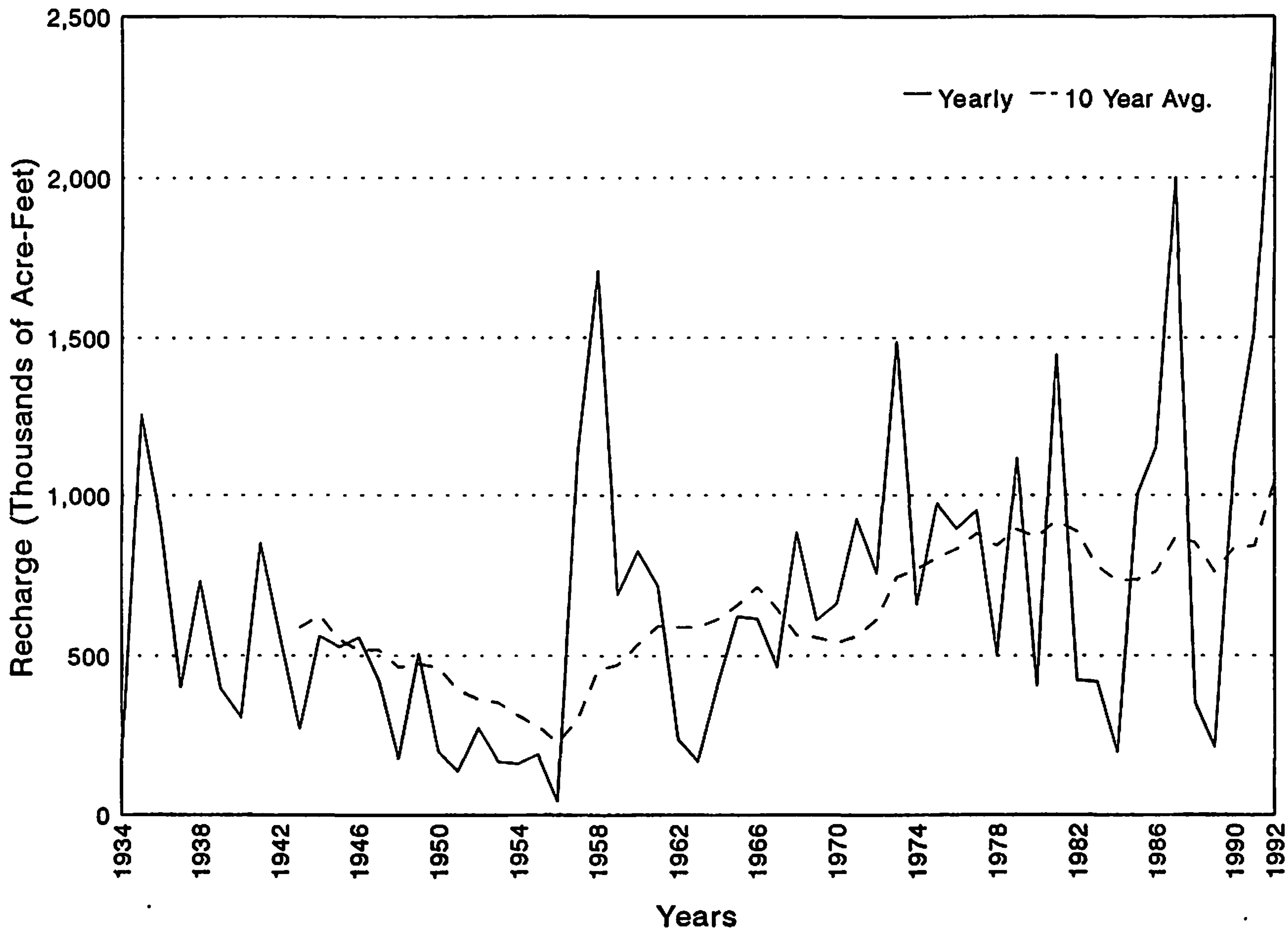
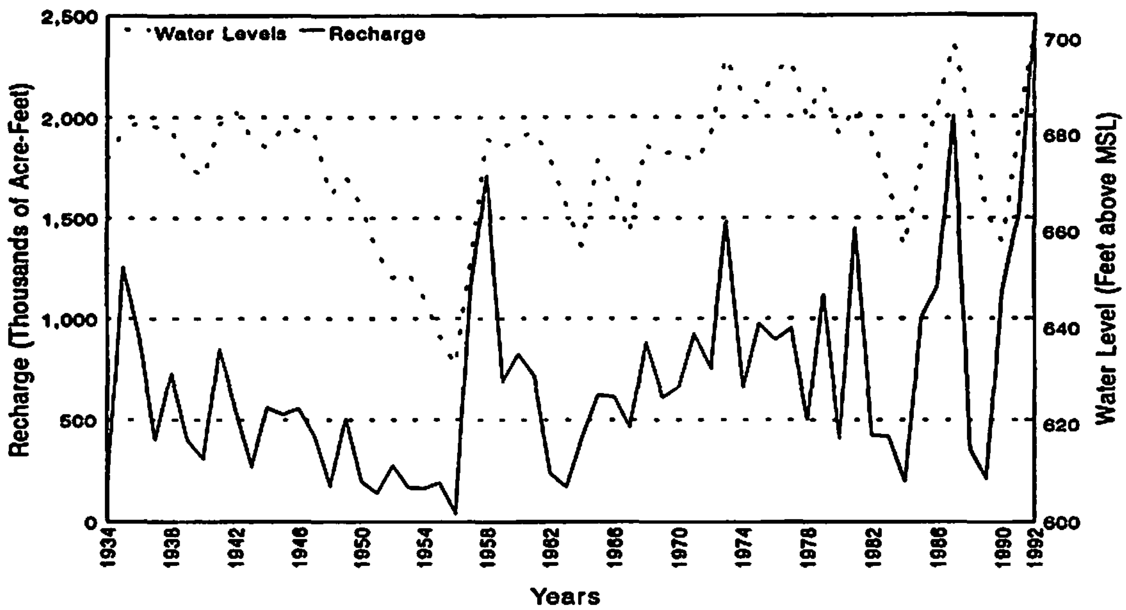
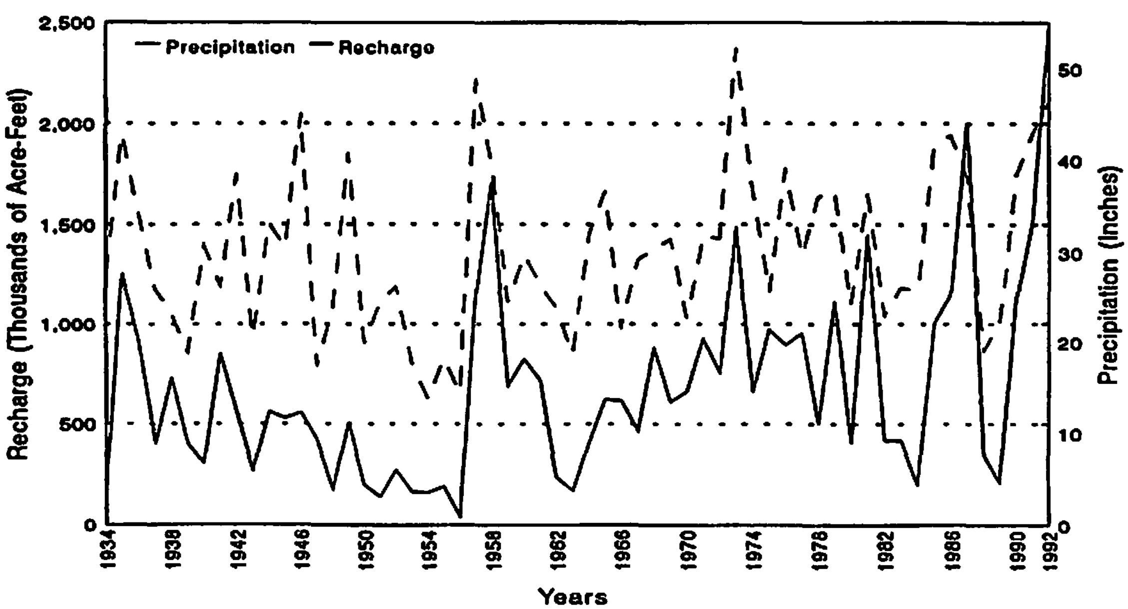


Figure 4.3 - Comparison of Edwards aquifer annual recharge to annual groundwater highs at the Bexar County index well and total annual precipitation in San Antonio, 1934-1992.

Comparison of yearly recharge to yearly high water levels at the Bexar County Index Well (J-17)



Comparison of yearly recharge to yearly precipitation in San Antonio, Bexar County.



4.4 1992 Recharge from District Recharge Structures

The District operates four recharge dams across the Edwards aquifer recharge zone. Data from the recharge structures show that about 21,000 acre-feet of water was recharge to the aquifer in 1992, with Seco dam supplying the most recharge (14,631 acre-feet). **Table 4.2** shows the recharge to the Edwards aquifer by each structure and **Table 4.3** shows annual recharge at each site since the structures were built. The locations of the recharge structures are shown in **Figure 4.1**.

TABLE 4.2

REPORT OF SURFACE WATER USED FOR THE YEAR ENDING DECEMBER 31, 1992
(Reported in Acre-feet of Recharge)

Name of Structure	Permit No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year End Total
Parker Creek Dam	2802 *3192	28.3	303.0	164.6	0	0	227.2	0	0	0	0	0	0	723.1
Verde Creek Dam	3444	88.8	166.6	659.8	470.6	471.2	1014.3	2.5	0	0	0	0	0	2873.8
San Geronimo Creek Dam	2956	310.1	564.5	604.1	168.2	312.5	604.8	158.4	0	0	0	8.5	0	2731.1
Seco Creek Dam	3551	1679.9	2930.1	2904.0	2274.1	1079.1	3521.5	201.4	0	0	0	41.4	0	14631.5

* Adjudication Certificate Number

TABLE 4.3

RECHARGE PROJECTS
EDWARDS UNDERGROUND WATER DISTRICT
DECEMBER, 1992
(Reported in acre-feet)

YEAR	PARKER	VERDE	SAN GERONIMO	SECO
1974	160(4-20-74)	____	____	____
1975	620	____	____	____
1976	2,018	____	____	____
1977	6	____	____	____
1978	98	150(4-24-78)	____	____
1979	2,315	1,725	0(11-13-79)	____
1980	0	371	903	____
1981	772	1,923	1,407	____
1982	3	112	91	0(10-21-82)
1983	0	254	0	0
1984	251	246	0	143
1985	232	440	1,097	643
1986	217	889	963	1,580
1987	2,104	4,141	1,176	12,915
1988	0	0	0	0
1989	0	0	0	0
1990	49	176	41	479
1991	647	966	1,647	2,160
1992	723	2,775	2,874	14,631
TOTAL RECHARGE	10,215	14,168	10,199	32,551
AVERAGE ANNUAL RECHARGE	547	966	775	3,202

1 Acre-Foot = 325,851 Gallons

1 Million Gallons Per Day = 3 Acre-Feet

5.0 Groundwater Discharge and Usage

The Edwards aquifer provides water for many diverse needs in the south-central Texas region, including agricultural, municipal, industrial, domestic and recreational needs. Natural springflow accounts for the majority of discharge in comparison to any of the other groups. This springflow supports recreational economies in New Braunfels and San Marcos and provides a habitat for several threatened and endangered species of animals and plants.

5.1 Groundwater Discharge Calculation Methods

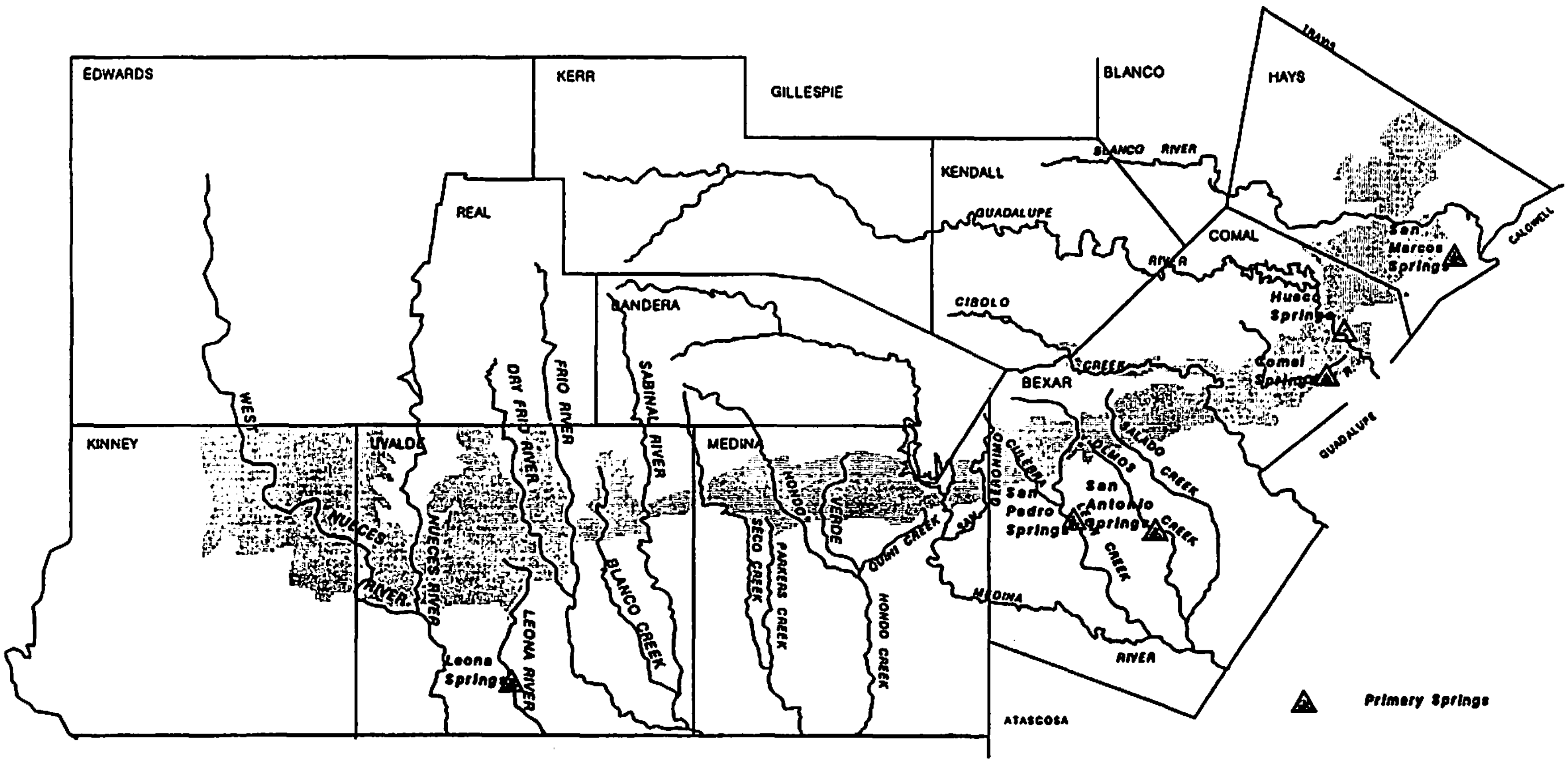
Groundwater discharge from the Edwards aquifer occurs as a result of springflow and by pumping or artesian flow from wells.

Groundwater discharge as a result of springflow is calculated by measuring downstream flow from spring orifices or by measuring water levels in observation wells near the springs.

Measuring downstream flow provides the most direct method available in estimating springflow and is used in this report to determine springflow discharge. Downstream flow from springs is measured on a continuous basis and provides a detailed history of springflow discharge. A location map of the primary springs in the Edwards aquifer is shown in **Figure 5.1.**

Calculating springflow by measuring groundwater levels in nearby observation wells is an alternative method of calculating discharge. This method is not as accurate as downstream flow measurements, however it may be used to fill gaps in incomplete data sets when downstream recorders are not functioning.

Figure 5.1 - Primary springs in the San Antonio area of the Edwards aquifer.



Groundwater discharge as a result of pumpage is calculated by tabulating reported water use data from public supply, irrigation, agricultural, industrial, commercial and domestic wells.

5.2 Historical Groundwater Discharge Trends

Estimates for annual groundwater discharge from springflow and pumping for the Edwards aquifer are available from 1934 to present and range from 388.1 thousand acre-feet in 1956 to 1.1 million acre-feet in 1992. **Table 5.1** contains annual estimated groundwater discharge data for the San Antonio area of the Edwards aquifer, 1934-1992.

Springflow for the same period has varied from 69.8 thousand acre-feet in 1956 to 802.8 thousand acre-feet in 1992. The estimated average annual springflow for the period of record is 361.9 thousand acre-feet with a ten year average (1983 to 1992) annual discharge of 395.3 thousand acre-feet. Springflow in the Edwards aquifer is directly related to groundwater levels. Generally, the higher the water levels the greater the springflow. As a result springflow may vary widely and is dependent on recharge and groundwater pumping.

While springflow has fluctuated from year to year, groundwater pumping has progressively increased. The lowest estimated pumpage recorded was 101.9 thousand acre-feet in 1934. Since 1934, pumping withdrawals from the Edwards aquifer have increased more than four fold. Though the average annual pumpage from wells is estimated as 285.6 thousand acre-feet for the period of record, the ten year (1983 to 1992) estimated average annual pumpage was 460.6 thousand acre-feet.

From 1934 to 1970, except during drought periods, spring discharge was generally greater than groundwater pumping. Since the early 1970's, annual groundwater pumpage has been

Table 5.1 - Annual estimated groundwater discharge data for the San Antonio area of the Edwards aquifer, 1934-1992 (Data from USGS). Measurement in thousands of acre-feet.

Year	Kinney-Uvalde	Medina	Bexar	Comal	Hays	Total	Wells	Spring flow
1934	12.6	1.3	109.3	229.1	85.6	437.9	101.9	336.0
1935	12.2	1.5	171.8	237.2	96.9	519.6	103.7	415.9
1936	26.6	1.5	215.2	261.7	93.2	598.2	112.7	485.5
1937	28.3	1.5	201.8	252.5	87.1	571.2	120.2	451.0
1938	25.2	1.6	187.6	250.0	93.4	557.8	120.1	437.7
1939	18.2	1.6	122.5	219.4	71.1	432.8	118.9	313.9
1940	16.1	1.6	116.7	203.8	78.4	416.6	120.1	296.5
1941	17.9	1.6	197.4	250.0	134.3	601.2	136.8	464.4
1942	22.5	1.7	203.2	255.1	112.2	594.7	144.6	450.1
1943	19.2	1.7	172.0	249.2	97.2	539.3	149.1	390.2
1944	11.6	1.7	166.3	252.5	135.3	567.4	147.3	420.1
1945	12.4	1.7	199.8	263.1	137.8	614.8	153.3	461.5
1946	6.2	1.7	180.1	261.9	134.0	583.9	155.0	428.9
1947	13.8	2.0	193.3	256.8	127.6	593.5	167.0	426.5
1948	9.2	1.9	159.2	203.0	77.3	450.6	168.7	281.9
1949	13.2	2.0	165.3	209.5	89.8	479.8	179.4	300.4
1950	17.8	2.2	177.3	191.1	78.3	466.7	193.8	272.9
1951	16.9	2.2	186.9	150.5	69.1	425.6	209.7	215.9
1952	22.7	3.1	187.1	133.2	78.8	424.9	215.4	209.5
1953	27.5	4.0	193.7	141.7	101.4	468.3	229.8	238.5
1954	26.6	6.3	208.9	101.0	81.5	424.3	246.2	178.1
1955	28.3	11.1	215.2	70.1	64.1	388.8	261.0	127.8
1956	59.6	17.7	229.6	33.6	50.4	390.9	321.1	69.8
1957	29.0	11.9	189.4	113.2	113.0	456.5	237.3	219.2
1958	23.7	6.6	199.5	231.8	155.9	617.5	219.3	398.2
1959	43.0	8.3	217.5	231.7	118.5	619.0	234.5	384.5
1960	53.7	7.6	215.4	235.2	143.5	655.4	227.1	428.3
1961	56.5	6.4	230.3	249.5	140.8	683.5	228.2	455.3
1962	64.6	8.1	220.0	197.5	98.8	589.0	267.9	321.1
1963	51.4	9.7	217.3	155.7	81.9	516.0	276.4	239.6
1964	49.3	8.6	201.0	141.8	73.3	474.0	260.2	213.8
1965	46.8	10.0	201.1	194.7	126.3	578.9	256.1	322.8
1966	48.5	10.4	198.0	198.9	115.4	571.2	255.9	315.3
1967	81.1	15.2	239.7	139.1	82.3	557.4	341.3	216.1
1968	58.0	9.9	207.1	238.2	146.8	660.0	251.7	408.3
1969	88.5	13.6	216.3	218.2	122.1	658.7	307.5	351.2
1970	100.9	16.5	230.6	229.2	149.9	727.1	329.4	397.7
1971	117.0	32.4	262.8	168.2	99.1	679.5	406.8	272.7
1972	112.6	28.8	247.7	234.3	123.7	747.1	371.3	375.8
1973	96.5	14.9	273.0	289.3	164.3	838.0	310.4	527.6
1974	133.3	28.6	272.1	286.1	141.1	861.2	377.4	483.8
1975	112.0	22.6	259.0	296.0	178.6	868.2	327.8	540.4
1976	136.4	19.4	253.2	279.7	164.7	853.4	349.5	503.9
1977	156.5	19.9	317.5	295.0	172.0	960.9	380.6	580.3
1978	154.3	38.7	269.5	245.7	99.1	807.3	431.8	375.5
1979	130.1	32.9	294.5	300.0	157.0	914.5	391.5	523.0
1980	151.0	39.9	300.3	220.3	107.9	819.4	491.1	328.3
1981	104.2	26.1	280.7	241.8	141.6	794.4	387.1	407.3
1982	129.2	33.4	305.1	213.2	105.5	786.4	453.1	333.3
1983	107.7	29.7	277.6	186.6	118.5	720.1	418.5	301.6
1984	156.9	46.9	309.7	108.9	85.7	708.1	529.8	178.3
1985	156.9	59.2	295.5	200.0	144.9	856.5	522.5	334.0
1986	91.7	41.9	294.0	229.3	160.4	817.3	429.3	388.0
1987	94.9	15.9	326.6	286.2	198.4	922.0	364.1	557.9
1988	156.7	82.2	317.4	236.5	116.9	909.7	540.0	369.7
1989	156.9	70.5	305.6	147.9	85.6	766.5	542.4	224.1
1990	118.1	69.7	276.8	171.3	94.1	730.0	489.4	240.6
1991	76.6	25.6	315.5	221.9	151.0	790.6	436.0	354.6
1992	76.5	9.3	370.5	412.4	261.3	1130.0	327.2	802.8
Average	67.6	17.0	230.0	215.6	117.2	647.3	285.5	362.0
10 Yr. Aver. (1983-92)	119.3	45.1	308.9	220.1	141.7	835.1	459.6	375.2
30 Yr. Aver. (1963-92)	108.4	29.4	271.2	226.2	132.3	767.5	385.1	382.3

Note: Calculations may vary due to rounding procedures.

greater than springflow during lower than normal to normal periods of recharge. **Figure 5.2** is a graph comparing groundwater pumpage to spring flow from 1934 to 1992.

5.3 1992 Regional Groundwater Discharge Estimates

In 1992, groundwater discharge was estimated by the USGS at a record 1,130.0 thousand acre-feet of which 802.8 thousand acre-feet was springflow and 327.2 thousand acre-feet was from groundwater pumpage.

Only eight percent of the total groundwater discharge was attributed to groundwater pumpage for Industrial, Commercial, Agricultural, Domestic and Stock usage. It should be noted that 1992 was an exceptionally wet year; therefore, agricultural usage was reduced. Municipal usage accounted for the remaining groundwater pumpage which constituted 21% of the total discharge. **Figure 5.3** is a pie chart showing the total distribution and percent discharge of groundwater from the Edwards aquifer. Record high groundwater levels and greater than normal precipitation allowed springflow to climb to almost 250,000 acre-feet above the old springflow discharge record of 557,900 acre-feet set in 1987. While springflow set new record highs for the year, groundwater pumpage was at the lowest levels since 1975. **Table 5.2** shows the 1992 discharge data for the six county area.

Springflow accounted for 71% of the total discharge from the Edwards, in 1992. **Table 5.3** shows discharge by spring for 1992. Underflow at Leona Springs has been included in total discharge from Leona Springs.

5.4 New Well Construction

An indication of growth in water demand is the rate that new wells are installed throughout the San Antonio area of the

Figure 5.2 - Comparison of estimated groundwater pumpage to springflow for the San Antonio area of the Edwards aquifer, 1934-1992.

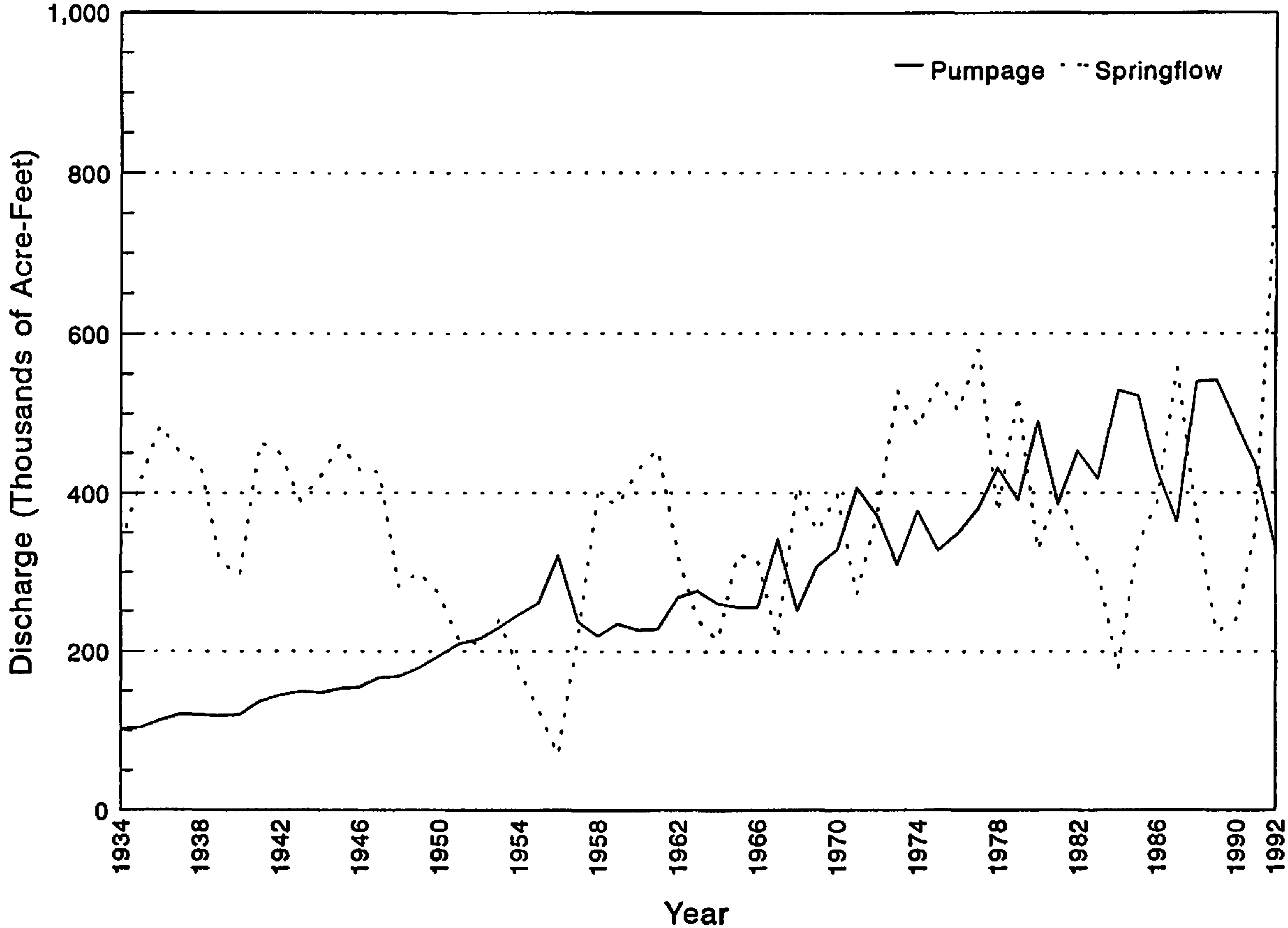
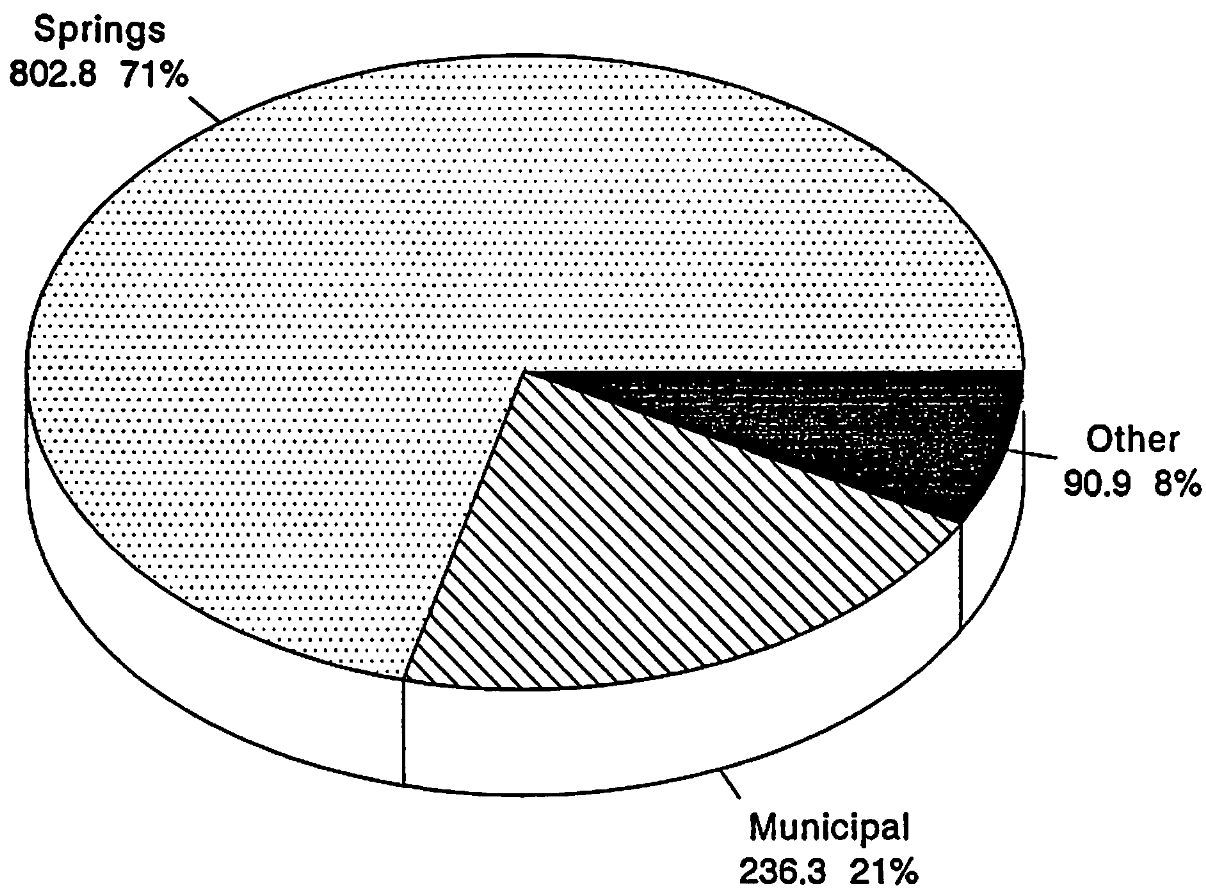


Figure 5.3 - Percent and total (thousands of acre-feet) discharge of groundwater from the San Antonio area of the Edwards aquifer, 1992.



Other includes industrial, commercial, agriculture, domestic and stock usage
Chart data includes discharge from Kinney, Uvalde, Medina, Bexar, Comal and Hays Counties.

Table 5.2 - Groundwater discharge in the San Antonio area of the Edwards aquifer, 1992. Measurements are in thousands of acre-feet.

County	Agriculture	Municipal	Domestic & Stock	Industry & Commercial	Springs	Total
Bexar	2.8	211.1	29.1	15.2	112.3	370.5
Comal	0.2	3.7	0.7	12.8	394.9	412.4
Hays	0.1	10.1	1.4	0.2	249.6	261.3
Medina	4.7	4.0	0.7	no data	0.0	9.3
Uvalde	18.7	4.0	2.7	0.7	46.0	72.1
Kinney	0.6	3.7	0.2	no data	no data	4.4
Totals	27.1	236.5	34.8	29.0	802.8	1130.0

Note: Calculations may vary due to rounding procedures
Data compiled by the Edwards Underground Water District and the United States Geological Survey.

Table 5.3 - Springflow in CFS-days from the San Antonio area of the Edwards aquifer, 1992.

Month	Leona	San Antonio	San Pedro	Hueco	Comal	San Marcos	Totals	Totals (ac.-ft.)
January	736	2112	368	2886	11701	11832	29636	58782
February	939	3200	567	3413	13538	12111	33768	66978
March	1272	4393	621	3983	15118	13806	39193	77738
April	1366	4548	604	3219	14448	12801	36986	73361
May	1543	4712	630	3117	14352	12619	36973	73335
June	1694	4573	616	3180	14514	12440	37017	73422
July	1965	4737	642	3070	14428	11810	36652	72698
August	2032	4706	648	2806	14413	9751	34356	68144
September	1934	4076	633	2603	12841	8071	30158	59817
October	1983	3733	681	2597	12675	7490	29159	57836
November	1761	3778	644	2261	12423	6639	27506	54557
December	1844	4702	671	2451	13067	6439	29204	57925
Totals	*19,070	49,270	7,325	35,586	163,518	125,839	400,608	
Totals Thousands of acre-feet	46.0	97.7	14.5	70.6	324.3	249.6		802.8 (thousands of ac/ft.)

Note: * Leona Springs underflow not calculated in Leona CFS-Day totals but calculated in acre-feet .
Data compiled by the U.S.G.S. in cooperation with the Edwards Underground Water District.

Edwards aquifer. New well completion data for 1992 are incomplete, however, over three hundred and fifty wells have been reported for 1992. More than three hundred wells were drilled in the five county area in 1991. Increased drilling in the San Antonio area in 1992 may have resulted from increased construction activity in the District and the threat imposed drilling moratoriums imposed by state and federal agencies, **Table 5.4** shows the new well construction in the District for 1992.

TABLE 5.4

Approximate number of wells drilled in 1992.

1992 Totals for:	Uvalde	Bexar Co.	Comal	Hays	Medina
Total number of wells drilled	24	77	147	135	29
Total number of Domestic wells drilled	23	73	144	134	28
Total number of Public Supply wells drilled		3	1		
Number of wells with a inside diameter larger than 8"		3	1		
Total number of Irrigation wells drilled	1	1	1	1	1
Number of wells with a inside diameter larger than 8"	1				1
Total number of Industrial wells drilled			1		
Number of wells with a inside diameter larger than 8"					
Test wells, observation and Monitor wells drilled					

6.0 Water Quality

The District, in cooperation with the USGS and the TWDB, has conducted a systematic program of data collection. The District's data collection efforts consist of a monitoring well network, springs, and stream gauging stations located across the Edwards aquifer, with information being recorded since 1968. Analysis of this data has been utilized to determine changes in water quality in the aquifer. A bulletin has been published annually to report the results of the sample analyses obtained from the data collection network.

6.1 Well and Spring Data

In 1992, USGS staff collected water quality samples from 61 wells and 3 springs. The locations of these wells are shown in **Figure 6.1**. These samples were analyzed for more than 90 constituents. The analyses included: common inorganic constituents, nutrients, dissolved organic carbon, heavy metals, and volatile organic compounds. Typical standards for these parameters are listed in **Table 6.1**. Analyses indicated that one well (AY 68-37-521), located in Bexar County has a concentration of fluoride which was slightly above the maximum contaminant level. Samples from 4 wells were analyzed for pesticides in 1992. No concentrations of pesticides were detected in the sampled wells.

Maximum Contaminant Levels (MCL) for nine volatile organic compounds are given in **Table 6.2**. MCLs are established by the U. S. Environmental Protection Agency (EPA) and are enforceable standards. Volatile organic compounds (VOC) have been detected at levels ranging from 0.2 to 0.5 micrograms/liter (very low concentrations and well below the maximum contaminant levels) in 2 of 9 wells sampled in 1992.

Figure 6.1 - Water quality data collection sites, 1992.

County	Well I.D. Number	County	Well I.D. Number	County	Well I.D. Number	County	Well I.D. Number	County	Well I.D. Number
Uvalde	YP 69-35-2A	Medina	TD 68-41-303	Bexar (Cont.)	AY 68-28-508	Comal	DX 68-23-601	Hays	LR 58-57-303
	YP 69-43-608		TD 68-42-503		AY 68-28-514		DX 68-23-602		LR 58-57-311
	YP 69-44-502		TD 68-42-608		AY 68-29-303		DX 68-23-616		LR 58-58-403
	YP 69-45-1B		TD 68-49-813		AY 68-29-503		DX 68-23-617		LR 67-01-303
	YP 69-45-405		TD 69-38-601		AY 68-29-510		DX 68-23-618		LR 67-01-308
	YP 69-50-203		TD 69-46-601		AY 68-29-810		DX 68-23-619		LR 67-01-801
	YP 69-50-501		TD 69-46-609		AY 68-36-102		DX 68-23-303		LR 67-01-808
	YP 69-50-508		TD 69-47-303		AY 68-37-521		DX 68-23-305		LR 67-01-812
	YP 69-50-6E				AY 68-37-522		DX 68-23-316		LR 67-01-813
	YP 69-51-102	Bexar	AY 68-21-604		AY 68-37-523		DX 68-15-901		LR 67-01-814
	YP 69-51-114		AY 68-27-101		AY 68-37-524		DX 68-16-502		LR 67-09-105
	YP 69-59-101		AY 68-27-303		AY 68-37-525				LR 67-09-111
			AY 68-27-503		AY 68-37-526				
			AY 68-28-205		AY 68-37 527				
			AY 68-28-207		AY 68-37-701				

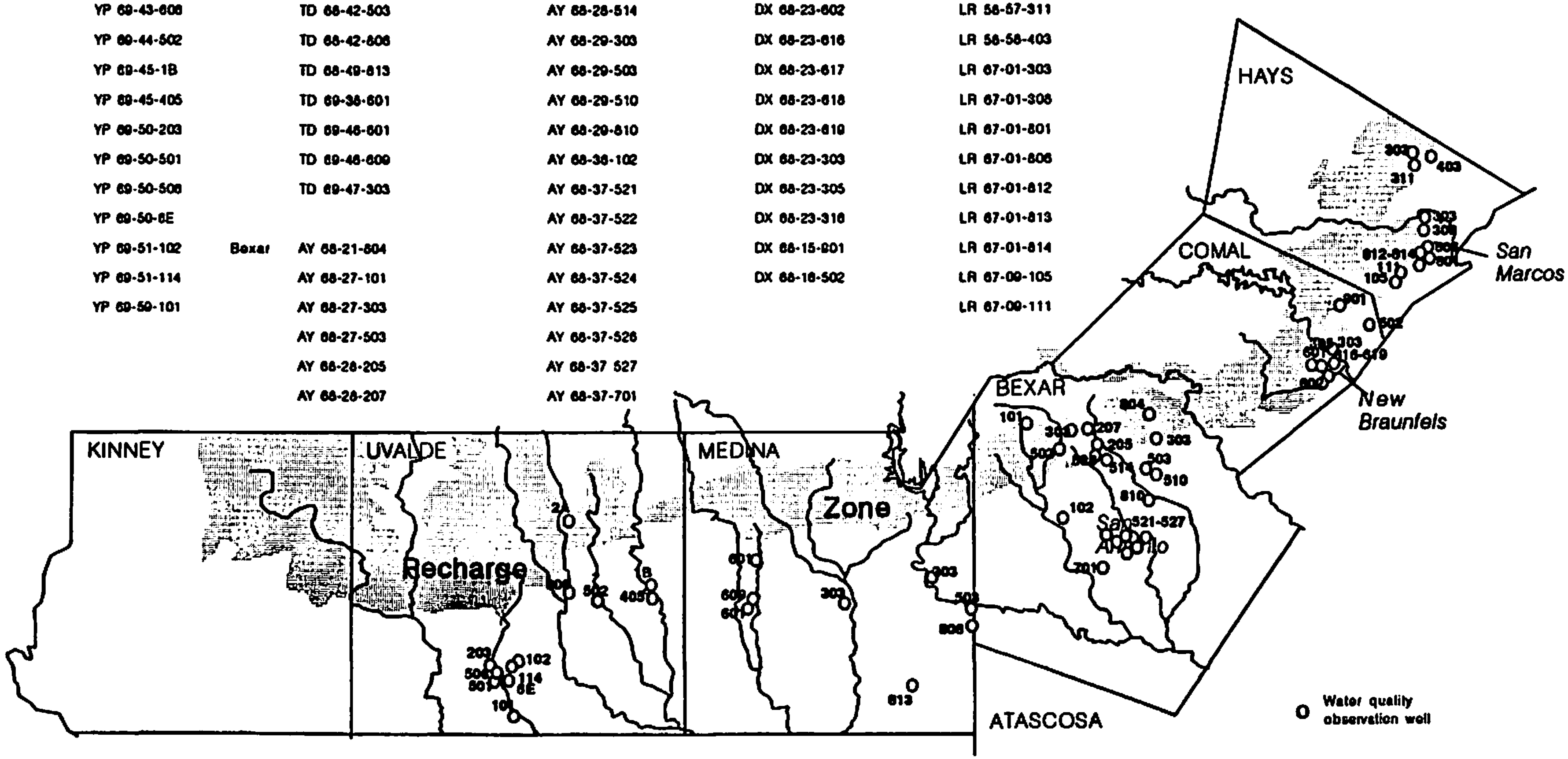


TABLE 6.1
GROUNDWATER QUALITY

PARAMETER	CURRENT MAXIMUM OR SECONDARY CONTAMINANT LEVELS	"EDWARDS AQUIFER TYPICAL RESULT"
PH	-	6.5-8.0
Hardness (mg/l)	-	250-300
Non-carbonate hardness (mg/l)	-	20-50
Calcium (Ca) (mg/l)	-	80-120
Magnesium (Mg) (mg/l)	-	10-20
Sodium (Na) (mg/l)	-	3-10
Potassium (K) (mg/l)	-	1-2
Bicarbonate (CO_3) (mg/l)	-	250-400
Carbonate (CO_3) (mg/l)	-	0
Sulfate (SO_4) (mg/l)	250*	10-30
Chloride (Cl) (mg/l)	250*	10-30
Fluoride (F) (mg/l)	4	0.1-0.5
Dissolved Solids (mg/l)	500*	250-450
Silica (SiO_2) (mg/l)	-	10-20
NUTRIENTS		
Total Nitrate Nitrogen (mg/l)	10	0-0.1
Total Nitrite Nitrogen (mg/l)	-	0-0.1
Total Ammonia Nitrogen (mg/l)	0.5	
Total phosphorus (mg/l)	-	
BACTERIA & BIOLOGICAL PARAMETERS		
Biochemical Oxygen Demand	-	0-1
Total Organic Carbon	-	1-5
Detergents (MBAS)	-	0-0.1
Total Coliform (Colonies/100ml)	10,000 (Raw water for drinking water supplies)	0-5000
Fecal Coliform (Colonies/100ml)	2,000 (raw water for drinking water supplies)	0-150
Fecal Streptococci	-	
METALS		
Arsenic (As) (ug/l)	50	0-2
Cadmium (Cd) (ug/l)	5	0-1
Chromium (Cr) (ug/l)	100	0-15
Copper (Cu) (ug/l)	1000*	0-40
Iron (Fe) (ug/l)	300*	0-500
Lead (Pb) (ug/l)	50	0-10
Manganese (Mn) (ug/l)	50*	0-50
Mercury (Hg) (ug/l)	2	0-1.5
Zinc (Zn) (ug/l)	5000*	0-2000
Nickel (Ni)	-	0-4
PESTICIDES		
Aldrin (ug/l)	1	0
Chlordane (ug/l)	3	0
DDD (ug/l)	-	0
DDE (ug/l)	-	0
DDT (ug/l)	50	0
Heptachlor (ug/l)	0.1	0
Heptachlor epoxide (ug/l)	-	0
Lindane (ug/l)	0.2	0
Mirex (ug/l)	-	0
Toxaphene (ug/l)	3	0
Diazinon (ug/l)	-	0
Ethion (ug/l)	-	0
Malathion (ug/l)	-	0
Methyl Parathion (ug/l)	-	0
Methyl Trithion (ug/l)	-	0
Parathion (ug/l)	-	0
Trithion (ug/l)	-	0
2, 4D (ug/l)	70	0
2, 4-DP (ug/l)	-	0
2, 4, 5-T (ug/l)	2	0
Silvex (ug/l)	50	0
PCB (ug/l)	-	0
Endosulfan (ug/l)	-	0
Ethyl trithion (ug/l)	-	0
Perthane (ug/l)	-	0
Toxaplene (ug/l)	-	0

* - Secondary Maximum Contaminant Level

TABLE 6.2
GROUNDWATER QUALITY

VOLATILE ORGANIC COMPOUNDS

PARAMETER	MAXIMUM CONTAMINANT LEVEL	"EDWARDS AQUIFER TYPICAL RESULT"
Benzene (ug/l)	5	0
Carbon tetrachloride (ug/l)	5	0
1, 4 - Dichlorobenzene (ug/l)	75	0
1, 2 - Dichloroethane (ug/l)	5	0
1, 1 - Dichloroethylene (ug/l)	7	0
Tetrachloroethylene (ug/l)	5	0
1, 1, 1 - Trichloroethane (ug/l)	200	0
Trichloroethylene (ug/l)	5	0
Vinyl Chloride	2	0

Well LR 67-01-806 in Hays County had a measured level of 0.50 ug/L for bromoform, a trihalomethane. The MCL for the total sum of all trihalomethanes in a single water sample is 100 ug/L. Trihalomethanes are formed primarily when chlorine, added to disinfect drinking water, interacts with natural organic substances in untreated water. In addition, tetrachloroethylene (TCE, MCL = 5 ug/L) was detected at a level of 0.4 ug/L in the LR-67-01-806 well. A second well, AY-68-27-303, in Bexar County had a measured level of chloroform of 0.2 ug/L. While these levels are detectable, they are well below the limits set by current EPA drinking water standards.

Results of the 1992 water sampling and analysis program illustrate the continued excellent quality of water in the Edwards aquifer.

6.2 Freshwater/Saline Water Interface

The classification of groundwater quality is based on total dissolved solids concentration, as follows:

Description	Total-Dissolved Solids Concentration (mg/l)
Fresh	Less than 1,000
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000
Brine	More than 35,000

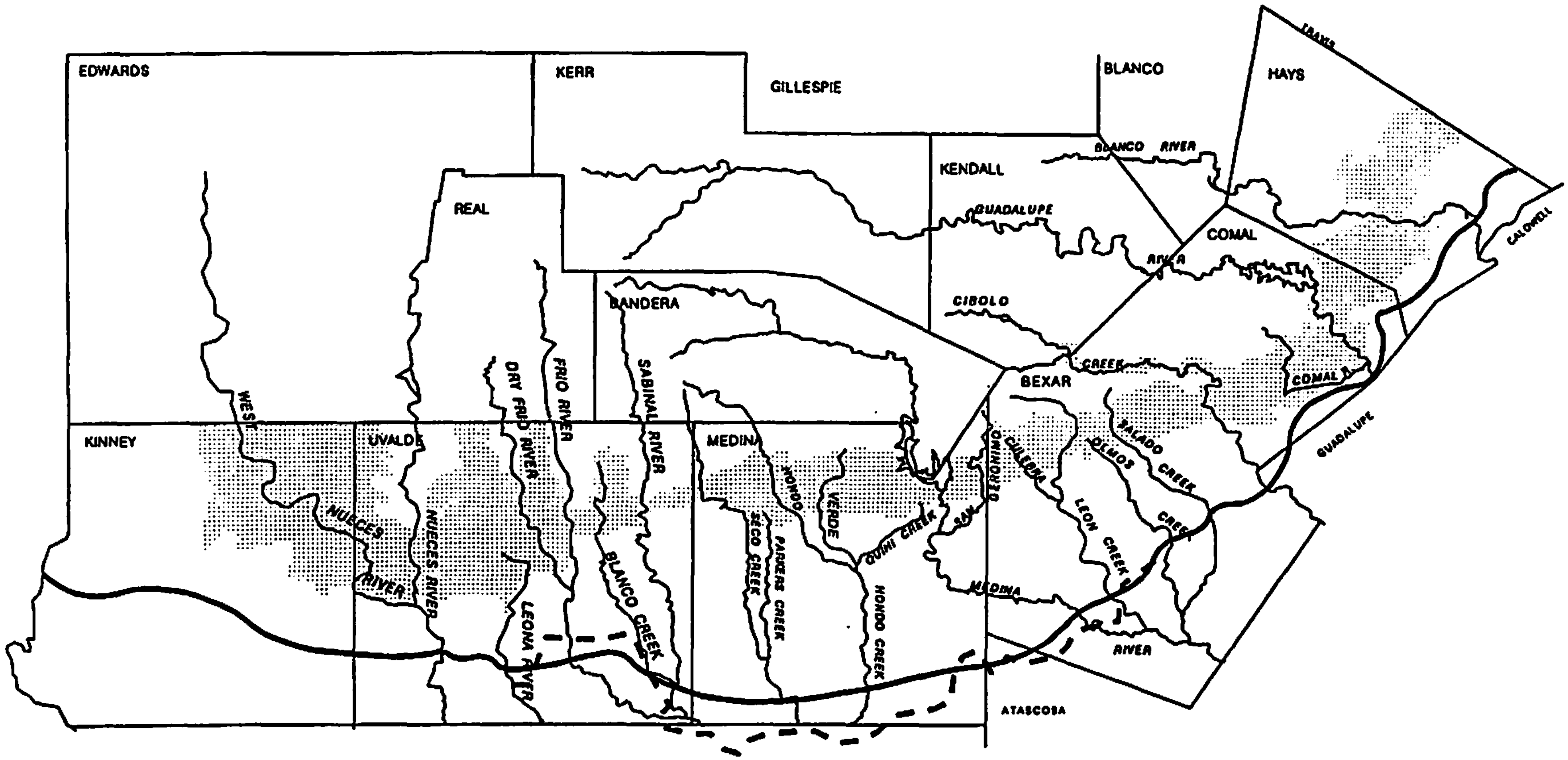
A transitional freshwater/saline-water interface (formerly called the bad water line), defined by TDS values greater than 1000 mg/L, represents the downdip hydrologic boundary of the Edwards aquifer. Water updip from this arbitrary boundary is considered to be fresh potable water. The interface is shown in **Figure 6.2**. South and southeast of the interface, water from the Edwards aquifer is slightly to moderately saline, and contains moderate to large concentrations of dissolved chloride and sulfate. The interface varies both laterally and vertically, as found in several wells near the boundary where fresh water has been encountered in the upper portion of the Edwards and saline water in lower portions of the aquifer.

Water quality analyses data from a series of wells near the freshwater/saline-water interface in southern Medina County are posted in **Table 6.3**, with well locations noted in **Figure 6.3**. The TDS values for Edwards water from each of these wells fall within the freshwater classification, with the exception of the TD 68-49-813 well, which is considered to be in close proximity to but slightly updip from the freshwater/saline-water interface.

The Quest No. 1 well, which was sampled by District staff in 1992, is located just south of the mapped interface. Water quality data from this well, as seen in **Table 6.3**, are very similar to data from wells located on the freshwater side of the interface.

When compared to data from wells TD 68-49-813 and the City of Devine No. 1, where several quality parameters and constituents change in a short distance downdip, water quality data from the Quest No. 1 and nearby wells indicate that the freshwater/saline-water interface is more transitional and further south in this area. The district plans to drill an observation well in 1993 south of this area to better define the interface in the western portion of the Edwards aquifer, and also to increase the number of water quality monitoring stations adjacent to and updip from

Figure 6.2 - Freshwater/saline water interface and proposed changes as a result of Edwards Underground Water District Report 92-03.



— — — Proposed freshwater/saline water interface (Report 92-03)

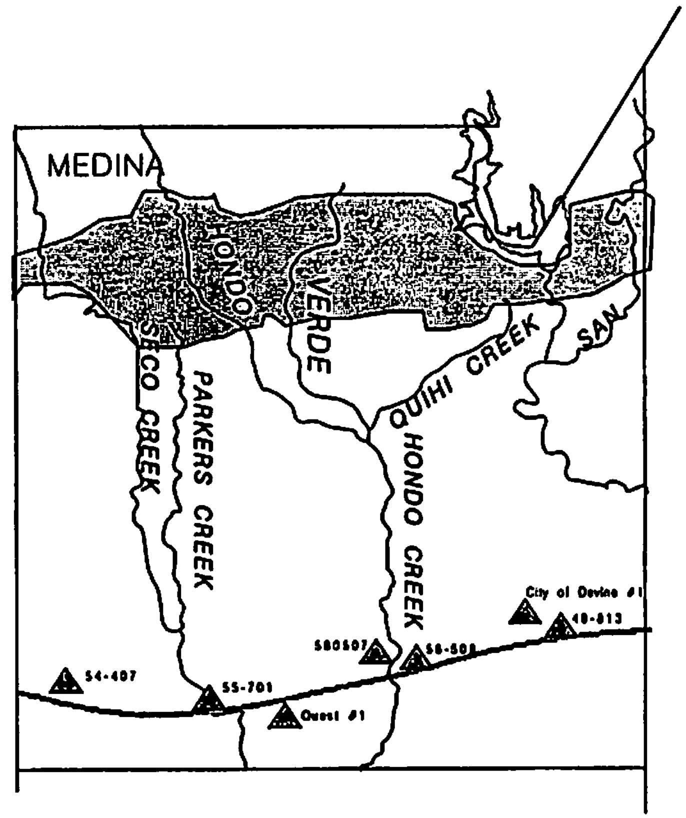
——— Freshwater/saline water interface (Modified from Puente, 1978)

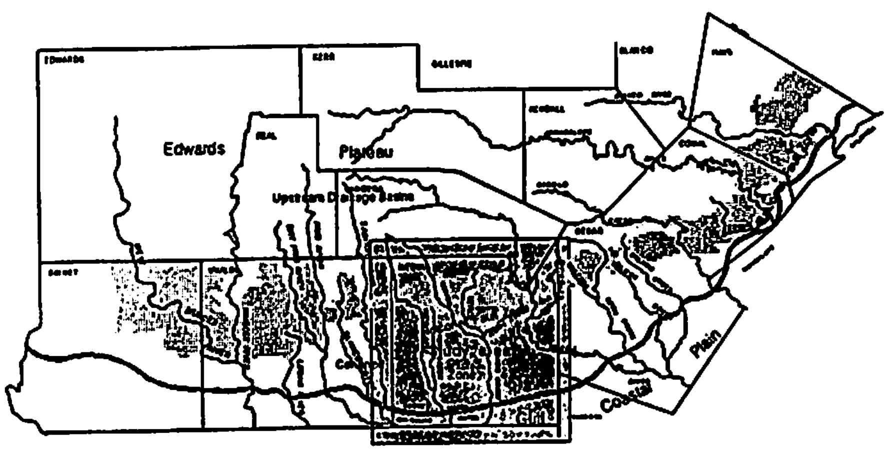
TABLE 6.3
WATER QUALITY - SOUTHERN MEDINA COUNTY

Well ID No.	#401		#701	QUEST #1	#508		#507	#813		"Typical Edwards Aquifer Results"
Year Sampled	1990	1991	1990	1992	1988	1990	1989	1989	1990	
pH (S.U.)	7.2	7.1	7.2	7.5	6.9	7.3	7.2	6.6	7.2	6.5-8.0
SpCond (umhos/cm)	500	550	491	490	481	624	503	1220	1190	-
TDS (mg/l)	255	306	274	308	270	270	276	706	640	250-450
HARDNESS (mg/l)	230	230	230	226	230	220	230	270	220	250-300
Ca (mg/l)	66	67	61	67	55	55	53	54	54	80-120
Cl (mg/l)	18	51	19	20	18	21	16	180	170	10-30
SO_4 (mg/l)	9.5	14	24	26	26	25	31	68	47	10-30
TOT ALK (mg/l)	200	200	200	196	200	200	194	282	290	-
F (mg/l)	0.30	0.40	0.30	1.68	1.0	0.90	0.60	4.5	4.4	0.1-0.5
HCO_3 (mg/l)	-	-	-	240	-	-	-	-	-	250-400
NO_3 (mg/l)	-	-	-	<.01	-	-	-	-	-	1.5-3.0
Na (mg/l)	12	24	9.1	13	12	11	10	140	140	3-10
Fe (mg/l)	-	51	<3	.22	-	-	-	-	-	0-500
Mn (mg/l)	-	9	<1	.01	-	-	-	-	-	0-50
Mg (mg/l)	16	15	18	15	22	21	21	22	21	10-20

Figure 6.3 - South Medina County water quality observation wells.

Freshwater/saline water interface
(Modified from Puente, 1978)





Location Map

the interface, which will allow changes in the position of the interface to be determined promptly, and may serve as a catalyst for further hydrologic studies of the area.

Two EUWD studies were completed in 1992 to evaluate the position of the fresh/saline-water interface. A study from San Antonio westward to Uvalde, Texas, was conducted to update the location of the fresh/saline-water interface. A second study to characterize the influence of the geologic structure on the fresh/saline-water interface near the San Marcos and Comal Springs was also concluded in 1992. Data and results from the first study, which utilized geophysical log data to calculate water quality values for TDS, indicate that the freshwater/saline-water interface west of San Antonio is further south in some areas than previously mapped. Further testing will be conducted to verify the results of this study. The position of the interface as determined in this study can be seen in **Figure 6.2**.

A series of well transects were constructed at New Braunfels and San Marcos, Texas to monitor changes in water quality near the springs in the northeastern portion of the Edwards aquifer. The final report on data collected during the drilling and testing of these wells was released in 1992 by the EUWD. Results indicate that the freshwater/ saline-water interface is in close proximity to San Marcos Springs, separated from them by a fault zone which offsets the entire thickness of the Edwards aquifer. Results from the New Braunfels wells indicate that the water in the Edwards aquifer at this location is vertically stratified, with less saline water overlying more saline water and separated by the Regional Dense Member of the Edwards Group. Water level and water quality in the wells will be monitored to detect any changes in position of the interface. This monitoring program, which also includes wells which transect the freshwater/saline-water interface in the San Antonio area, was begun in 1985 in response to concerns that increased withdrawal might result in movement of the saline water updip into previously fresh water areas of the Edwards aquifer.

Total dissolved solids concentrations show little variation laterally in the recharge and freshwater zones of the Edwards aquifer, as seen in **Figure 6.4**, which illustrates changes in TDS for wells in Bexar, Comal, Hays, Medina and Uvalde counties during the period of 1980-1992. These wells were sampled from one to three times per year, usually in late spring and summer. **Figure 6.5** illustrates changes in TDS for 3 wells in the recharge, artesian, and saline water zones during the below average rainfall period in 1988, as well as two periods of above average precipitation in 1987 and 1992. As seen in the graphs, none of the wells exhibited changes in water quality as a result of significant differences in recharge to the aquifer. This would suggest that there is little if any movement of saline-water into the freshwater zone during periods of lower than normal water levels. Concerns that this may be possible in a future dry period have led to the ongoing monitoring programs conducted by the District across the Edwards aquifer.

The District has also continued programs to protect the water quality of the aquifer through groundwater investigations of contamination or anomalous data from the aquifer-wide sampling program, the diligent monitoring of development activities over the recharge zone, and a program which locates and causes abandoned wells in the Edwards aquifer to be plugged. All of these programs are intended to insure that the quality of water in the aquifer will remain at its current excellent level.

The District's staff has been actively monitoring development activities over the recharge zone, including commercial and residential subdivisions, sewer systems, and

Figure 6.4 - Changes in total dissolved solids for wells in Bexar (AY), Comal (DX), Hays (LR) , Medina (TD), and Uvalde (YP) counties, 1980-1992.

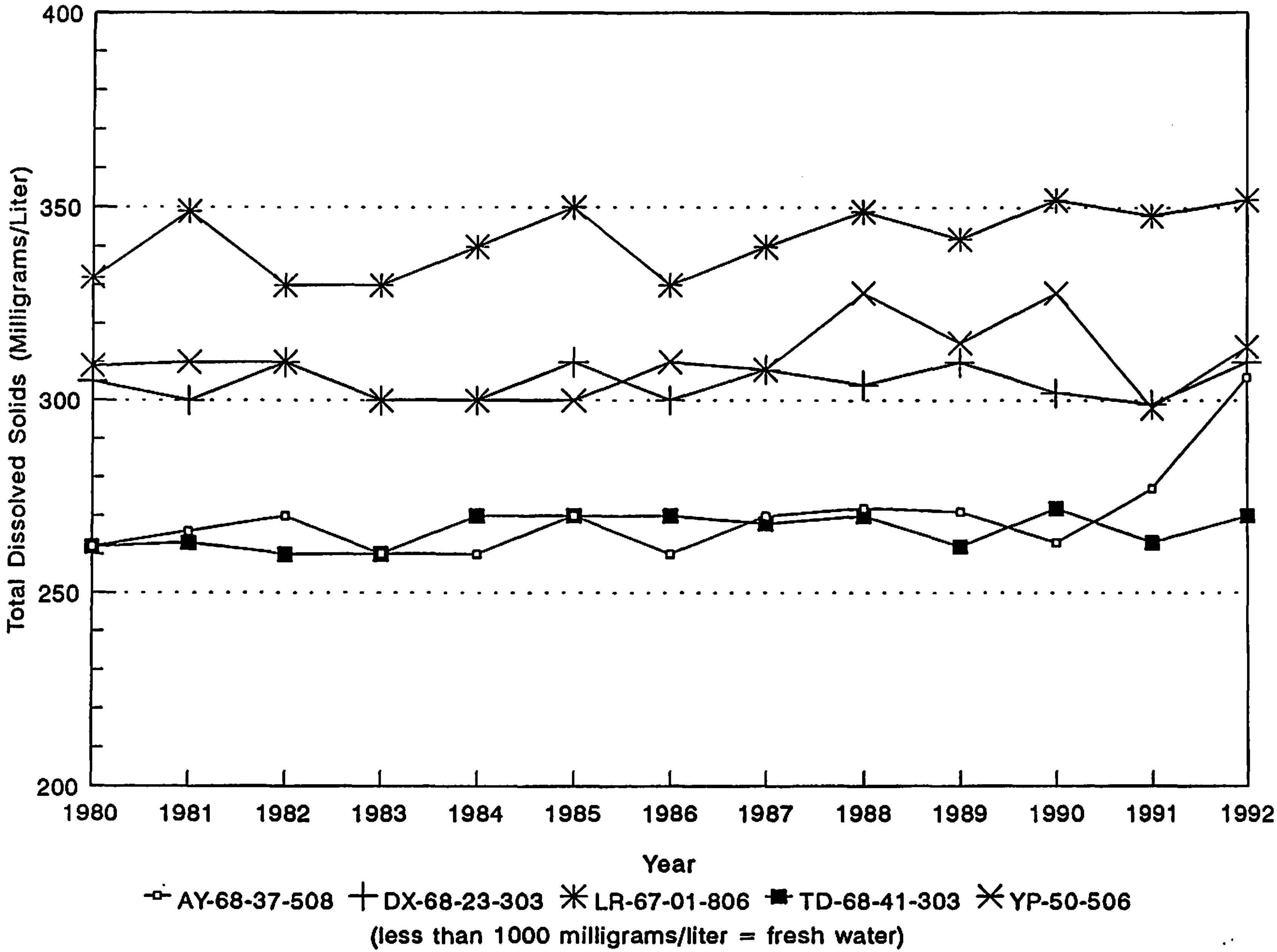
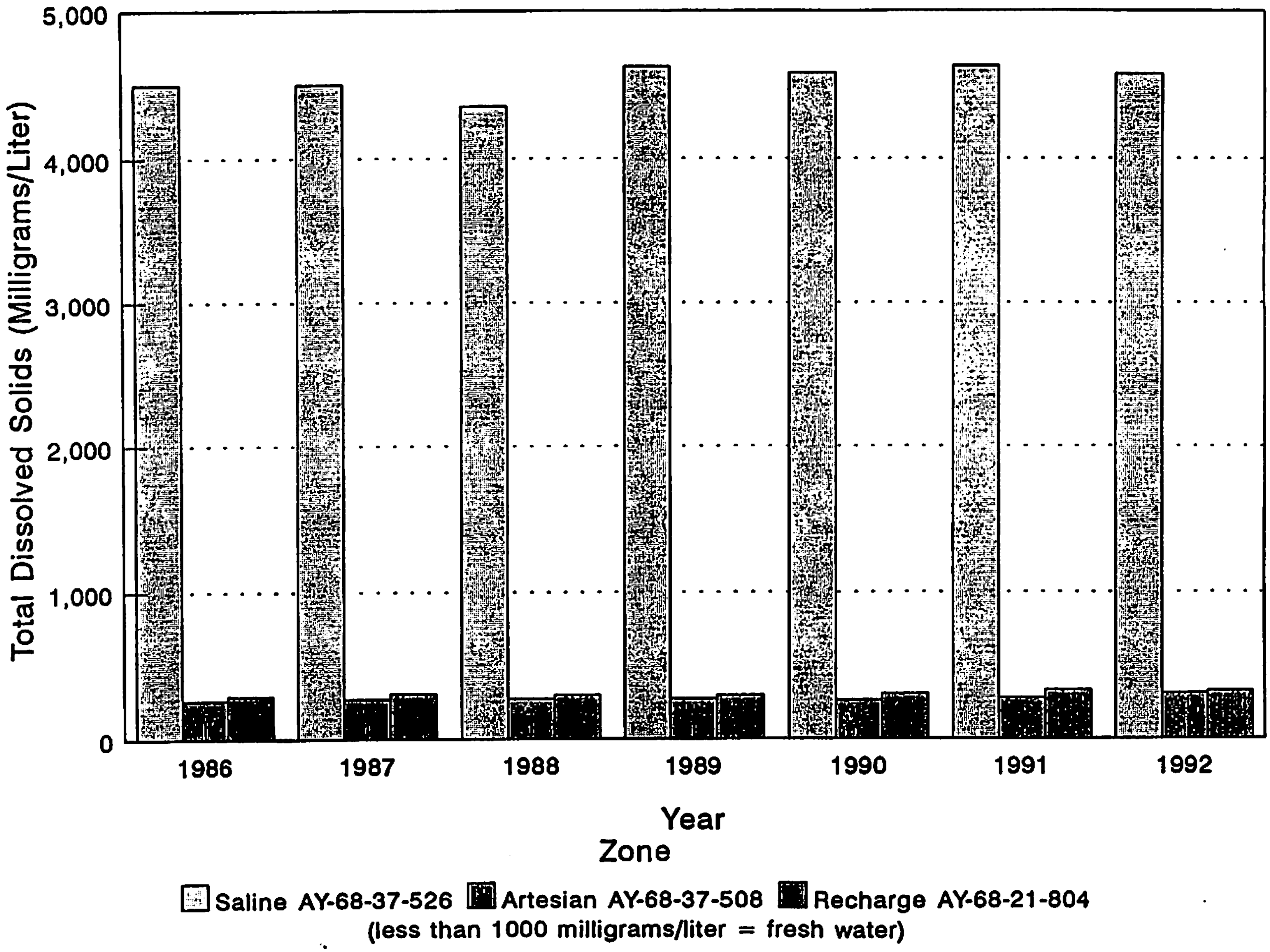


Figure 6.5 - Changes in total dissolved solids in the Saline Zone, Artesian Zone, and Recharge Zone of the Edwards aquifer, 1986-1992.



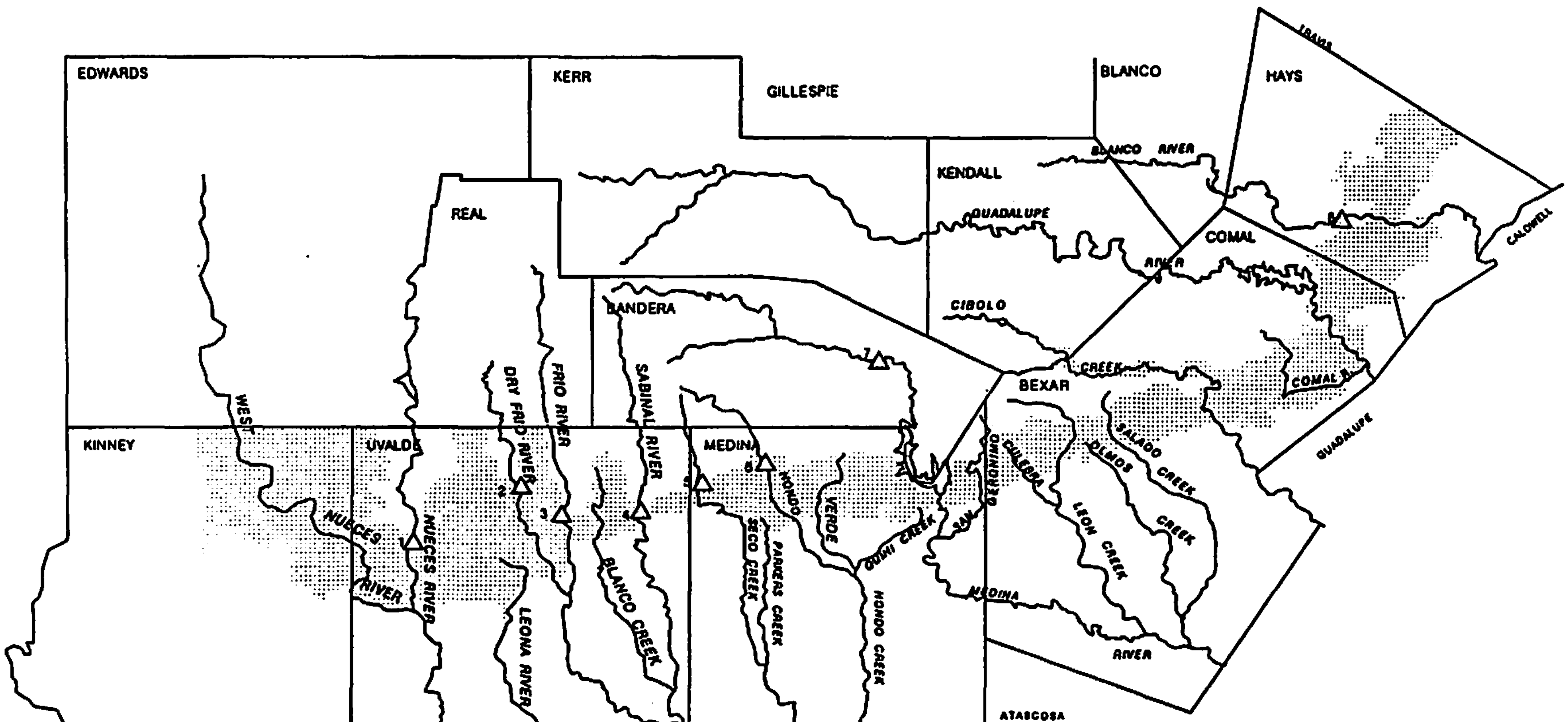
hazardous material storage and transportation. Trained District field investigators conduct inspections, and report their results to the TWC for appropriate action. During 1992, District staff conducted 254 facility investigations, completed two field sampling programs in response to public complaints, reviewed over 30 water pollution abatement proposals and 10 or more petroleum storage tank applications, and responded to 12 or more illegal discharge complaints.

The well closing program has identified a number of unused and abandoned wells which are open to the Edwards aquifer, and provide pathways for contaminants to reach the aquifer. The District's staff locates the owners of these wells and causes them to be properly plugged. During 1992, when aquifer water levels reached record highs, over thirty five previously undetected abandoned wells began flowing. EUWD staff investigated these incidents and included these wells in the plugging program.

6.3 Surface - Water Quality Data

Surface water data is collected at stations upstream from the recharge zone as well as stations located throughout the aquifer area. This data is used to analyze the quality of water recharging the aquifer. Data from the network of gaging stations can be used as a base level to evaluate water quality and its sensitivity to land use in various areas of the Edwards aquifer region. Locations of data collection sites are illustrated in **Figure 6.6**. The analysis results from the samples collected in 1992 indicate no evidence of detectable amounts of pesticides, volatile organic compounds, or other constituents or parameters in excess of typical standards. However, care must always be exercised when proceeding with development in the recharge area.

Figure 6.6 - Surface water quality sites sampled in 1992.



Site Number	Name (Location)
1	Nueces River at Laguna, TX
2	Dry Frio River near Reagan, TX
3	Frio River at Concan, TX
4	Sabinal River near Sabinal, TX
5	Seco Creek at Miller Ranch near Utopia, TX
6	Hondo Creek near Tarpley, TX
7	Medina River at Bandera, Tx
8	Blanco River at Wimberley, TX

7.0 Summary

Surface-water data for the San Antonio area used to calculate annual recharge and discharge of the Edwards aquifer, consist of flow data for streams and discharge data for springs, and quantity data for reservoirs. The data is stored in the National Water Information System, a computerized data base operated by the U. S. Geological Survey.

The average estimated annual groundwater recharge to the Edwards aquifer in the San Antonio area, Texas, from 1934 through 1992 was 682,860 acre-feet. Recharge in 1992 was 2,486,000 acre-feet, which is the largest estimated annual recharge. The lowest annual recharge of 43,700 acre-feet occurred in 1956.

The estimated annual discharge from the Edwards aquifer by wells and springs in 1992 was 1,130,000 acre-feet, which is the largest calculated annual discharge for the period of record which began in 1934. The lowest annual discharge by wells and springs for the same time period was 388,800 acre-feet in 1955.

Water level data for wells during 1992 reflected above average to record volume of groundwater in storage in the Edwards aquifer during most of the year.

Water samples from 61 wells and 3 springs in the Edwards aquifer were analyzed for more than 90 properties or constituents, most of which affect the suitability of the water for domestic use. Concentrations of constituents in water from one well completed in the freshwater zone exceeded the maximum contaminant level for fluoride established for public water systems.

Trace concentrations of volatile organic compounds were detected in samples from three wells.

Results of the 1992 water sampling and analysis program illustrate the continued excellent quality of water in the Edwards aquifer.

8.0 Definitions of Terms

Technical terms and abbreviations used in this report are defined as follows:

acre-foot (ac-ft) is the quantity of water required to cover 1 acre to a depth of 1 ft and is equivalent to 43,560 ft^3 (cubic feet), about 325,900 gal (gallons), or 1,233 m^3.

bacteria (colonies 100 ML) are microscopic unicellular organisms, typically spherical, rodlike, or spiral and threadlike in shape, often clumped in colonies. Some bacterial cause disease, while others perform an essential role in nature in the recycling of materials; for example, by decomposing organic matter into a form available for reuse by plants.

WSP is used as an abbreviation for "Water-Supply Paper" in references to previously published reports.

recharge is the process involved in absorption and addition of water to the zone of saturation.

recharge zone is an area in which water is infiltrates into the ground and eventually reaches the zone of saturation in one or more aquifers.

zone of saturation is a subsurface zone in which all interstices are filled with water under pressure greater than that of the atmosphere.

water table is the interface between the zone of saturation and the zone of aeration; that surface of a body of unconfined groundwater at which pressure is equal to the atmosphere.

unconfined aquifer a aquifer having a water table and containing groundwater that is not under pressure beneath relatively impermeable rocks.

potentiometric surface is an imaginary surface representing the total head of groundwater and defined by the level that water will rise in a well.

confined aquifer is an artesian aquifer or an aquifer bounded above and below by impermeable strata, or by strata with lower permeability than the aquifer itself.

9.0 References

Brown, D.S., Gilhousen, J.R., and Nalley, G.M., 1991, Compilation of hydrologic data for the Edwards aquifer, San Antonio area, Texas, 1990, with 1934-90 summary: Edwards Underground Water District Bulletin 50, 169 p.

Poteet, D., Collier, H., Maclay, R.W., 1992, Investigation of Fresh/Saline-Water Interface in the Edwards Aquifer in New Braunfels and San Marcos, Texas: Edwards Underground Water District Report 92-02.

Puente, Celso, 1978, Method of estimating natural recharge to the Edwards aquifer in the San Antonio area, Texas: U.S. Geological Survey Water-Resources Investigations Report 78-10, 38 p.

Schultz, A.L., 1992, Using Geophysical Logs in the Edwards Aquifer to Estimate Water Quality Along the Freshwater/Saline-Water Interface (Uvalde, Texas to San Antonio, Texas): Edwards Underground Water District Report 92-03, p. 47.

U.S. Department of Agriculture, 1934-40, Climatological data, Texas, annual summaries: Weather Bureau, v. 39-45, no. 13.

U.S. Department of Commerce, 1941-64, Climatological data, Texas, annual summaries: Weather Bureau, v. 46-69, no. 13.

-----1965-69, Climatological data, Texas, annual summaries: Environmental Science Services Administration, v. 70-74, no. 13.

-----1970-91, Climatological data, Texas, annual summaries: National Oceanic and Atmospheric Administration, v. 75-96, no. 13.

U.S. Environmental Protection Agency, 1990a, Maximum contaminant levels (subpart B of part 141, National primary drinking water regulations): U.S. Code of Federal Regulations, Title 40, parts 100 to 149, revised as of July 1, 1990, p. 559-563.

-----1990b, Secondary maximum contaminant levels (section 143.3 of part 143, National secondary drinking water regulations): U.S. Code of Federal Regulations, Title 40, parts 100 to 149, revised as of July 1, 1990, p. 674.

-----1991, National primary and secondary drinking water regulations; synthetic organic compounds and inorganic chemicals (sections 141.11, 141.12, 141.32, 141.50, 141.51, 141.61 and 141.62 of part 141 and 143.3 of part 143): U.S. Federal Register, v. 56, no. 20, Jan. 30, 1991, p. 3,526-3,597.

Waugh, J.R., and Walthour, S.D., 1993, Government Canyon Geologic and Hydrologic Assessment: Edwards Underground Water District Open File Report 93-01, p. 19.