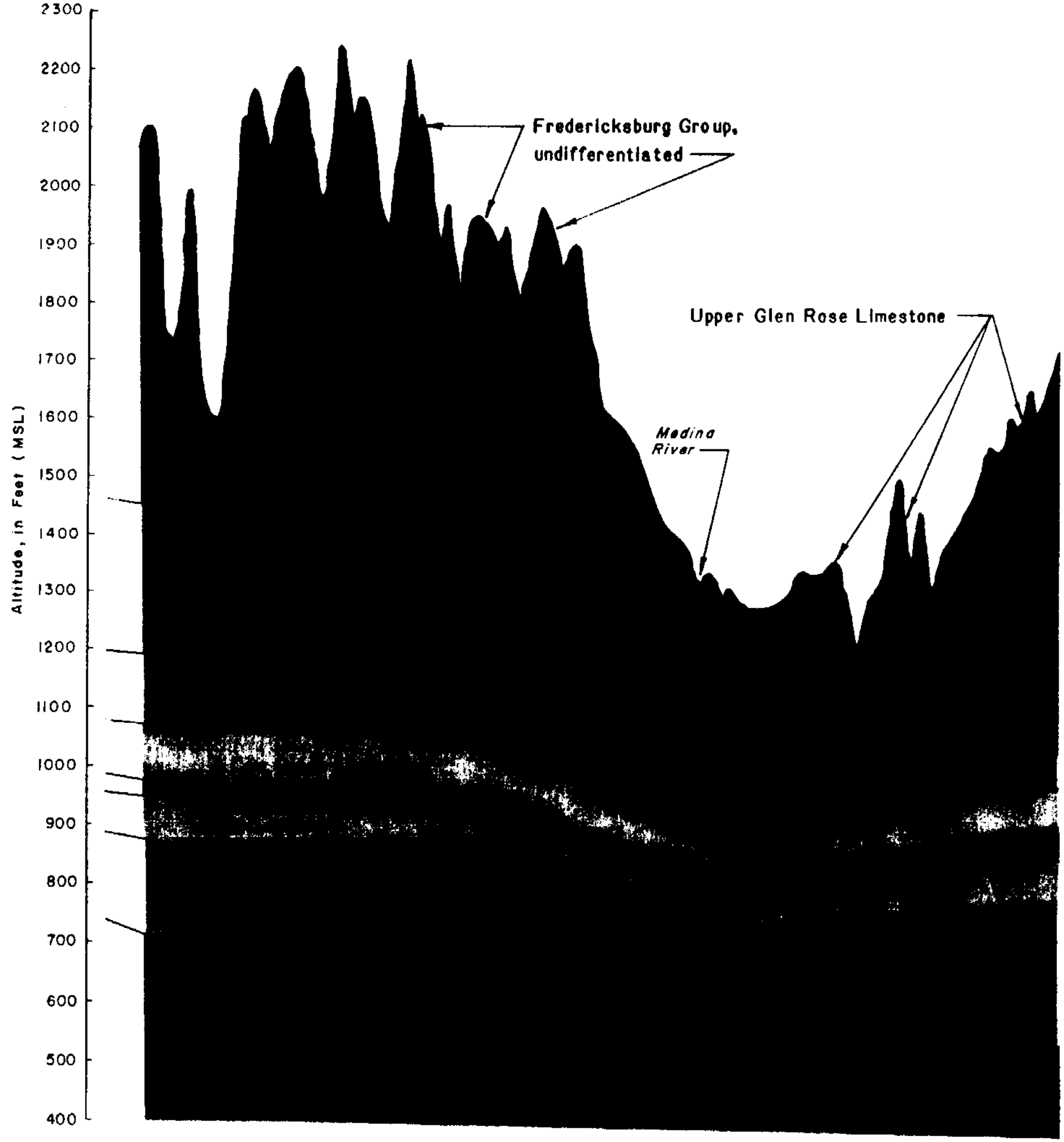
Regional Water Supply Study



Springhills Water Management District

October, 1991

SPRINGHILLS WATER MANAGEMENT DISTRICT
REGIONAL WATER SUPPLY STUDY
10- BANDERA COUNTY

19- Basin

October, 1991

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SPRINGHILLS WATER MANAGEMENT DISTRICT
REGIONAL WATER SUPPLY STUDY
BANDERA COUNTY

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SPRINGHILLS WATER MANAGEMENT DISTRICT
REGIONAL WATER SUPPLY STUDY
BANDERA COUNTY

1.0 INTRODUCTION

1.1 Study Background

The Springhills Water Management District (hereafter referred to as Springhills WMD or District) was created by Act of the Texas Legislature in 1989 (S.B. No. 1636). Springhills WMD has all the rights, powers, privileges, authority, functions, and duties provided by the general law of the state (including Chapters 50 and 52, Water Code, applicable to underground water conservation districts) created under Article XVI, Section 59, of the Texas Constitution. The District has additional authority (under its former identification as the Bandera County River Authority) to exercise the rights, powers, purposes, authority, and functions provided by Chapter 629, Acts of the 62nd Legislature, Regular Session, 1971 (Article 8280-526, Vernon's Texas Civil Statutes). Springhills WMD's service area includes all of Bandera County.

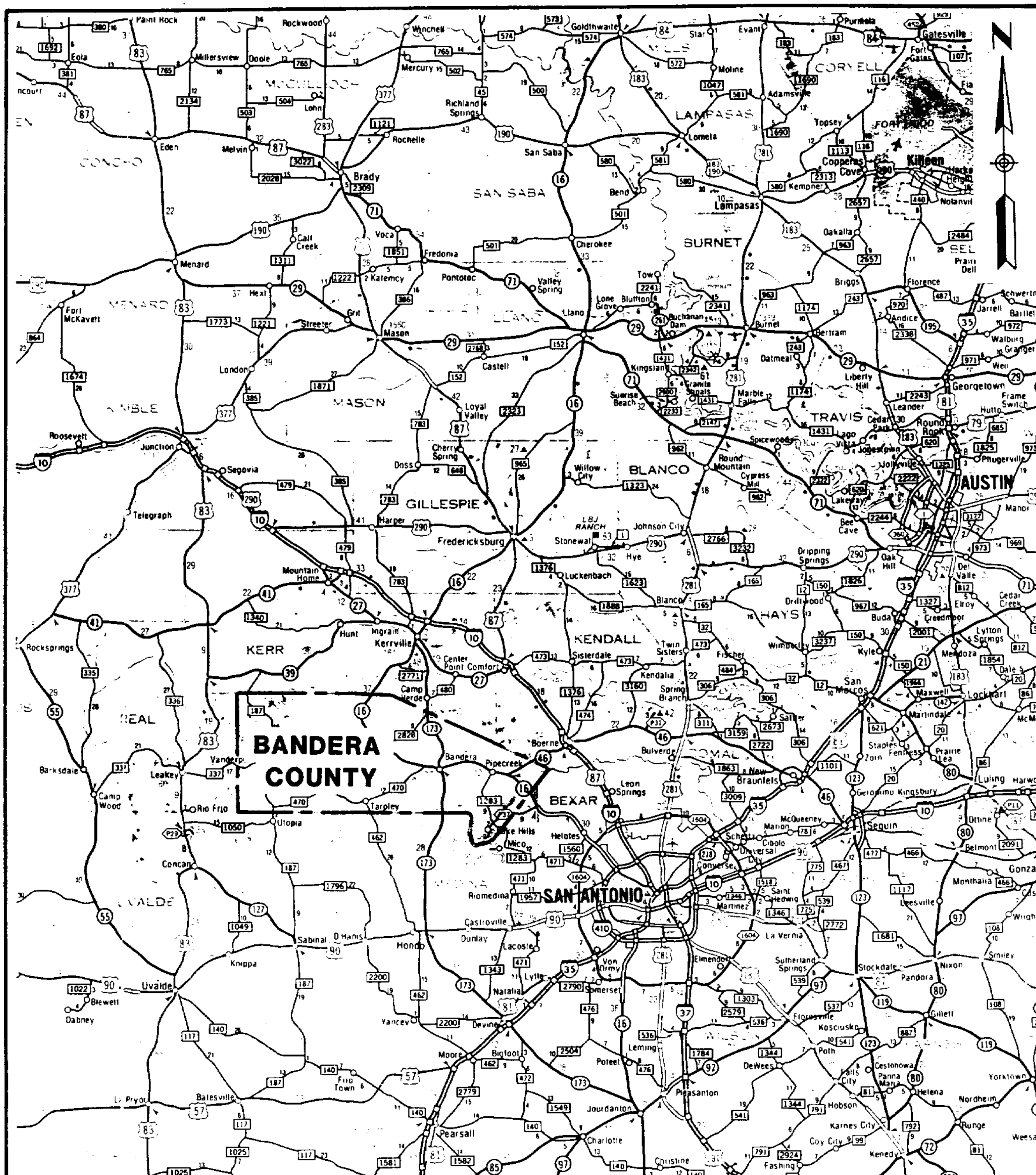
In July of 1990, the Texas Department of Health (TDH), Public Health Region 6, Uvalde, Texas informed Springhills WMD that all of Bandera County is deficient in drinking water supply, and particularly emphasized the deficiency in the eastern part of the county. In November of 1990, the District applied for grant funds from the Texas Water Development Board (TWDB) Research and Planning Fund to develop a regional water supply plan for the District's service area. A contract between the TWDB and Springhills WMD for matching grant funds was finalized in January of 1991. HDR Engineering, Inc. (HDR) was retained by the District in March of 1991 to serve as the District's consultant for the development of a regional water supply plan.

1.2 Study Area

The study area includes all of Bandera County, which is located in the hill country of the Edwards Plateau region. The county seat, the City of Bandera, is located about 40 miles northwest of San Antonio (Figure 1-1). During the decade of the 1980's, Bandera County was the ninth fastest-growing county in Texas. During this decade, the county grew at an annual rate of 4.3 percent, which was more than twice the average growth rate for the state. Between 1980 and 1990, the county population increased from 7,084 to 10,562 persons as both retirement settlers and San Antonio commuters relocated to the hill country environment in Bandera County.

Bandera County lies in an area of the Edwards Plateau which contains portions of three major river basins; about 73 percent of the county is in the San Antonio River Basin, about 25 percent is in the Nueces River Basin, and about two percent is in the Guadalupe River Basin (Figure 1-2). The principal source of water for municipal purposes in Bandera County is groundwater from the Trinity Group Aquifer. The Medina River which originates in north-central Bandera County and flows southeasterly through the county has significant flows, however, nearly all of the flow has been allocated to downstream demands.

Almost all of the county is served by wells, with each city, community, subdivision, and individual having their own wells, storage, and distribution facilities. Both well yields and water quality are declining as pumping increases. In the City of Bandera, water use restrictions are often necessary in the summer. Attempts to find new groundwater supplies have been only marginally successful.



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LOCATION MAP

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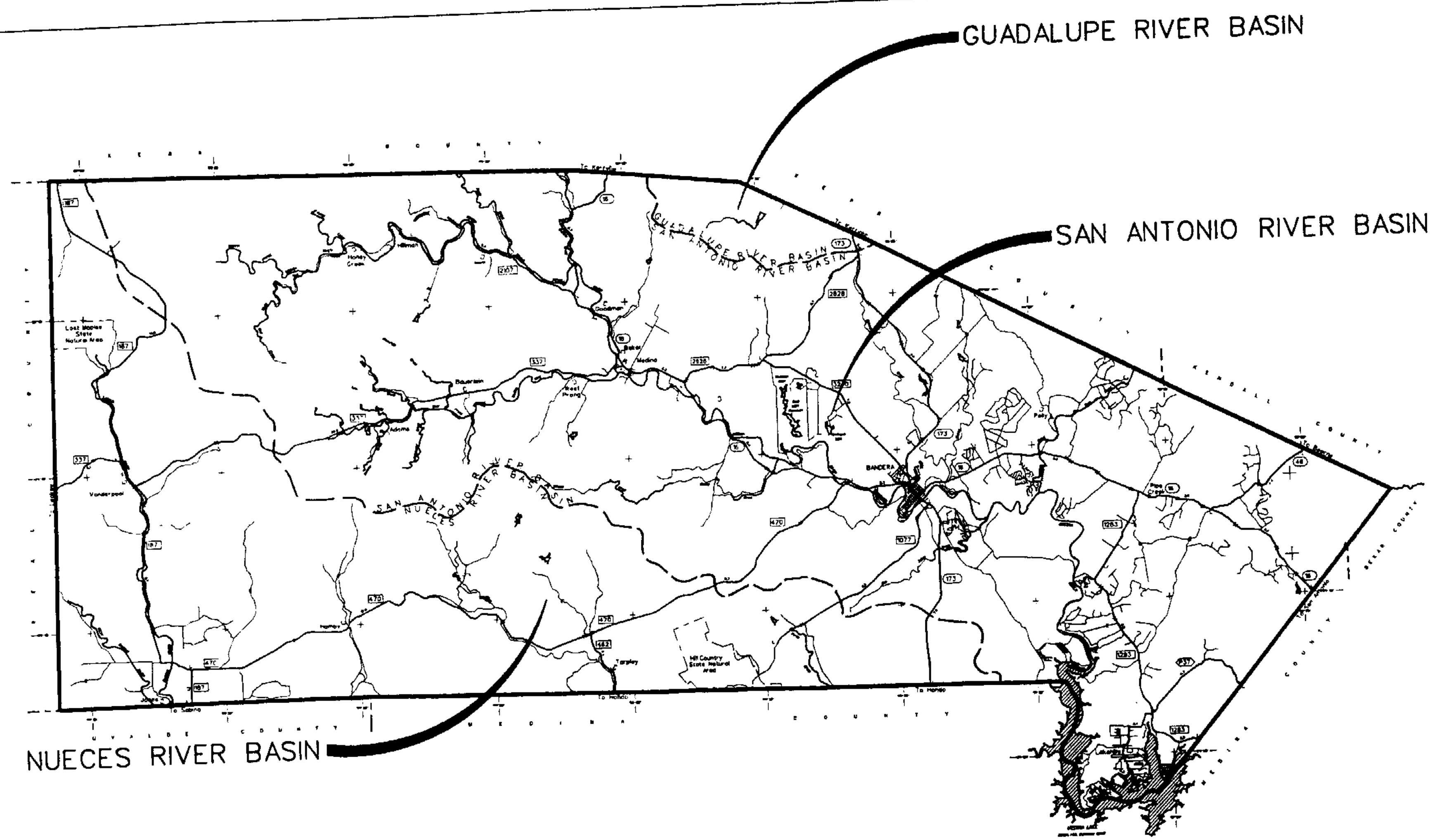
FIGURE 1-1



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REGIONAL WATER SUPPLY STUDY

RIVER BASINS IN BANDERA COUNTY

FIGURE 1-2

1.3 Study Objectives

In a broad sense, the objective of this study is to provide a plan to conserve existing water supplies and to guide the implementation of new water supplies for Bandera County. To accomplish this objective, several aspects of water supply planning were identified and undertaken as tasks in the study.

Task 1.0 - Obtain Advisory Committee Input

Springhills WMD established an Advisory Committee consisting of the District's Board and General Manager, city and county officials, water supply corporations, and water users. Coordination meetings, which were open to the public, were held in May, June, and August of 1991 to discuss the status of the study and solicit input from the Advisory Committee and public. Representatives of the TDH and TWDB attended the meetings.

Task 2.0 - Available Water Resources

An assessment was made as to the quantity and quality of existing ground and surface water resources within the county. The most recent data available regarding water quality, stream flow, surface water availability, and ground water levels were obtained from various agencies including the TWDB, TDH, Texas Water Commission (TWC), and U.S. Geological Survey (USGS) to accomplish this task.

Task 3.0 - Water Conservation Plan

A water conservation and drought contingency plan has been prepared in accordance with TWDB guidelines to promote the efficient use of water, extend the life of existing supplies, and reduce the costs of new or supplemental water supplies (Appendix A).

Task 4.0 - Population and Water Use Projections

Historic population and water use data were collected and analyzed for the county and surrounding communities. To determine future water needs for the county, population and associated water use projections were performed for each decade of the 50-year planning period.

Task 5.0 - Areas of Need

A comparison between available water resources and projected water usage was made to determine areas within the county that are or will be in need of additional and/or better quality water for municipal purposes.

Task 6.0 - Potential Water Resource Developments

Ten new water supply alternatives have been identified and evaluated as supplemental sources to the county's existing groundwater supplies. For each alternative, costs, water availability, conservation, and potential environmental impacts were considered. Alternatives were evaluated on the basis of cost and adequacy to meet projected water quantity and quality needs. Procedures and financing options for implementing the selected alternative were explored.

Task 7.0 - Report

A draft report was prepared and submitted to the District and TWDB for review and comments. The final report has been prepared after consideration of the review comments.

SECTION 2

2.0 POPULATION PROJECTIONS

The quantity of water needed in an area depends on the size of the population, the types and sizes of water-using industries, the acreage and kinds of crops irrigated, and the number and types of livestock and wildlife of the area. For this study Bandera County was divided into 10 subareas using the U.S. Bureau of the Census Block Groups for which 1990 census data were tabulated (Figure 2-1). Population and water use information were tabulated for each subarea, and low and high population and water use requirements were projected for each decade from 1990 to 2040. Water use projections are presented in Section 3.0

During the decade of the 1980's, Texas' population increased 19.38 percent, from 14.23 million to 16.99 million. Bandera County had the ninth-highest population increase of Texas' 254 counties with a 49.1 percent increase. Population in the county increased from 7,084 in 1980 to 10,562 in 1990. During the 1980's, Bandera County had a greater percentage increase than any of its neighboring counties (Table 2-1). During this period, Bandera County's compound annual growth rate was 4.08 percent, with four of its subareas having compound annual growth rates greater than 5.0 percent (Table 2-2 and Figure 2-1).

Low and high population projections have been prepared for each subarea for the 50-year water supply planning period. The projections assume that neither a shortage of water nor regulatory limitations on land use will restrict population growth. The high projections were based on the growth rates of the 1980's for each census block group, with variations to the basic method used for Subareas C, E, and H. The low projections were

TABLE 2-1
Texas County Population Growth -- 1980's
Top 10 and Bandera Neighbors

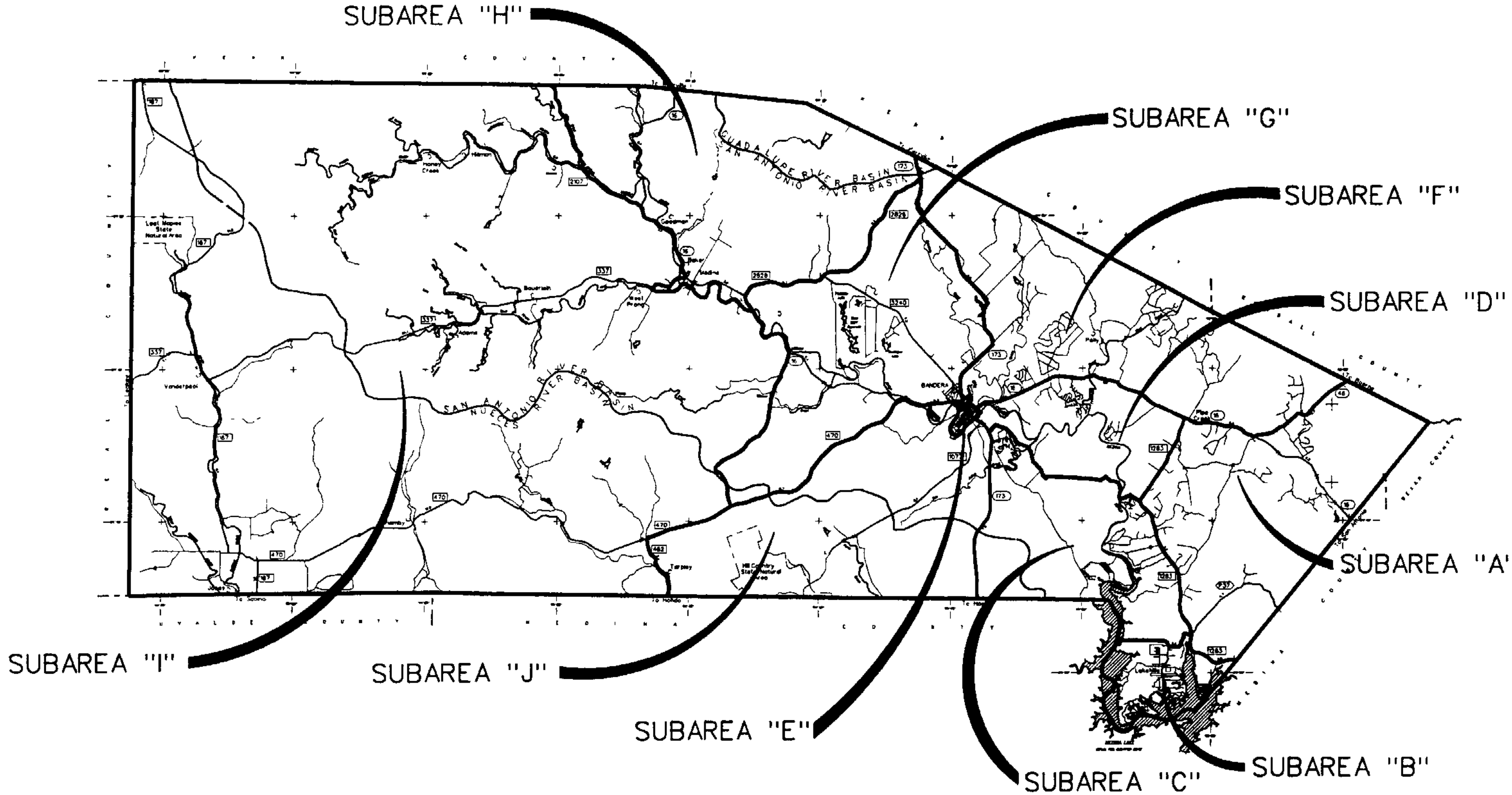
Texas Top 10 Fastest Growing Counties: 1980-1990		Bandera Neighboring County Growth: 1980-1990	
County	**Percent Growth**	**County**	**Percent Growth**
1. Denton	91.11	1. Kendall	37.18
2. Collin	82.63	2. Kerr	26.14
3. Williamson	82.37	3. Bexar	19.88
4. Rockwall	76.24	4. Medina	17.91
5. Fort Bend	72.28	5. Uvalde	4.01
6. Hood	63.61		
7. Hays	61.63	State	19.38
8. Bastrop	54.75		
9. Bandera	**49.10**		
10. Parker	45.23		

Source: U.S. Bureau of the Census

TABLE 2-2
Bandera County Subareas
Population Growth Rates -- 1980-1990

Subarea	Population		Compound Annual Growth Rate (%)
	1980	1990	
A	519	1,323	9.81
B	1,026	1,562	4.29
C	590	632	0.69
D	348	792	8.57
E	1,015	1,034	0.19
F	991	1,722	5.68
G	924	1,313	3.58
H	744	776	0.42
I	707	1,041	3.94
J	220	367	5.25
County	7,084	10,562	4.08
State	14,229,191	16,986,510	1.78

Source: U.S. Bureau of the Census, Block Groups.



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BANDERA COUNTY SUBAREAS

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FIGURE 2-1

generally based on the high projection growth rates lagged 10 years. The exceptions for Subareas C, E, and H are explained and shown in Table 2-3.

The projected population growth rates used in the study (Table 2-4) take into account recent growth within the county, including the large number of platted residential subdivisions (more than 120) readily available for development. The growth rates for the different subareas generally reflect the subdivision locations and potential for development.

Using the subarea population growth rates in Table 2-4, population projections were made for each subarea (Table 2-5 and Figures 2-2 through 2-4). Total low and high population projections for Bandera County are shown in Table 2-6 and Figure 2-5. The Texas Water Development Board (TWDB) projections used in the 1990 Texas Water Plan for Bandera County are also shown in Table 2-6. The TWDB's projections were based on Bandera County's births and deaths, together with net in-migration rates of the 1960's for the low projection, and net in-migration rates of the 1970's for the high projection. The TWDB's low projection compares favorably with the low projection developed for this study. However, the TWDB's high projection is lower than the high projection of this study. The high projection of this study is based upon more recent in-migration data which reflect greater rates than those used in the TWDB projections. These higher rates are supported by school enrollment data (an increase of 35 percent between 1980 and 1988), recent economic development projects such as Bandera Downs, and residential subdivision development in the eastern parts of Bandera County. Thus, the high population projection developed for this study was chosen as a basis for examination of the 50-year water supply

TABLE 2-3
Multipliers for Projecting Population Growth Rates

Subarea	1980-1990	1990-2000		2000-2010		2010-2020		2020-2030		2030-2040	
	Actual	Low	High	Low	High	Low	High	Low	High	Low	High
A	9.81	0.5	0.9	0.3	0.5	0.2	0.3	0.1	0.2	0.1	0.2
B	4.29	0.5	0.9	0.3	0.5	0.2	0.3	0.1	0.2	0.1	0.2
C	0.69	1.0	1.0	0.9	1.0	0.8	0.9	0.4	0.8	0.4	0.8
D	8.57	0.5	0.9	0.3	0.5	0.2	0.3	0.1	0.2	0.1	0.2
E	0.19	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
F	5.68	0.5	0.9	0.3	0.5	0.2	0.3	0.1	0.2	0.1	0.2
G	3.58	0.5	0.9	0.3	0.5	0.2	0.3	0.1	0.2	0.1	0.2
H	0.42	1.0	1.0	0.9	1.0	0.9	0.9	0.5	0.9	0.5	0.8
I	3.94	0.5	0.9	0.3	0.5	0.2	0.3	0.1	0.2	0.1	0.2
J	5.25	0.5	0.9	0.3	0.5	0.2	0.3	0.1	0.2	0.1	0.2

Notes:

1. The values in this table are multiplication factors to determine projected population growth rates. For example, the actual 1980-1990 growth rate for Subarea A is multiplied by 0.5 to obtain the low series projected growth rate for 1990-2000 for Subarea A. The results of the calculations are shown in Table 2-4 - Projected Population Growth Rates.
2. For Subarea E, which is predominately the City of Bandera, the growth rate was held constant at the 1980-1990 rate for both the low and high projections.

The high projection growth rate in Subarea C was held constant at the 1980-1990 rate for two decades (1990-2010) and then reduced to nine-tenths the 1980-1990 rate for the decade 2010-2020 and to eight-tenths the 1980-1990 rate for the period 2020-2040. The low projection growth rate for Subarea C was based on the high rates lagged 10 years (i.e., the rate for the decade of the 1990's is the same as for the 1980's, the rate for 2000-2010 is nine-tenths that of the 1980's, the rate for 2010-2020 is eight-tenths the rate of the 1980's, and the rate for 2020-2040 is set at four-tenths the rate for the 1980's).

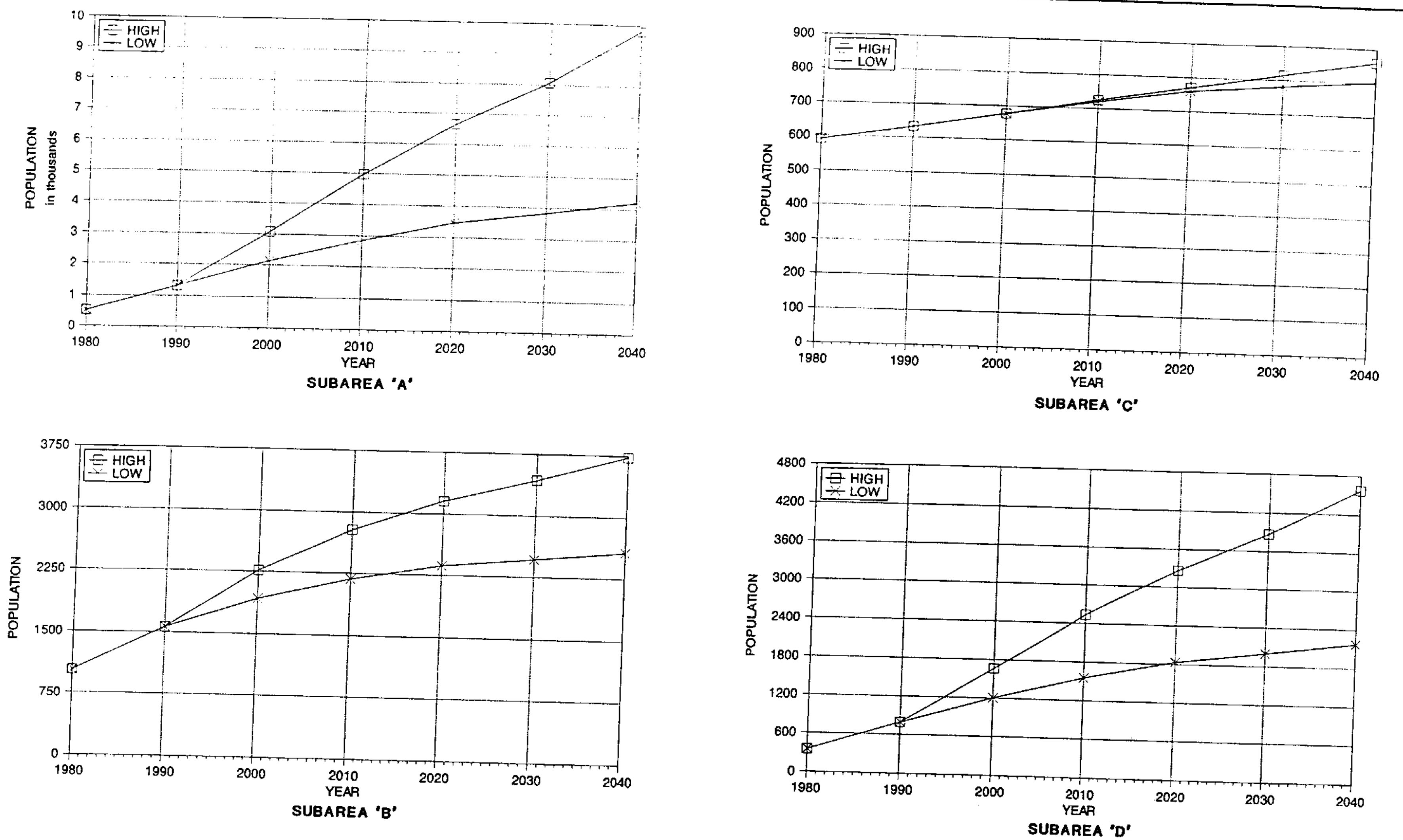
The high projection growth rate for Subarea H was held constant at the 1980-1990 rate for the period 1990-2010, reduced to nine-tenths the 1980-1990 rate for the period 2010-2020, and reduced to eight-tenths the 1980-1990 rate for the decades of 2020-2040. The low projection growth rate for Subarea H was based upon the high rates lagged 10 years; except for the decades 2020-2040, for which the rate was set at one-half the 1980-1990 growth rate.

TABLE 2-4
Projected Population Growth Rates (Compound Annual Percent)

Subarea	1980-1990	1990-2000		2000-2010		2010-2020		2020-2030		2030-2040	
	Actual	Low	High	Low	High	Low	High	Low	High	Low	High
A	9.81	4.91	8.82	2.94	4.91	1.96	2.94	0.98	1.96	0.98	1.96
B	4.29	2.10	3.78	1.26	2.10	0.84	1.26	0.42	0.84	0.42	0.84
C	0.69	0.69	0.69	0.62	0.69	0.55	0.62	0.27	0.55	0.27	0.55
D	8.57	4.28	7.71	2.57	4.28	1.71	2.57	0.85	1.71	0.85	1.71
E	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
F	5.68	2.84	5.11	1.70	2.84	1.14	1.70	0.57	1.14	0.57	1.14
G	3.58	1.72	3.09	1.03	1.72	0.69	1.03	0.34	0.69	0.34	0.69
H	0.42	0.42	0.42	0.38	0.42	0.34	0.38	0.21	0.34	0.21	0.34
I	3.94	1.97	3.54	1.18	1.97	0.79	1.18	0.39	0.79	0.39	0.79
J	5.25	2.62	4.72	1.57	2.62	1.05	1.57	0.52	1.05	0.52	1.05
County	4.08	2.39	4.38	1.56	2.78	1.10	1.79	0.57	1.25	0.57	1.28

TABLE 2-5
Subarea Population Projections

Subarea	1980	1990	2000		2010		2020		2030		2040	
			Low	High	Low	High	Low	High	Low	High	Low	High
A	519	1323	2137	3081	2855	4975	3466	6647	3821	8072	4213	9801
B	1026	1562	1923	2264	2179	2787	2369	3158	2471	3434	2577	3733
C	590	632	677	677	720	725	761	771	782	815	803	861
D	348	792	1204	1665	1552	2531	1839	3262	2001	3865	2178	4579
E	1015	1034	1054	1054	1074	1074	1095	1095	1116	1116	1137	1137
F	991	1722	2279	2834	2697	3751	3021	4439	3197	4972	3384	5569
G	924	1313	1557	1780	1725	2111	1848	2339	1912	2505	1978	2684
H	744	776	809	809	840	844	870	876	888	907	907	938
I	707	1041	1265	1474	1423	1792	1539	2015	1600	2180	1664	2358
J	220	367	475	582	555	754	617	881	649	978	684	1086
County	7084	10562	13380	16220	15621	21343	17424	25484	18437	28842	19524	32745
TWDB			13277	14837	15395	19748	16689	21851	17779	23295	18351	24054



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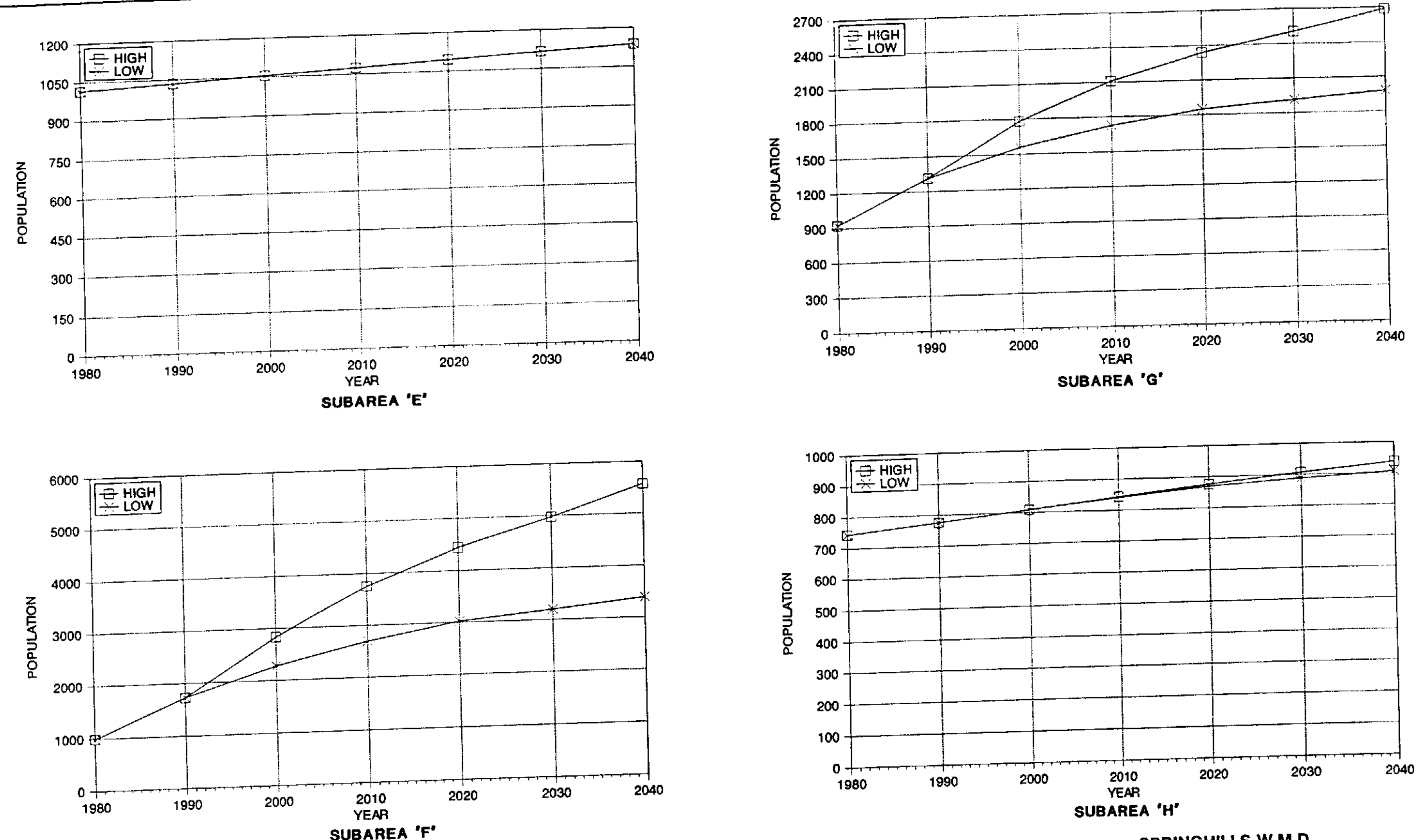
SUBAREA POPULATION PROJECTIONS HIGH AND LOW SERIES

FIGURE 2-2



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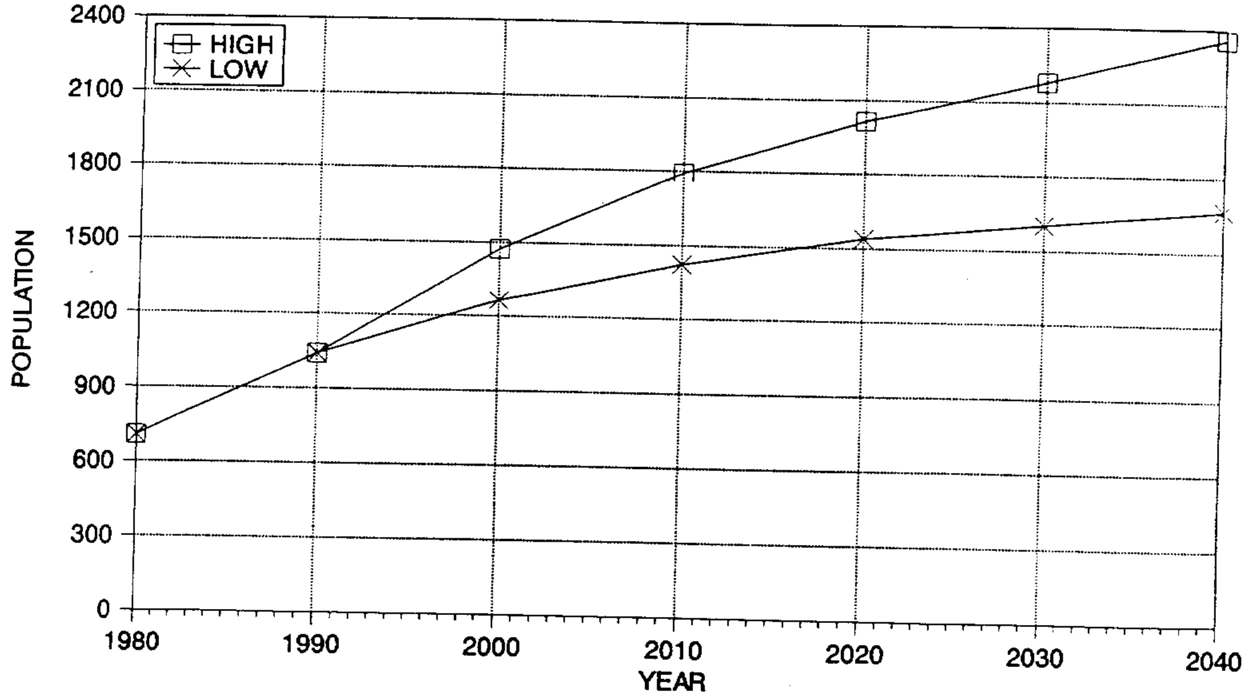
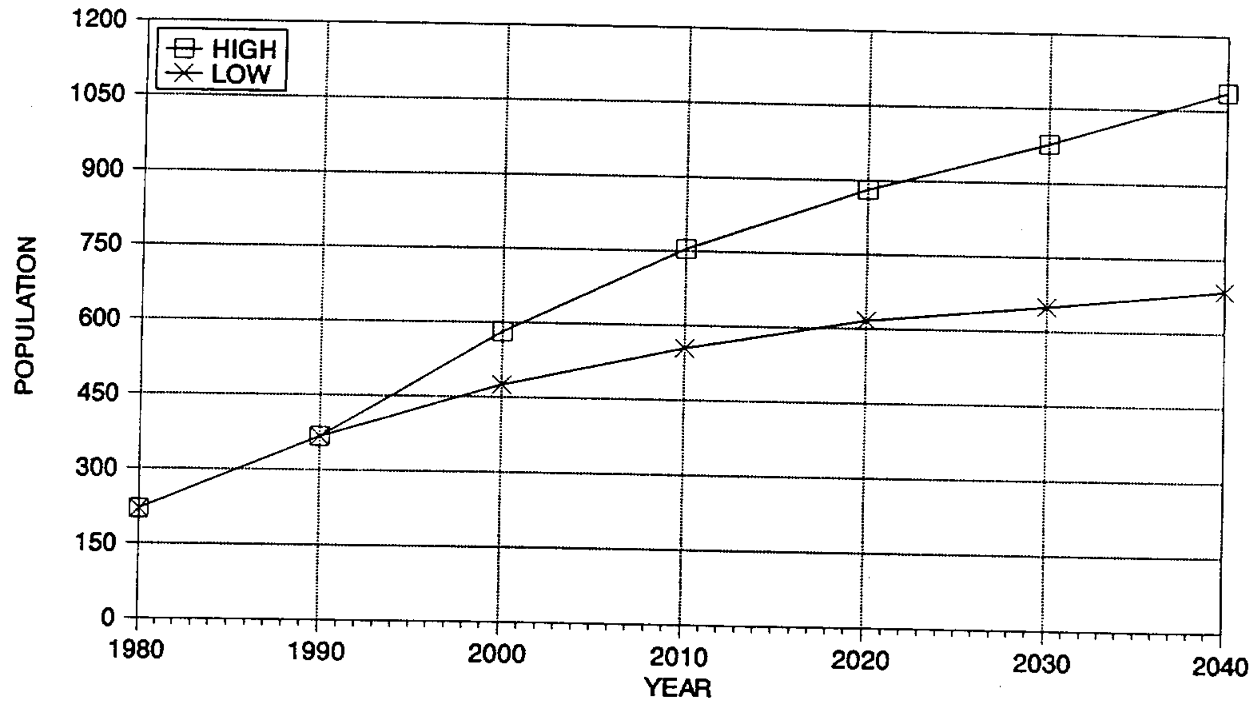
SUBAREA POPULATION PROJECTIONS HIGH AND LOW SERIES

FIGURE 2-3



SUBAREA 'I'



SUBAREA 'J'

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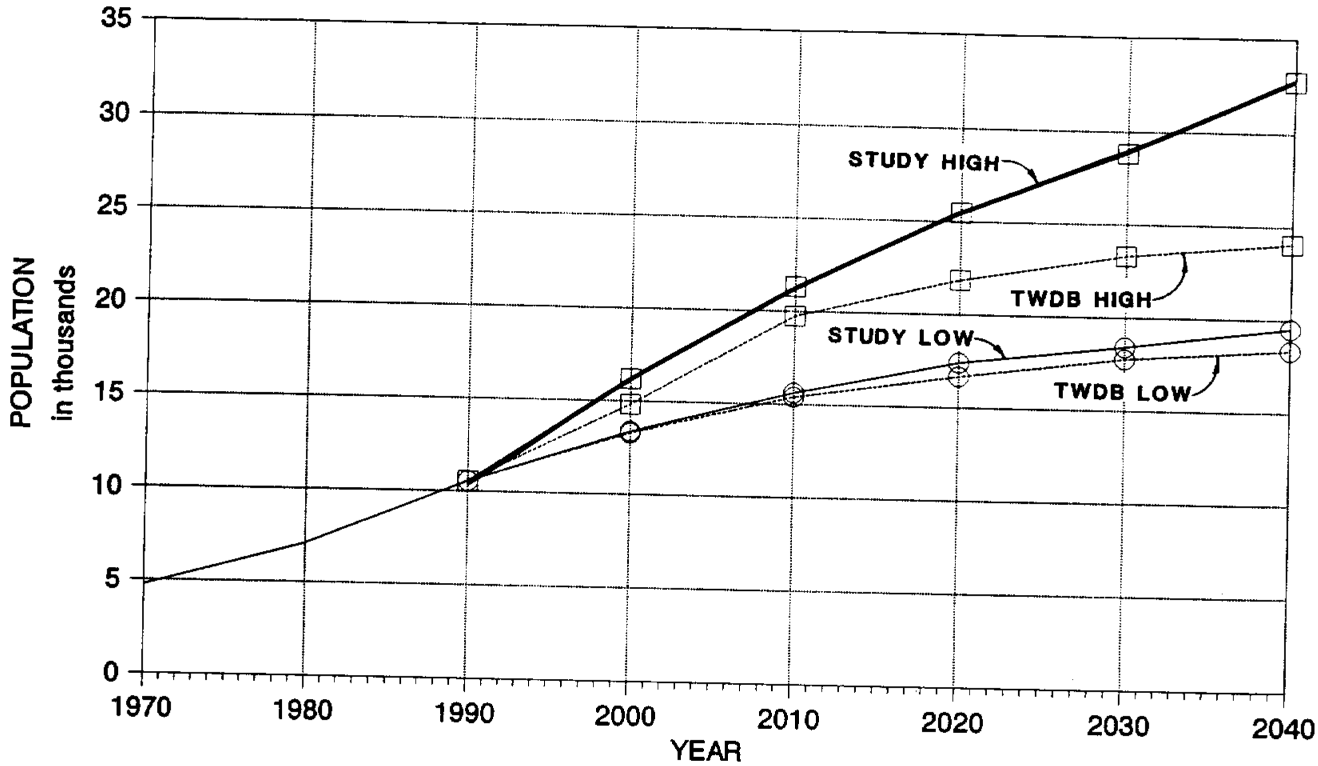
SUBAREA POPULATION PROJECTIONS HIGH AND LOW SERIES

FIGURE 2-4

TABLE 2-6 Bandera County Population Projections				
Year	Texas Water Development Board		Springhills WMD Regional Water Supply Study	
	Low	High	Low	High
1970	4,747	4,747	4,747	4,747
1980	7,084	7,084	7,084	7,084
1990	10,562	10,562	10,562	10,562
2000	13,277	14,837	13,380	16,220
2010	15,395	19,748	15,621	21,343
2020	16,689	21,851	17,424	25,484
2030	17,779	23,295	18,437	28,842
2040	18,351	24,054	19,524	32,745

planning needs of the county. Figure 2-6 shows the 1990 and 2040 projected populations for each subarea and the total county.



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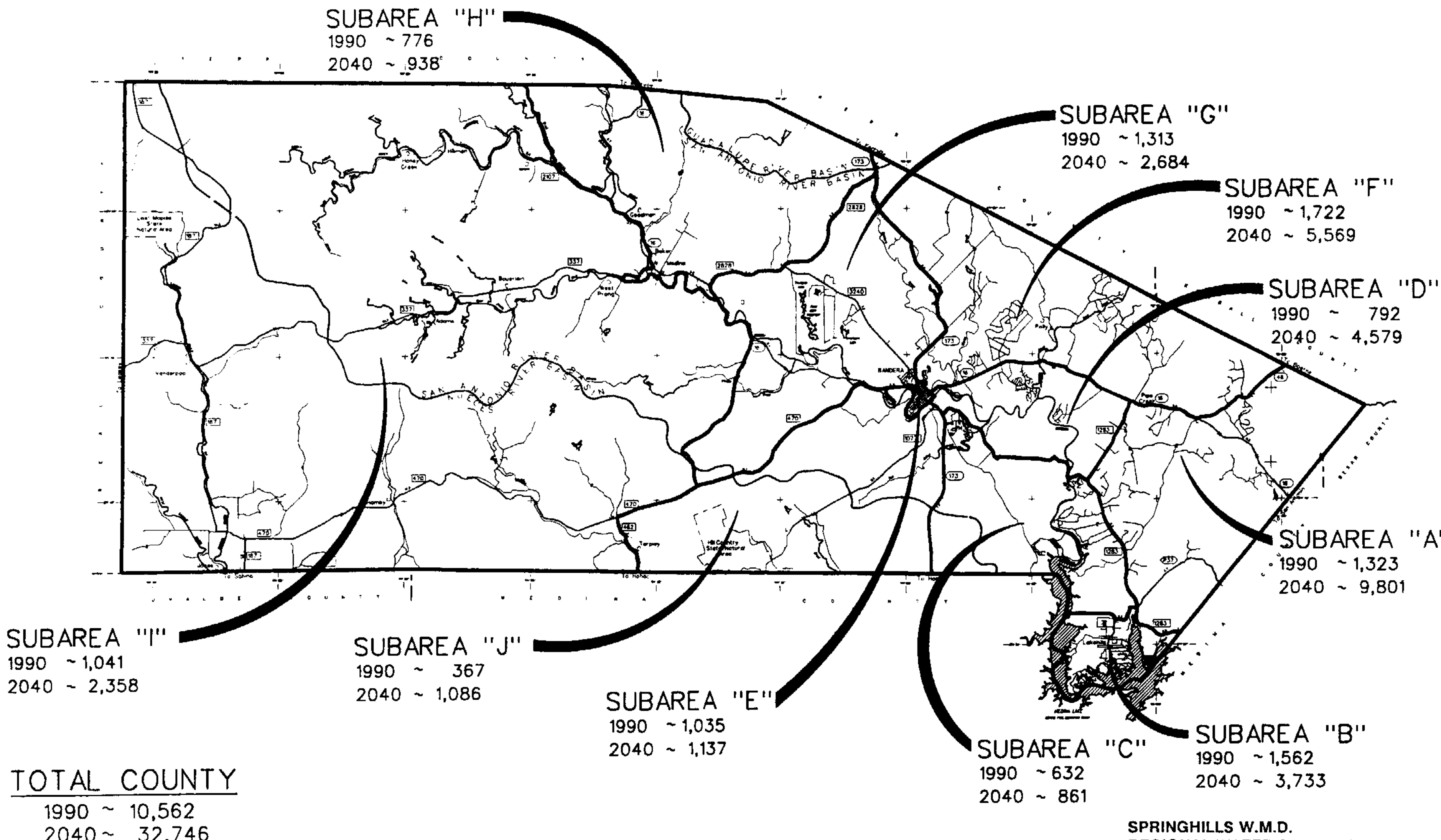
**BANDERA COUNTY
POPULATION PROJECTIONS
HIGH AND LOW SERIES**

FIGURE 2-5



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1990 AND 2040 PROJECTED POPULATIONS BY SUBAREA

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FIGURE 2-6

SECTION 3

3.0 WATER USE PROJECTIONS

3.1 Per Capita Water Use

The quantity of water needed by the population of an area depends on both the number of people who live there and the number of gallons each person uses per day (commonly referred to as per capita water use). In this section, information about per capita water use is presented, along with water conservation goals which affect per capita water use (see Table 3-1 which compares per capita water use in the study area with neighboring cities and the state average).

In the 1990 Texas Water Plan, the TWDB established a water conservation goal of reducing per capita water use in Texas by 15 percent by 2020. In the Texas Water Plan, this goal would be achieved by reducing per capita water use five percent per decade between 1990 and 2020.

Per capita water use under average conditions in the City of Bandera between 1977 and 1986 was 156 gallons per person per day, which is 94 percent of the statewide average of 165 gallons per person per day. This rate is also one of the lowest compared to neighboring cities. (1977-1986 period was used as the base period in the 1990 Texas Water Plan.) Therefore, because Bandera's rate is already less than the statewide average, it is recommended that the water conservation goal for this study be established at 10 percent reduction in per capita water use for the City of Bandera (rather than 15 percent), to be phased in at five percent per decade between 1990 and 2010. This results in ultimate water use rates for the City of Bandera (Subarea E) of 140 gallons per person per day for average conditions and 161 gallons per person per day for drought conditions.

TABLE 3-1 Per Capita Water Use for Bandera, Neighboring Cities, and Statewide*		
	Without Conservation	
City	**Average Use**	**Drought Use**
Converse	130	165
Devine	155	179
Bandera	**156**	**179**
Rock Springs	158	190
Boerne	162	182
Statewide	**165**	**194**
Blanco	166	191
Kerrville	179	197
San Antonio	185	208
Sabinal	203	246
Hondo	233	291
Uvalde	267	302
Castroville	284	320
State Rural	**110**	**130**
Bandera Rural	**112**	**133**

*Source: Texas Water Development Board water planning data. Average use is for 1977-1986. Drought use is for four driest years of the 1977-1986 period.

It is further recommended that per capita water use goals for the rural subareas (C, G, H, I, and J) of Bandera County be set at 110 gallons per person per day for average conditions and 130 gallons per person per day for drought conditions. These are the rates used by the TWDB for rural areas in the 1990 Texas Water Plan, and are nearly identical to existing rural water use rates in the county. For the rural areas, water use rates would be held constant through the 50-year planning period, and water conservation programs would be implemented to keep per capita water use rates from rising as development occurs and the subareas take on the characteristics of urban communities, which typically exhibit higher per capita water use than rural areas.

For the rapidly growing subareas (A, B, D, and F) of Bandera County, per capita water use can be expected to increase in comparison to the historic rural levels as public water systems are developed and the communities become more urban in their water-using characteristics. For example, additional water will be needed for fire protection, sanitation, landscaping, and commercial establishments. For these rapidly growing subareas, it is recommended that per capita water use goals be established at the ultimate conservation rates of the City of Bandera. This recommendation is based on the idea that efficient plumbing fixtures will be installed in new homes, native plants will be used in landscaping, and a water conservation rate structure will be established.

The differences in per capita water use with and without water conservation are shown in Table 3-2. Projected per capita drought water use rates, with conservation, are recommended for use in projecting the future water requirements for each subarea in the county.

3.2 Projected Water Requirements

The major types of water use in Bandera County are (1) municipal and commercial, (2) irrigation, and (3) livestock watering. Each of these is described, and low and high projections of future water requirements are presented in the following subsections. All water use projections consider the potential for water conservation programs to increase the efficiency of water use and reduce the total requirements for a given population. The water conservation plan is presented in Appendix A.

TABLE 3-2
Projections of Per Capita Water Use for Average and Drought Conditions, Without and With Conservation

Sub-Area	1990		2000				2010				2020				2030				2040			
	Base		Without Conserv.		With Conserv.		Without Conserv.		With Conserv.		Without Conserv.		With Conserv.		Without Conserv.		With Conserv.		Without Conserv.		With Conserv.	
	Avg	Dry	Avg	Dry	Avg	Dry	Avg	Dry	Avg	Dry	Avg	Dry	Avg	Dry	Avg	Dry	Avg	Dry	Avg	Dry	Avg	Dry
A	110	130	156	179	140	161	156	179	140	161	156	179	140	161	156	179	140	161	156	179	140	161
B	110	130	156	179	140	161	156	179	140	161	156	179	140	161	156	179	140	161	156	179	140	161
C	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130
D	110	130	156	179	140	161	156	179	140	161	156	179	140	161	156	179	140	161	156	179	140	161
E	156	179	156	179	148	170	156	179	140	161	156	179	140	161	156	179	140	161	156	179	140	161
F	110	130	156	179	140	161	156	179	140	161	156	179	140	161	156	179	140	161	156	179	140	161
G	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130
H	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130
I	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130
J	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130	110	130

Conserv. = Conservation   Avg = Average per capita water use.   Dry = Drought per capita water use.

3.2.1 Municipal Water Use Projections

Municipal water includes water used in homes for drinking, bathing, flushing toilets, food preparation, dish washing, laundering, lawn watering, air conditioning, swimming pools, fire protection, public fountains, car washing, restaurants, public buildings, offices, street washing, and other sanitation and aesthetic purposes. In 1980, municipal water use within Bandera County was 925 acre-feet (one acre-foot is 325,851 gallons) and was projected to be 1,355 acre-feet in 1990[1]. Projected low and high municipal water requirements for each subarea were computed by multiplying the projected subarea population (Table 2-5) times the per capita water use (Table 3-2). The projections for each subarea, and the totals for Bandera County are shown in Table 3-3. Municipal water use in the county is projected to range between 1,947 acre-feet per year in 2000 for the low population projection at average per capita water use (with conservation) to 5,629 acre-feet per year in 2040 for the high population projection with drought per capita water use (with conservation).

3.2.2 Irrigation Water Use Projections

Since the 1960's, irrigated acreage in Bandera County has ranged from a high of 318 acres in 1969 to a low of 127 acres in 1974.[2] Irrigation water use was 95 acre-feet in 1974 and 532 acre-feet in 1979, two-thirds of which was supplied by surface water and one-third

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[1]Unpublished planning data, Texas Water Development Board, Austin, Texas, October, 1989.

[2]"Surveys of Irrigation in Texas: 1958, 1964, 1969, 1974, 1979, and 1984," Report 294, Texas Water Development Board, Austin, Texas, August, 1986.

TABLE 3-3
Projected Municipal Water Requirements for Average and Drought Conditions Without and With Conservation
(Acre-Feet Per Year)

SUB AREA	1980	1990	2000 LOW POPULATION WITHOUT CONS. AVG	2000 LOW POPULATION WITHOUT CONS. DRY	2000 LOW POPULATION WITH CONS. AVG	2000 LOW POPULATION WITH CONS. DRY	2000 HIGH POPULATION WITHOUT CONS. AVG	2000 HIGH POPULATION WITHOUT CONS. DRY	2000 HIGH POPULATION WITH CONS. AVG	2000 HIGH POPULATION WITH CONS. DRY	2010 LOW POPULATION WITHOUT CONS. AVG	2010 LOW POPULATION WITHOUT CONS. DRY	2010 LOW POPULATION WITH CONS. AVG	2010 LOW POPULATION WITH CONS. DRY	2010 HIGH POPULATION WITHOUT CONS. AVG	2010 HIGH POPULATION WITHOUT CONS. DRY	2010 HIGH POPULATION WITH CONS. AVG	2010 HIGH POPULATION WITH CONS. DRY
A	64	163	373	428	335	385	538	618	483	555	499	572	448	515	869	997	780	897
B	126	192	336	385	301	347	396	454	355	408	381	437	342	393	487	559	437	502
C	73	78	83	99	83	99	83	99	83	99	89	105	89	105	89	106	89	106
D	43	98	210	241	189	217	291	334	261	300	271	311	243	280	442	507	397	456
E	177	181	184	211	175	201	184	211	175	201	188	215	168	194	188	215	168	194
F	122	212	398	457	357	411	495	568	444	511	471	541	423	436	655	752	588	676
G	114	162	192	229	192	227	219	259	219	259	213	251	213	251	260	307	260	307
H	92	96	100	118	100	118	100	118	100	118	104	122	104	122	104	123	104	123
I	87	128	156	184	156	184	182	215	182	215	175	207	175	207	221	261	221	261
J	27	45	59	69	59	69	72	85	72	85	68	81	68	81	93	110	93	110
TOTAL	925	1355	2091	2421	1947	2258	2560	2961	2374	2751	2459	2842	2273	2584	3408	3937	3137	3632

SUB AREA	2020 LOW POPULATION WITHOUT CONS. AVG	2020 LOW POPULATION WITHOUT CONS. DRY	2020 LOW POPULATION WITH CONS. AVG	2020 LOW POPULATION WITH CONS. DRY	2020 HIGH POPULATION WITHOUT CONS. AVG	2020 HIGH POPULATION WITHOUT CONS. DRY	2020 HIGH POPULATION WITH CONS. AVG	2020 HIGH POPULATION WITH CONS. DRY
A	606	695	544	625	1161	1333	1042	1199
B	414	475	372	427	552	633	495	569
C	94	111	94	111	95	112	95	112
D	321	369	288	332	570	654	511	588
E	191	219	172	197	191	219	172	197
F	528	606	474	545	776	890	696	800
G	228	269	228	269	288	341	288	341
H	107	127	107	127	108	128	108	128
I	190	224	190	224	248	293	248	293
J	76	90	76	90	109	128	109	128
TOTAL	2755	3185	2545	2947	4098	4731	3764	4355

SUB AREA	1980	1990	2030 LOW POPULATION WITHOUT CONS. AVG	2030 LOW POPULATION WITHOUT CONS. DRY	2030 LOW POPULATION WITH CONS. AVG	2030 LOW POPULATION WITH CONS. DRY	2030 HIGH POPULATION WITHOUT CONS. AVG	2030 HIGH POPULATION WITHOUT CONS. DRY	2030 HIGH POPULATION WITH CONS. AVG	2030 HIGH POPULATION WITH CONS. DRY	2040 LOW POPULATION WITHOUT CONS. AVG	2040 LOW POPULATION WITHOUT CONS. DRY	2040 LOW POPULATION WITH CONS. AVG	2040 LOW POPULATION WITH CONS. DRY	2040 HIGH POPULATION WITHOUT CONS. AVG	2040 HIGH POPULATION WITHOUT CONS. DRY	2040 HIGH POPULATION WITH CONS. AVG	2040 HIGH POPULATION WITH CONS. DRY
A	64	163	668	766	599	689	1410	1618	1266	1455	736	845	661	760	1712	1965	1537	1767
B	126	192	432	495	387	446	600	688	538	619	450	517	404	465	652	748	585	673
C	73	78	96	114	96	114	100	119	100	119	99	117	99	117	106	125	106	125
D	43	98	350	401	314	361	675	775	606	697	381	437	342	393	800	918	718	826
E	177	181	195	224	175	201	195	224	175	201	199	238	178	205	199	228	178	205
F	122	212	559	641	501	577	869	997	780	897	591	678	531	610	973	1116	873	1004
G	114	162	236	278	236	278	309	365	309	365	244	288	244	288	331	391	331	391
H	92	96	109	129	109	129	112	132	112	132	112	132	112	132	116	137	116	137
I	87	128	108	233	197	233	269	317	269	317	205	242	205	242	291	343	291	343
J	27	45	80	95	80	95	120	142	120	142	84	100	84	100	134	158	134	158
TOTAL	925	1355	2922	3376	2694	3123	4659	5377	4275	4944	3101	3594	2860	3312	5314	6129	4869	5629

Cons = Conservation Avg = Average Dry = Drought by groundwater (wells).[3] Until recently, Bandera County irrigation was primarily for the production of forage for livestock. However, in recent years, apple (dwarf trees of popular varieties) and pecan orchards have been planted in the Medina area (Subareas G, H, and I). Representatives of the agricultural businesses expect acreages of orchards, particularly apples, and forage production for the developing horse racing industries to increase in the immediate future. It is expected that these industries will obtain irrigation water from locally available ground and surface water sources.

The apple orchards use water from both the shallow and deep aquifers for drip irrigation. Pecan orchards and forage crops are irrigated with both surface water and groundwater using sprinkler application methods. The irrigation application rate for apples is estimated at 1.5 acre-feet per acre per year, depending upon the amounts and timeliness of rainfall during the spring and summer months. Application rates for forage crops are approximately 1.5 acre-feet per acre per year, and application rates for pecans are approximately 4.0 acre-feet per acre per year. The application rates and irrigation methods used in Bandera County are considered to include conservation practices. Thus, the low and high irrigation water use projections are for low and high acreage projections of each crop, as opposed to with and without water conservation, (i.e., the conservation effect is included in the application rate).

The irrigation water use estimates for 1991 and projections of water requirements for future years are based on the subarea location relative to existing irrigation surface water

[3]Ibid.

rights.[4] The permitted irrigation diversions in the county total 1,592 acre-feet annually to irrigate 1,270 acres. Estimates of irrigated acreages within each subarea are shown in Table 3-4. Presently, it is estimated that 300 acres of forage crops, 70 acres of apple orchards, and 130 acres of pecans are irrigated in Bandera County. Irrigation water use projections assume acreages of forage will range between 289 and 330; acreages of apple orchards will range between 105 and 270; and acreages of pecans will range between 130 and 160 (Table 3-4). Based on these assumptions, projected irrigation water requirements for Bandera County could increase from historic levels of 400 to 532 acre-feet per year to 1,129 to 1,383 acre-feet per year in 2000 and 1,202 to 1,522 acre-feet per year during the 2010 to 2040 period (Table 3-5). The ultimate level of irrigation water use will depend on the profitability of orchards and the market for forage.

3.2.3 Livestock Water Use Projections

Water for livestock drinking and sanitation in the county is obtained from stock watering tanks and wells. In 1980, it was estimated that total livestock water use was 376 acre-feet.[5] The principal types of livestock produced in the county are beef, sheep, goats, poultry, and horses. Projections of future water requirements for livestock were calculated

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[4]Note: Texas Water Plan projections of Irrigation and Livestock Water use for Bandera County were made prior to recent developments of orchards and horse racing in Bandera County. The water plan irrigation projections are used in this study for forage production, and the livestock water projections of the water plan are used as the low projection for livestock water requirements. Separate projections of high irrigation and livestock water use were made based upon recent information about irrigation and livestock developments within Bandera County. It should be further noted that Texas Water Plan projections are for the entire county. For this study, projections were made for Subareas and the County.

[5]Unpublished planning data, Texas Water Development Board, Austin, Texas, October, 1989.

TABLE 3-4
Projected Irrigation Acreages by Subarea*

Subarea	1991			2000						2010-2040					
				Forage**		Apples		Pecans		Forage**		Apples		Pecans	
	Forage	Apples	Pecans	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	10	0	0	10	11	0	0	0	0	10	11	0	0	0	0
D	18	0	0	18	20	0	0	0	0	18	20	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	9	10	0	9	10	15	30	0	0	9	10	30	45	0	0
H	12	20	0	12	13	30	45	0	0	0	0	45	75	0	0
I	240	40	130	240	263	60	90	130	160	240	263	90	150	130	160
J	12	0	0	12	13	0	0	0	0	12	13	0	0	0	0
Total	301	70	130	301	330	105	165	130	160	289	317	165	270	130	160

* Estimates are based upon interviews with local representatives of the agricultural industries.
** Unpublished water planning data, Texas Water Development Board, Austin, Texas, October, 1989.

TABLE 3-5
Projected Irrigation Water Requirements*
(Acre-Feet Per Year)

Subarea	1991	2000		2010		2020		2030		2040	
		Low	High	Low	High	Low	High	Low	High	Low	High
A	0	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0	0	0	0
C	15	15	16	15	16	15	16	15	16	15	16
D	27	27	30	27	30	27	30	27	30	27	30
E	0	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0	0	0	0
G	28	36	60	59	83	59	83	59	83	59	83
H	48	63	87	68	113	68	113	68	113	68	113
I	940	970	1170	1015	1260	1015	1260	1015	1260	1015	1260
J	18	18	20	18	20	18	20	18	20	18	20
Total	1076	1129	1383	1202	1522	1202	1522	1202	1522	1202	1522

*Irrigation application rates:
Forage 1.5 acre-feet per acre.
Apples 1.5 acre-feet per acre.
Pecans 4.0 acre-feet per acre.

on the basis of the expected numbers of each type, and the number of gallons of water needed per day (Table 3-6).

TABLE 3-6
Bandera County Livestock Numbers and Water Requirements

Livestock	Number		Gallons Per Head Per Day*
	Low	High	
Beef Cattle	24,900	32,600	15.00
Sheep	7,000	8,000	0.75
Goats	6,000	7,000	0.50
Poultry (thousands)	10	12	30.00
Horses	585	2,485	20.00

*Source: "The Importance of Evaluating Livestock Water," The Texas Agricultural Extension Service, The Texas A&M University System, MP-1157, College Station, Texas. 1976.

It should be noted that the quantity of livestock water (gallons per head per day) is the minimum quantity needed for drinking and sanitation purposes and does not lend itself to water conservation practices. Thus, the low and high livestock water requirements projections are based upon low and high projections of livestock numbers, as opposed to without and with water conservation.

The projected livestock water use was distributed among the subareas in proportion to the size of each subarea relative to the total area of the county, except that no livestock water was included for the City of Bandera (Subarea E). A further exception was that the projected increase in numbers of horses (1,900) was allocated 47 percent to Subarea F (location of Bandera Downs), 16 percent to Subarea I, eight percent each to Subareas G, H, and J, five percent each to Subareas C and D, and 2.5 percent to Subarea A. The projected livestock water requirements range from a low of 506 acre-feet per year to a high of 548 acre-feet per year throughout the planning period (Table 3-7). It should be recognized that livestock water requirements, although extremely important in the total projected water demand for Bandera County, will likely be met from sources coincident with or very near to the lands on which the livestock graze. The major exception to this is for the horse racing industry, which will require water at stables and the racetrack locations. For these purposes, it may be necessary to develop water supply systems to serve more concentrated areas than are generally required for range livestock.

3.2.4 Recreation Water Use

Recreation water use in Bandera County is mainly for small recreation lakes and water-oriented activities at Medina Lake. For the most part, recreation is a by-product of other water use functions, and although it is recognized as an important part of the county economy, it was not considered necessary to make projections of recreation water requirements in this study.

3.2.5 Total Water Use Projections

In Sections 3.2.1, 3.2.2, and 3.2.3, projections of water needed during the 50-year planning period have been presented for: (1) municipal purposes, (2) irrigation of forage and orchard crops, and (3) livestock watering, respectively. These separate water use projections were summed to obtain the total projected water requirement for each subarea and the county (Table 3-8).

TABLE 3-7
Projected Livestock Water Requirements*
(Acre-Feet Per Year)

Subarea	1991	2000		2010		2020		2030		2040	
		Low	High	Low	High	Low	High	Low	High	Low	High
A	31	36	37	36	37	36	37	36	37	36	37
B	4	5	5	5	5	5	5	5	5	5	5
C	22	25	27	25	27	25	27	25	27	25	27
D	13	15	17	15	17	15	17	15	17	15	17
E**	0	0	0	0	0	0	0	0	0	0	0
F***	40	46	66	46	66	46	66	46	66	46	66
G	31	36	39	36	39	36	39	36	39	36	39
H	40	46	49	46	49	46	49	46	49	46	49
I	224	257	264	257	264	257	264	257	264	257	264
J	35	40	44	40	44	40	44	40	44	40	44
Total****	440	506	548	506	548	506	548	506	548	506	548

* Water conservation for livestock can only be achieved through the control of livestock numbers, since the quantities per head are required for drinking and sanitation.

** The City of Bandera occupies more than 95 percent of this subarea, thus no livestock water is included.

*** Bandera Downs racetrack and stables located in subarea F.

**** Low projection is from unpublished water planning data, Texas Water Development Board, Austin, Texas, October, 1989.

TABLE 3-8
Projected Total Water Requirements for Average and Drought Conditions Without and With Conservation
(Acre-Feet Per Year)

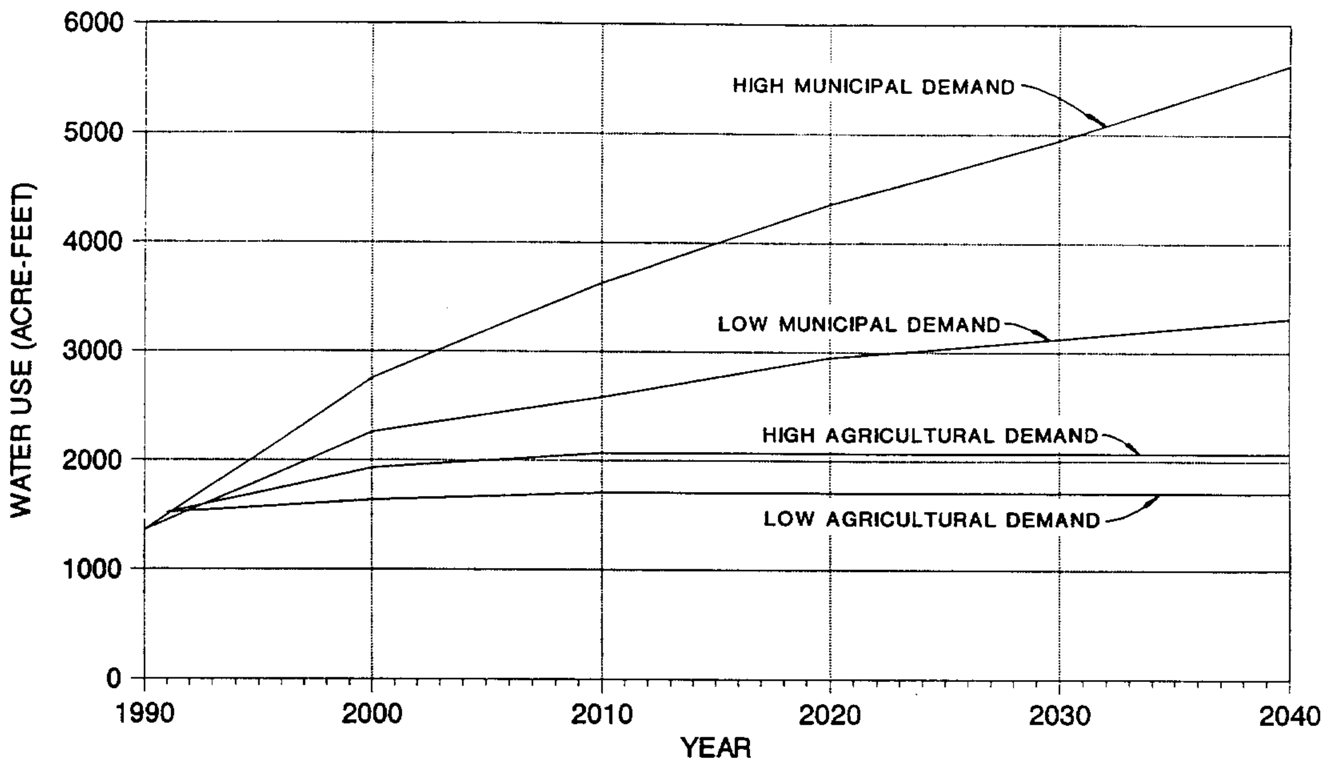
		2000								2010								2020							
		LOW POPULATION				HIGH POPULATION				LOW POPULATION				HIGH POPULATION				LOW POPULATION				HIGH POPULATION			
		WITHOUT CONS.		WITH CONS.		WITHOUT CONS.		WITH CONS.		WITHOUT CONS.		WITH CONS.		WITHOUT CONS.		WITH CONS.		WITHOUT CONS.		WITH CONS.		WITHOUT CONS.		WITH CONS.	
SUB AREA	1991*	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY
A	194	409	464	371	421	575	655	520	592	535	608	484	551	906	1034	817	934	642	731	580	661	1198	1370	1079	1236
B	196	341	390	306	352	401	459	360	413	386	442	347	398	492	564	442	507	419	480	377	432	557	638	500	574
C	115	123	139	123	139	126	142	126	142	129	145	129	145	132	149	132	149	134	151	134	151	138	155	138	155
D	138	252	283	231	259	338	381	308	347	313	353	285	322	489	554	444	503	363	411	330	374	617	701	558	635
E	181	184	211	175	201	184	211	175	201	188	215	168	194	188	215	168	194	191	219	172	197	191	219	172	197
F	252	444	503	403	457	561	634	510	577	517	587	469	482	721	818	654	742	574	652	520	591	842	956	762	866
G	221	264	301	264	299	318	358	318	358	308	346	308	346	382	429	382	429	323	364	323	364	410	463	410	463
H	184	209	227	209	227	236	254	236	254	218	236	218	236	266	285	266	285	221	241	221	241	270	290	270	290
I	1292	1383	1411	1383	1411	1616	1649	1616	1649	1447	1479	1447	1479	1745	1785	1745	1785	1462	1496	1462	1496	1772	1817	1772	1817
J	98	117	127	117	127	136	149	136	149	126	139	126	139	157	174	157	174	134	148	134	148	173	192	173	192
TOTAL	2871	3726	4056	3582	3893	4491	4892	4305	4682	4167	4550	3981	4292	5478	6007	5207	5702	4463	4893	4253	4655	6168	6801	5834	6425

		2030								2040							
		LOW POPULATION				HIGH POPULATION				LOW POPULATION				HIGH POPULATION			
		WITHOUT CONS.		WITH CONS.		WITHOUT CONS.		WITH CONS.		WITHOUT CONS.		WITH CONS.		WITHOUT CONS.		WITH CONS.	
SUB AREA	1991*	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY	AVG	DRY
A	194	704	802	635	725	1447	1655	1303	1492	772	881	697	796	1749	2002	1574	1804
B	196	437	500	392	451	605	693	543	624	455	522	409	470	657	753	590	678
C	115	136	154	136	154	143	162	143	162	139	157	139	157	149	168	149	168
D	138	392	443	356	403	722	822	653	744	423	479	384	435	847	965	765	873
E	181	195	224	175	201	195	224	175	201	199	238	178	205	199	228	178	205
F	252	605	687	547	623	935	1063	846	963	637	724	577	656	1039	1182	939	1070
G	221	331	373	331	373	431	487	431	487	339	383	339	383	453	513	453	513
H	184	223	243	223	243	274	294	274	294	226	246	226	246	278	299	278	299
I	1292	1469	1505	1469	1505	1793	1841	1793	1841	1477	1514	1477	1514	1815	1867	1815	1867
J	98	138	153	138	153	184	206	184	206	142	158	142	158	198	222	198	222
TOTAL	2871	4630	5084	4402	4831	6729	7447	6345	7014	4809	5302	4568	5020	7384	8199	6939	7699

Cons = Conservation Avg = Average Dry = Drought

*Values in this column are 1990 municipal water use, with estimates of 1991 water use for irrigation and livestock.

Total water requirements for the county are projected to increase from 2,871 acre-feet per year in 1991 to a range of 3,582 to 4,892 acre-feet per year in 2000; 4,253 to 6,801 acre-feet per year in 2020; and 4,568 to 8,199 acre-feet per year in 2040, depending on growth rates, water use rates, and the success of a water conservation program. For purposes of this study, which is primarily to address the water supply needs of the area, the recommended municipal water use scenario is the high series population projection, with conservation, and drought water use conditions. The recommended agricultural water use scenario is the sum of the high projections for irrigation and livestock watering. Figure 3-1 shows the low and high ranges for municipal and agricultural water use. The municipal water use values shown in the figure assume drought water use conditions with conservation practices implemented.



NOTE: PROJECTIONS ARE FOR DROUGHT WATER USE CONDITIONS WITH CONSERVATION.

SPRINGHILLS W.M.D.
REGIONAL WATER SUPPLY STUDY

BANDERA COUNTY
WATER USE PROJECTIONS

HDR

HDR Engineering, Inc.

FIGURE 3-1

SECTION 4

4.0 EXISTING WATER RESOURCES

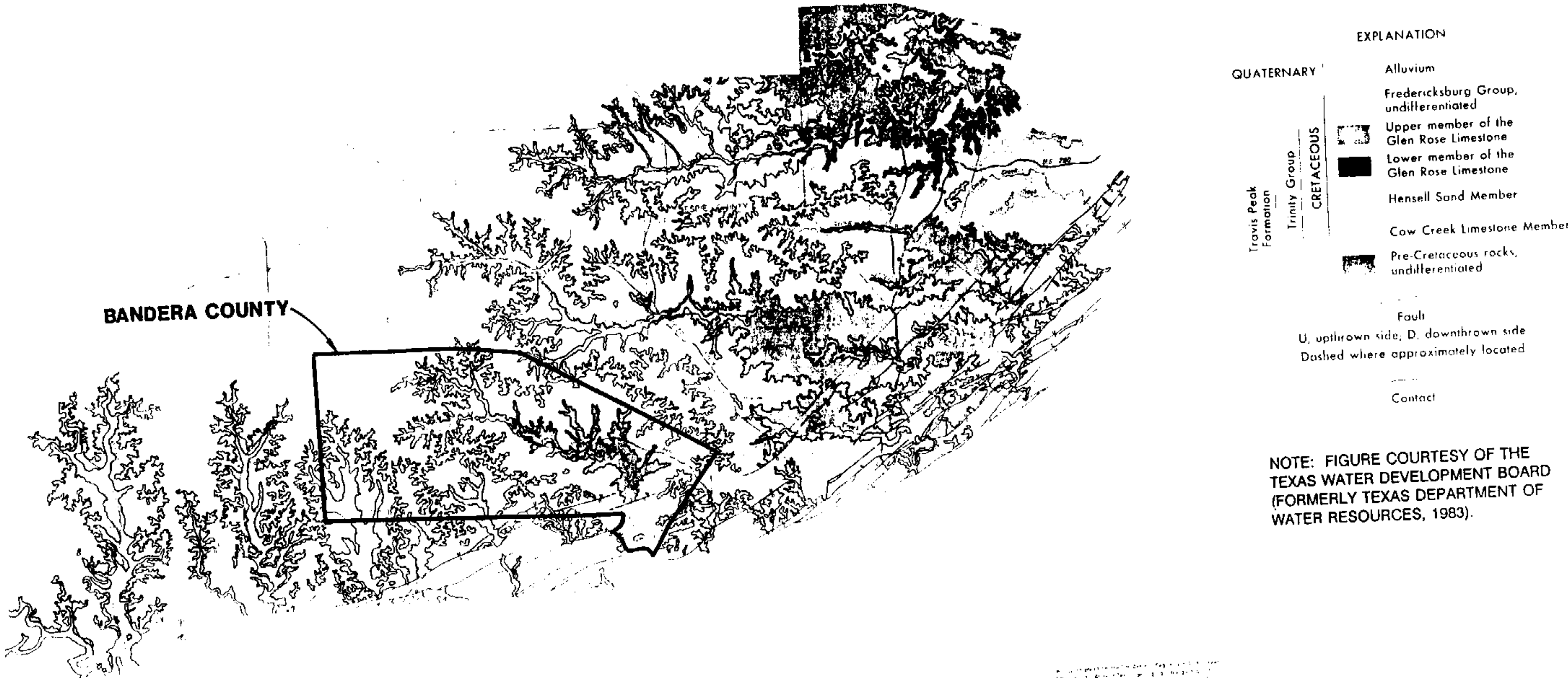
4.1 Background

Bandera County lies in an area of the state which includes portions of three major river basins and overlies four major aquifer systems. Virtually all of the county's municipal demand is served by groundwater, with only a very small fraction served by surface water sources. Although the county contains portions of three major river basins, most of the surface water within these basins has been allocated to water rights downstream of Bandera County. This section of the report describes the existing groundwater and surface water resources in the county, and discusses the availability and quality of each of these sources.

4.2 Groundwater Resources

Bandera County is located in the Hill Country area of south-central Texas (Figure 4-1). This region, which includes all or parts of Bandera, Bexar, Blanco, Comal, Gillespie, Hays, Kerr, Kendall, and Travis counties, receives groundwater from the Edwards Plateau Aquifer and the Trinity Group Aquifer. The 10-county region receives average annual rainfall amounts ranging from 24 inches in the western counties to 33 inches in the eastern counties, which equates to a volume of approximately 9.0 million acre-feet of average annual rainfall. Only 450,000 acre-feet (five percent) of this total rainfall volume is estimated to be available as recharge to the various aquifers by infiltration and seepage of stream flow in the outcrop areas.[1] Much of the recharge received by the aquifers is discharged as spring flow, which provides a large part of the base flow to the area's rivers and streams. Only a

[1] Texas Water Development Board, "Evaluation of the Groundwater Resources of the Paleozoic and Cretaceous Aquifers in the Hill Country of Central Texas," October, 1990 (Manuscript Draft).



NOTE: FIGURE COURTESY OF THE TEXAS WATER DEVELOPMENT BOARD (FORMERLY TEXAS DEPARTMENT OF WATER RESOURCES, 1983).

SPRINGHILLS W.M.D.
REGIONAL WATER SUPPLY STUDY

GEOLOGIC MAP-BANDERA COUNTY AND SURROUNDING HILL COUNTRY

HDR

HDR Engineering, Inc.

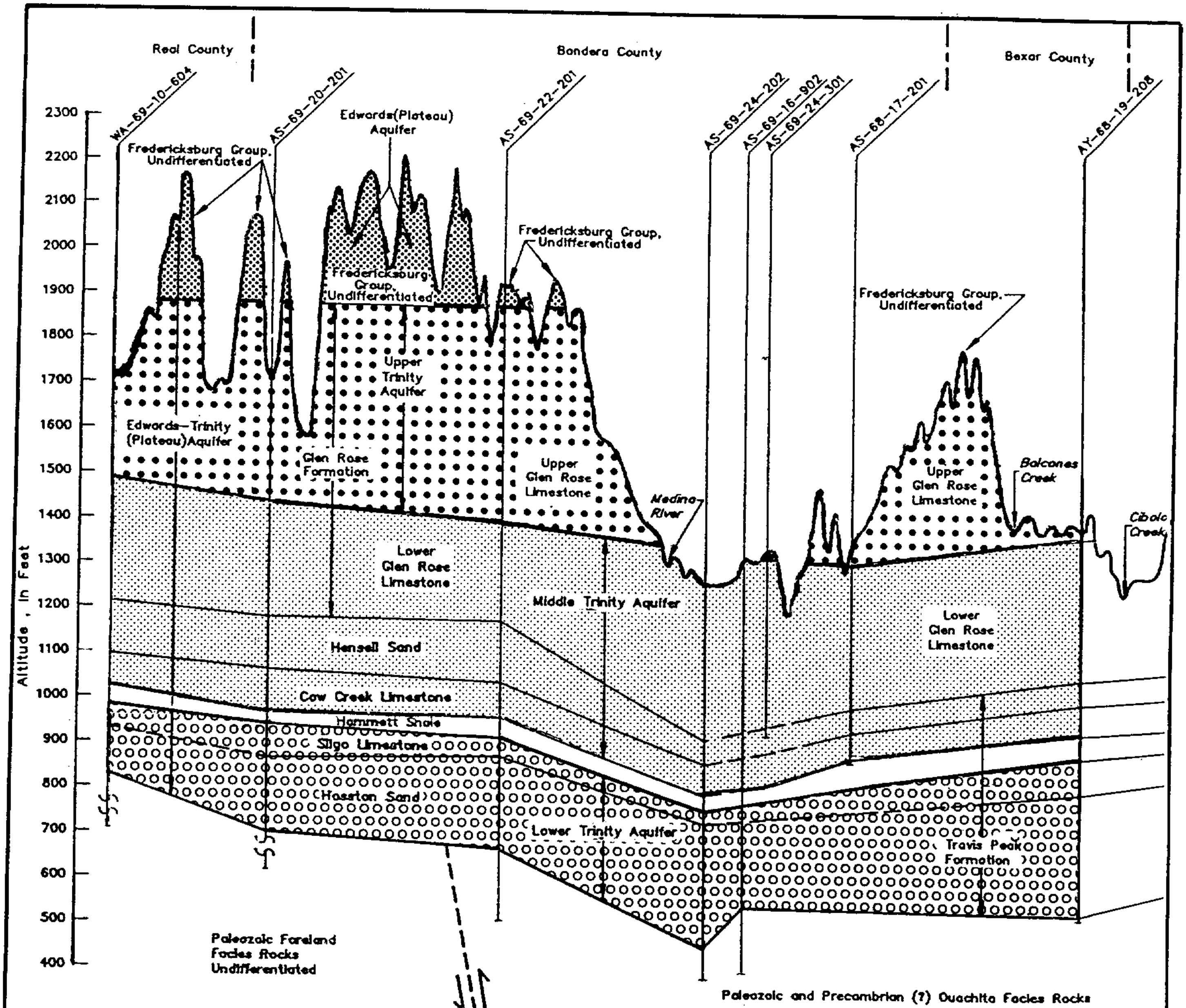
FIGURE 4-1

small portion of the remaining water can be recovered by the wells, on a sustained basis, primarily because of the extremely poor physical ability of the geologic formations to transmit water.

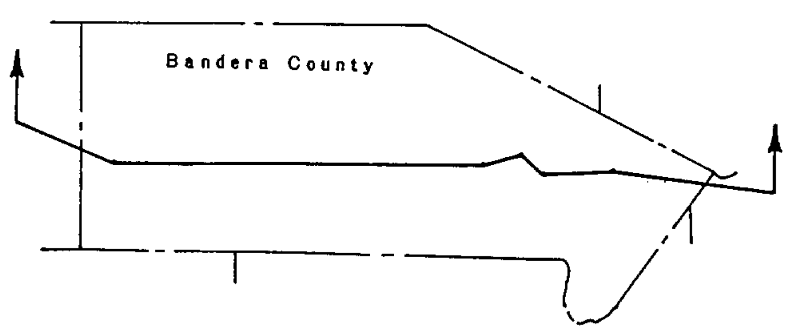
A geologic section through Bandera County is shown in Figure 4-2 and descriptions of each of the geologic units are provided in Figure 4-3. In Bandera County, the Edwards Plateau Aquifer is limited primarily to the higher elevations in the northwest. This aquifer overlies the Trinity Group Aquifer, as shown in Figure 4-2, and is characterized as a limestone formation with a maximum thickness of about 400 feet in Bandera County. The aquifer is composed of the Edwards Limestone, the Comanche Peak Limestone, and the Walnut Clay formations, in descending order. The Walnut Clay unit is a thin confining bed which separates the Edwards Plateau Aquifer from the Trinity Group Aquifer. A large portion of the recharge to the Edwards Plateau Aquifer is discharged as spring flow throughout the area. Discharge from the Edwards Plateau Aquifer by well pumpage accounts for only a small portion of the aquifer's total discharge. Wells completed in the Edwards Plateau Aquifer may be expected to yield 20 gpm or less.

The Trinity Group Aquifer underlies all of Bandera County, underlying the Edwards Plateau Aquifer in the northwest portion of the County and extending south into Medina and Uvalde counties and east into Kendall and Bexar counties. This aquifer is divided into three groups: the Upper Trinity, Middle Trinity, and Lower Trinity.

The Upper Trinity Aquifer is composed of the upper member of the Glen Rose Limestone, and has a maximum thickness of about 500 feet in Bandera County. Recharge to the Upper Trinity occurs over the outcrop areas of the upper Glen Rose formation which



Source:Texas Water Development Board



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GEOLOGIC SECTION

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FIGURE 4-2

Geological Units: Era	System	Group	Formation	Member or Unit	Hydrological Units	Approximate Range in Thickness (feet)	Character of Rocks	Water-Bearing Properties
Cenozoic	Quaternary	Pliestocene to Recent floodplain, terrace and fan alluvial deposits			Very Local Alluvial Aquifers	0-50	Gravel, sand, silt, clay and caliche.	May be capable of yielding very small to small quantities of fresh water.
Mesozoic	Cretaceous	Fredericksburg Group	Edwards Formation	Segovia Member	Edwards Plateau Aquifer	170 - 380 (thickens southward)	**Upper Part** - Cherty, light-gray, fossiliferous limestone. **Middle Part** - Brownish-gray, porous, cherty, massive to thin-bedded dolomite with collapse breccia. **Lower Part** - Yellowish-gray, fossiliferous limestone and marl and marly limestone.	1 Yields small to moderate quantities of fresh waters to wells in the northwestern part of the study area. Well yields may be increased significantly by acidizing. Yields small to very large quantities of fresh water to numerous springs.
				Fort Terrett Member	Edwards Plateau Aquifer; Confining Bed	150 - 300 (thickens southward)	**Upper Part (Quarter)** - Porcelaneous aphanitic limestone with collapse breccia, chert, and recrystallized limestone. **Middle Part** - Gray, cherty, fossiliferous limestone and brownish-gray dolomite. **Lower Part (Quarter)** - Nodular limestone and yellow fossiliferous clay at base which is equivalent to "Walnut Formation".	2 Confining bed of clay at base is not known to yield significant amounts of water to wells and springs.
		Trinity Group	Glen Rose Formation	Upper Unit	Upper Trinity Aquifer	0 - 515 (pinches-out northward toward Llano uplift and thins northwestward)	Alternating resistant and recessive beds of hard to soft, fossiliferous limestone, porous dolomite, and nodular marl. Contains two distinct evaporite zones composed of gypsum and anhydrite. Is relatively thinner bedded, more dolomitic and less fossiliferous than lower unit.	3 Yields very small to small quantiites of some fresh water, but mostly slightly to moderately saline water to wells. Well yields may be increased significantly by acidizing. Yields very small to small quantities of fresh water to numerous springs.
				(Corbula Bed) Lower Unit	Middle Trinity Aquifer	0 - 400 (pinches-out toward Llano uplift and thins northwestward)	Massive, fossiliferous limestone and limestone reefs with numerous caves in lower portion grading upward into thinner beds of limestone, dolomite, marl, and shale. At top, has a consistant Corbula bed (fossiliferous limestone) dividing Glen Rose Formation into upper and lower units.	4 Yields small to very large quantities of fresh to moderately saline water to wells. With proper well construction and proper acidizing, well yields may be increased two-fold. With proper acidizing, well yields have been reported to have increased from 325 gallons per minute to 700 gallons per minute. Yields very small to small quantities of fresh water to numerous small springs.
			Travis Peak Formation	Hensell Member / Bexar Member	Middle Trinity Aquifer	10 - ±300 (thins eastward)	***Hensell Member*** - Red to gray clay, silt, sand, sandstone, conglomerate and thin limestone beds. Thickest sand and sandstone predominate around Llano uplift. Limestone underlain by sandstone predominates in areas farther away from Llano uplift. Grades downdip (southward) into ***Bexar Member*** consisting of a thin sequence of silty dolomite, marl, calcareous shale, and shaley limestone.	
				Cow Creek Member	Middle Trinity Aquifer	0-100 (pinches-out northward and northwestward)	Massive, locally crossbedded, highly fossiliferous, white to gray, sandy, argillaceous to dolomitic limestone with local thin layers of sand, shale, lignite, gypsum and anhydrite.	
				Hammett Member	Confining Bed	0-60 (pinches-out northward and northwestward)	Dark blue, gray to greenish gray, fossiliferous, calcareous and dolomitic shale with interbedded thin layers of limestone and sand.	Not known to yield significant amounts of water to wells and springs.
				Sligo Member	Lower Trinity Aquifer	0-120 (pinches-out northward and northwestward)	Sandy dolomitic limestone, limestone, dolomite and shale.	Yields small to very large quantities of fresh to slightly saline water to wells. With proper well construction and proper acidizing, well yields may be increased two-fold. After acidizing, well yields of 500 to 1,200 gallons per minute have been reported.
				Hosston Member (Sycamore Member in outcrop)	Lower Trinity Aquifer	0-350 (pinches-out northward and northwestward)	Sandstone, siltstone, claystone, shale, dolomite, limestone and basal conglomerate.	

6 Edwards-Trinity (Plateau) Aquifer (in and adjacent to northwestern portion of study area.)

5 Yields small to moderate quantities of fresh water to wells and small to very large quantities of fresh water to numerous springs.

Source : Texas Water Development Board

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GEOLOGIC DESCRIPTIONS

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FIGURE 4-3

comprise a large portion of the county. Discharge from the Upper Trinity Aquifer occurs in part by pumpage from wells, but primarily through springs and seeps. Wells completed in the Upper Trinity generally yield less than 20 gpm; however, some wells may produce yields above 20 gpm.

The Middle Trinity Aquifer is composed of the lower member of the Glen Rose Limestone, the Hensel Sand, and the Cow Creek Limestone formations. This aquifer, which lies between the Upper Trinity and Lower Trinity, has a combined thickness ranging from approximately 400 feet in the northern part of the county to just over 500 feet along the southern edge of the county. The Upper and Middle Trinity Aquifers are hydrologically connected between the upper and lower Glen Rose Limestone formations (Figure 4-2). These two aquifers have been differentiated primarily because they have very different water quality characteristics. The Upper Trinity has significant beds of anhydrite and gypsum which cause much of the water to have a high sulfate content. The Middle Trinity Aquifer has, in general, fewer occurences of the anhydrite and gypsum beds, resulting in much better water quality. The Middle Trinity Aquifer is recharged primarily in areas where the lower member of the Glen Rose Limestone and the Hensell Sand out crop in the region. Of these two units, only the lower member of the Glen Rose Limestone out crops in Bandera County. As shown in Figures 4-1 and 4-2, this occurs in the lower elevations along the Medina River and its tributaries. The Cow Creek Limestone in the Middle Trinity Aquifer is recharged primarily from vertical leakage from the overlying strata. Discharge from the Middle Trinity Aquifer occurs by pumpage from wells and naturally by springs and seeps. Wells in the Middle Trinity Aquifer typically yield 6 to 100 gpm; however, some larger wells may produce yields in excess of 100 gpm.

The Lower Trinity Aquifer is composed of the Sligo Limestone and Hosston Sand members. The Lower Trinity Aquifer is separated from the Middle Trinity Aquifer by a thin confining bed (maximum thickness of about 80 feet) called the Hammett Shale. The combined thickness of this aquifer ranges from 150 feet in the extreme northwestern portion of the county to 400 feet in the southeastern corner. The Sligo Limestone and Hosston Sand members do not out crop in the region. These two units receive recharge by leakage from the overlying strata, especially the Hensell Sand. The recharge occurs primarily in the northern area of the region where the Hammett Shale, which normally provides a hydrologic barrier at the base of the Hensell Sand, is thin or absent. In other portions of the region, recharge may also occur to the Lower Trinity Aquifer through the Hammett Shale, particularly in faulted areas. Discharge from the Lower Trinity Aquifer occurs primarily by pumpage from wells. Wells completed in the Lower Trinity Aquifer generally yield 20 to 500 gpm; however, larger wells may produce in excess of 500 gpm[2].

4.3 Groundwater Availability

Throughout Bandera County and surrounding counties, significant water level declines in the Trinity Group Aquifer have occurred historically within and near the centers of pumpage for public supply purposes. Figure 4-4 shows various well level hydrographs at selected wells throughout Bandera County. Water levels have declined steadily in the Lower Trinity Aquifer near Bandera (Well No. 69-24-202) and at other large public supply wells

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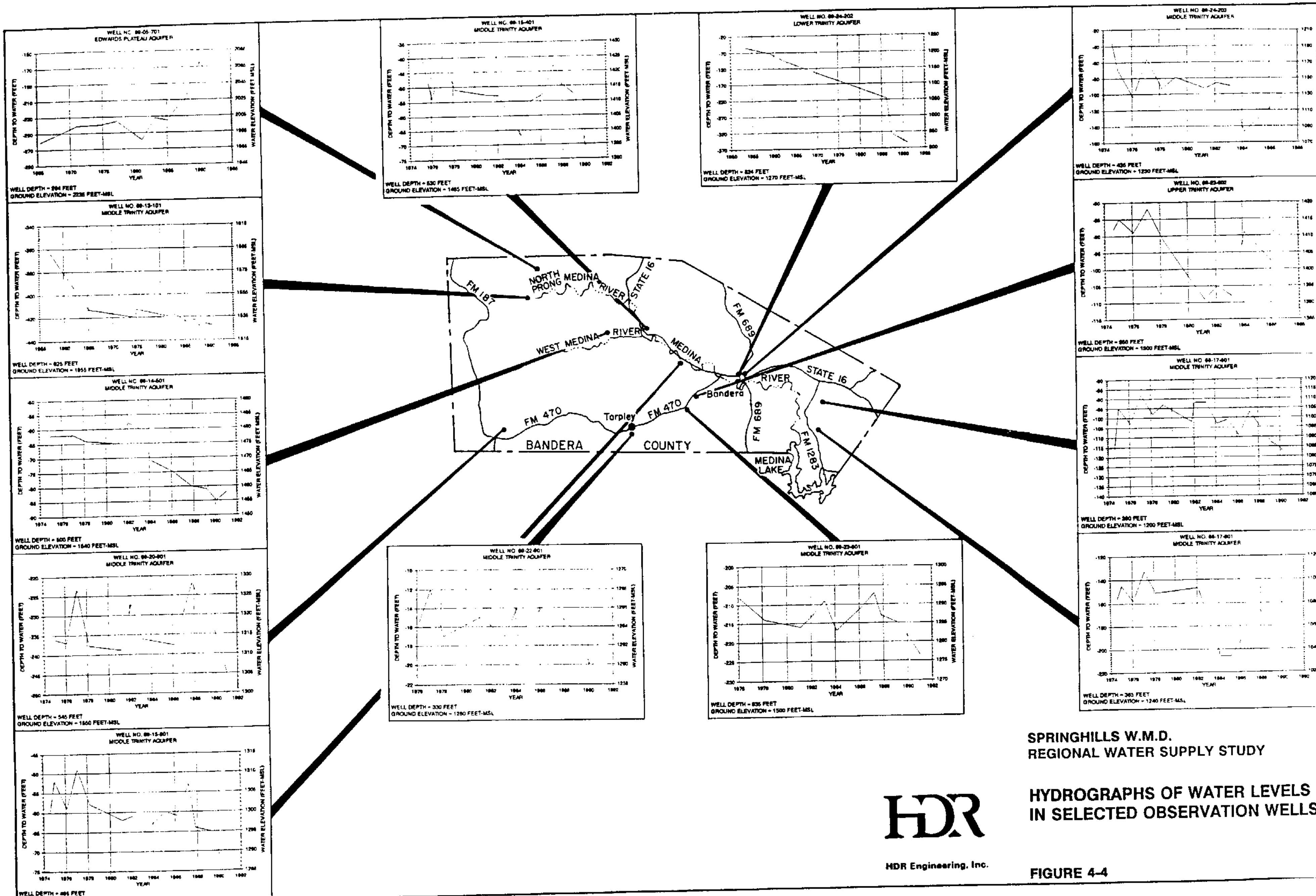
[2]Ibid.



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HYDROGRAPHS OF WATER LEVELS IN SELECTED OBSERVATION WELLS

FIGURE 4-4

in and surrounding Bandera County. Long-term water level declines in the Middle Trinity Aquifer have been more gradual; however, they indicate a more widespread depletion of water from storage in the Middle Trinity, particularly in eastern Bandera County (Well Nos. 69-24-203, 68-17-801, 68-17-501, and 69-15-801). If this gradual depletion or mining of water in the Middle Trinity Aquifer continues, it will eventually cause well yields to significantly decrease. As additional wells are constructed to meet increasing water needs, water levels and well yields will likely continue to decline. In addition, as levels decline in the Middle Trinity Aquifer, water high in sulfates from the evaporite beds of the overlying Upper Trinity Aquifer may begin to naturally leak downward into the Middle Trinity and deteriorate water quality.

As a result of continuing long-term water level declines near areas of public supply pumpage and the potential for deteriorating water quality, a method was developed by the TWDB to estimate the annual sustained yield of the Trinity Group Aquifer. Utilizing available hydrographs of historical water levels from observation wells near centers of pumpage and the historical pumpage records, the TWDB estimated an annual sustained yield or "duty" for an approximate area which was estimated to be influenced by pumpage.[3] This duty is considered to be a gross estimate because of approximations of the area of pumping influence and the limited number of observation wells. However, the data were sufficient to provide a reasonable estimate of the annual sustained yield of the Trinity Group Aquifer (i.e., the yield that can be realized without adverse long-term water level declines and encroachment of poor quality water). Duties for the Trinity Group Aquifer

[3] Ibid.

at and near the cities of Bandera, Kerrville, Boerne, and Comfort were calculated by the TWDB using available data. With these results and other hydrogeological knowledge of the aquifer, the TWDB estimated the annual sustained yield of the Trinity Group Aquifer in Bandera County to be 6,500 acre-feet per year. This equates to a duty of about 8.5 acre-feet per year per square mile. An estimated duty for the Edwards Plateau Aquifer was also made by the TWDB. The duty for the Edwards Plateau Aquifer in northwest Bandera County was computed to be 700 acre-feet per year, or about 4 acre-feet per year per square mile.

4.4 Groundwater Quality

The quality of the groundwater in Bandera County is generally characterized as being highly mineralized as a result of the solubility of the soil and rock minerals, the pH of the recharge water, and the carbon dioxide content of the water. The high mineralization is predominantly calcium and magnesium bicarbonates, which are also associated with water hardness. All aquifers in the county are considered to have very hard water.

With regard to drinking water standards for Community Systems established by the U.S. EPA and Texas Department of Health (TDH), the groundwater in Bandera County meets all the primary standards, with the exception of high nitrate levels identified in the Edwards Plateau Aquifer in the northwestern section of the county. However, the groundwater in Bandera County does not meet several of the secondary standards established by the TDH. These include standards for sulfates, fluoride, TDS, and iron. Although these secondary standards are recommended limits and are aesthetic in nature, failure to meet them can cause some adverse health effects, and the TDH does not necessarily allow exceedence of the recommended levels.

New water systems cannot use a water supply source that does not meet the recommended secondary constituent levels without written approval by the TDH. The determining factor is whether or not there is an alternate source of water of acceptable chemical quality available to the area to be served. In cases where drinking water does not meet the recommended limits and is accepted for use, the acceptance is valid only until water of acceptable chemical quality from an alternate source can be made available at reasonable cost. At that time, water previously accepted would have to be treated to lower the constituents to acceptable levels, or water would have to be secured from the alternate source. Customers of systems that exceed the secondary fluoride limits must be notified annually as prescribed by the TDH.

Results of water quality analyses obtained from the TWDB for the major aquifers in Bandera County are presented in Table 4-1. Nitrate levels in the Edwards Plateau Aquifer are highly variable and often exceed the limit of 10 mg/l of NO_3 as N. The source of nitrate pollution is typically attributed to non-point source pollution, such as septic tank discharges, raising of livestock, and fertilizers.

The Upper Trinity Aquifer generally produces poor quality water which is characterized as mineralized and very hard. The low permeability of the Upper Glen Rose Limestone member restricts water movement, which in turn causes an increase in mineral concentration. This slow movement and long contact of groundwater with the soluble anhydrite and gypsum beds which are prominent in the limestone results in excessive sulfate

TABLE 4-1
Groundwater Quality Data for Aquifers in Bandera County

Constituent	Texas Department of Health Secondary Standards (mg/l)	Concentration of Constituents for Aquifers (mg/l)											
		Edwards Plateau Aquifer			Upper Trinity Aquifer			Middle Trinity Aquifer			Lower Trinity Aquifer		
		Median	Range		Median	Range		Median	Range		Median	Range	
			Min	Max		Min	Max		Min	Max		Min	Max
pH	≥7.0	7.8	7.4	8.1	8.1	7.5	8.1	7.8	6.9	8.2	7.9	7.6	8.5
Silica	N/A	12	9	14	11	8	14	11	0	14	11	9	15
Calcium	N/A	88	71	110	69	68	96	86	10	580	41	32	68
Magnesium	N/A	17	10	27	15	10	18	67	29	421	22	20	48
Sodium	N/A	7	4	16	7	6	9	41	9	124	96	43	140
Potassium	N/A	0	0	16	0	0	0	1	0	21	13	1	16
Carbonate	N/A	0	0	0	0	0	0	0	0	0	0	0	6
Bicarbonate	N/A	323	266	355	278	239	342	354	220	405	368	348	378
Sulfates	300	7	3	20	18	13	23	290	94	2910	51	46	120
Chlorides	300	12	7	36	11	10	17	32	15	46	56	36	85
Fluoride	2.0*	0.1	0.1	0.2	0.2	0.2	0.3	2.7	0.0	5.2	2.5	1.9	3.0
Nitrate	10**	5.4	0.1	140	2.3	0.7	3.2	0.4	0.0	1.5	0.4	0.0	0.9
TDS	1000	319	258	444	263	251	338	701	473	4139	502	457	561
Total Hardness	N/A	289	253	342	242	214	304	516	368	3020	201	166	368
Number of Samples		13			3			28			11		
Number of Samples Exceeding Standards		4			0			21			7		

*Secondary Standard for Fluoride = 2.0 mg/l, Primary Standard = 4.0 mg/l
**Primary Standard
Shading indicates value exceeds Texas Department of Health Standard.
Data obtained from Texas Water Development Board.

concentrations. Water quality data available for the Upper Trinity Aquifer in Bandera County do not indicate high sulfate concentrations; however, the data were limited to three samples (Table 4-1). Data for other constituent concentrations do not indicate any values in excess of TDH Standards.

The Middle Trinity Aquifer produces water that is of poor quality and often not very palatable. The water is very hard and has high concentrations of sulfates, fluorides, and total dissolved solids, often exceeding TDH secondary standards (Table 4-1). The high dissolved solids and sulfates can give the water a salty taste and a laxative effect. The excessive sulfate concentrations in this aquifer are believed to be caused by the existence and dissolution of thin beds of anhydrite and gypsum in the Cow Creek Limestone member. Another reason for the excessive sulfate levels may be inadequate well construction and development. Improperly sealed wells which pass through prominent anhydrite and gypsum beds in the Upper Trinity Aquifer provide pathways for high sulfate groundwater to percolate downward and contaminate the Middle and Lower Trinity Aquifers.

Concentrations of dissolved minerals in groundwater generally increase with depth and are also found in areas where circulation has been restricted due to faulting or zones of lower permeability. Sulfates have also been shown to increase in the downdip direction, resulting in a rapid increase in dissolved solids. These may be the reasons for the high sulfate and dissolved solids levels exhibited in public water supply systems near the eastern boundary of Bandera County. Table 4-2 contains data from recent TDH water analysis reports for public water systems in Bandera County. Concentrations of sulfates and total dissolved solids are noticably higher in the Spring Creek, Big Valley, and Cedar Hill

TABLE 4-2
Water Quality Data for Water Systems in Bandera County

Constituent	Texas Dept. Of Health Standard (mg/l)	Concentration of Constituents for Water Systems (mg/l)												
		City of Bandera	Medina WSC	Bandera FWSD #1	Bandera River Ranch No.1	Holiday Water Service	Flying L Ranch P.U.D.	Enchanted River Estates	San Julian Creek Estates	River Bend Estates	Elmwood Estates	Spring Creek Subdiv.	Big Valley Subdiv.	Cedar Hill Subdiv.
Calcium	N/A	33	84	116	70	120	73	71	15	89	75	366	511	468
Chloride	300*	55	42	24	34	20	36	34	51	32	26	47	14	12
Flouride	2.0**	2.0	2.4	0.3	2.5	0.2	2.5	2.3	2.1	2.3	2.1	1.5	1.0	3.3
Magnesium	N/A	22	55	32	46	21	48	47	21	51	48	71	75	156
Nitrate	10	0.24	0.02	0.07	0.32	2.54	0.27	0.01	< 0.01	0.02	< 0.01	0.10	<0.01	0.27
Sodium	N/A	104	48	13	40	11	45	44	97	39	34	6	8	11
Sulfates	300*	41	205	89	118	95	144	132	29	194	120	1058	1438	1554
Total Hardness	N/A	171	436	423	367	385	379	373	123	431	386	1210	1587	1811
pH	≥ 7.0*	8.3	8.0	8.1	8.0	8.3	8.0	8.1	8.5	8.2	8.0	6.8	7.9	7.7
Total Alkalinity	N/A	287	286	326	299	281	295	297	247	293	311	175	128	222
Bicarbonate	N/A	350	349	398	365	343	360	362	292	357	379	175	156	271
Carbonate	N/A	0	0	0	0	0	0	0	5	0	0	0	0	0
TDS	1000*	441	624	471	505	449	541	522	376	597	504	1145	2127	2351
Arsenic	0.05	< 0.01	<0.01	< 0.01	<0.01	< 0.01	< .01	< 0.01	< 0.01	< 0.01	< 0.01	N/A	N/A	< 0.01
Barium	1.0	< 0.50	0.02	0.04	< 0.5	0.06	0.032	< 0.5	0.02	0.03	0.04	N/A	N/A	< 0.5
Cadmium	0.01	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	<0.005	< 0.005	< 0.005	< 0.005	< 0.005	N/A	N/A	< 0.005
Chromium	0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	N/A	N/A	< 0.02
Copper	1.0*	< 0.02	< 0.02	0.06	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.02	N/A	< 0.02
Iron	0.3*	0.06	0.22	0.42***	0.25	< 0.02	0.23	0.15	0.34	0.16	0.65***	0.12	1.21***	0.29
Lead	0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.20	< 0.02	< 0.02	N/A	N/A	< 0.02
Manganese	0.05	< 0.02	< 0.02	0.07	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.04	<0.04	< 0.02
Mercury	0.002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	N/A	N/A	< 0.0002
Selenium	0.01	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	N/A	N/A	< 0.002
Silver	0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	N/A	N/A	< 0.01
Zinc	5.0*	< 0.02	0.02	0.03	0.21	0.07	< 0.02	0.23	0.62	0.04	0.83	0.034	N/A	0.25
SAMPLE DATE		6/14/88	1/25/89	5/16/89	2/17/88	5/26/89	10/27/89	1/22/88	9/27/88	11/10/88	5/3/89	6/16/87	7/23/86	12/19/90

NOTES:

Shading indicates value exceeds Texas Department of Health Standard.
Data obtained from Texas Department of Health Water Analysis Reports
*Secondary Standard
**Secondary Standard = 2.0 mg/l, Primary Standard = 4.0 mg/l
***Texas Department of Health acceptable treatment in progress

subdivisions compared with other water systems in the county. These three subdivisions are located along the extreme eastern boundary of the county in the furthest downdip direction of the Trinity Group Aquifer and adjacent to extensive faulting in the Edwards-Balcones Fault zone.

Water from the Lower Trinity Aquifer is of better quality than the Middle Trinity Aquifer in terms of sulfate and dissolved solids. Like water from the other aquifers, water from the Lower Trinity is also highly mineralized and very hard. The geologic formations that are the source of the minerals can also be a source of fluoride. As shown in Table 4-1, fluoride levels for water from the Lower Trinity Aquifer are near or exceed the 2.0 mg/l secondary standard.

4.5 Surface Water Resources

Bandera County is located in portions of three major river basins: the San Antonio, Nueces, and Guadalupe (Figure 4-5). In Bandera County, the San Antonio River Basin is made up of the Medina River and its contributing tributaries, as well as Medina Lake. The Medina River flows from the northwest to the southeast through the county and into Medina Lake. Historically, flow in the Medina River near its confluence with Pipe Creek averaged 105,800 acre-feet per year over a period of record of 44 years, with a minimum annual flow of 4,000 acre-feet recorded in 1956 during the drought of the 1950's.[4]

Medina Lake, completed in 1913, controls 634 square miles of the Medina River watershed. The reservoir is owned and operated by the Bexar-Medina-Atascosa Counties

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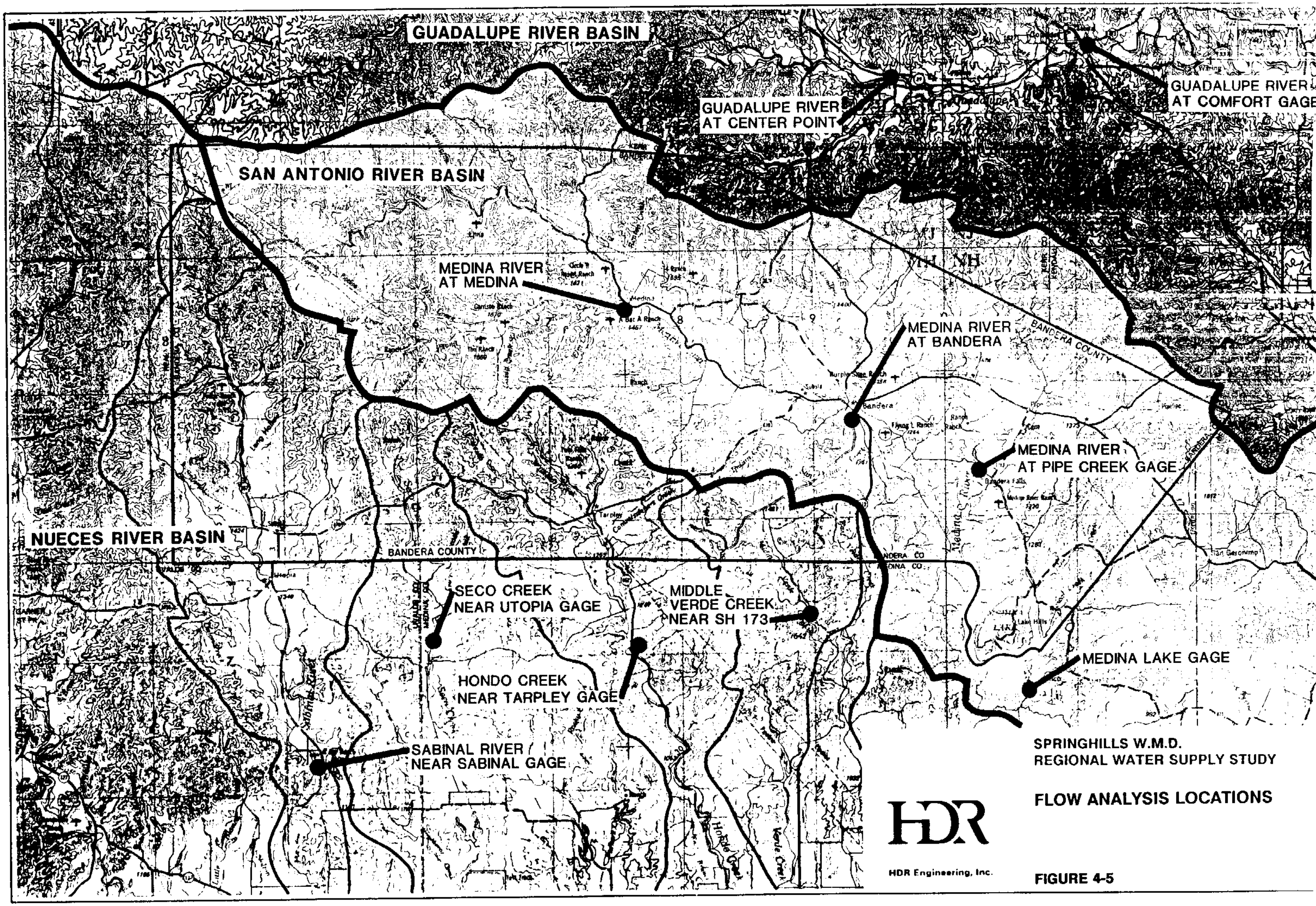
[4] U.S. Geological Survey, "Water Resources Data, Texas," Annual Volumes.



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FLOW ANALYSIS LOCATIONS

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FIGURE 4-5

Water Control Improvement District No. 1 (BMA), which has a permit to irrigate 150,000 acres annually using a total annual diversion of 66,000 acre-feet. The lake has a capacity of 254,000 acre-feet at the conservation pool level of 1064.2 feet-msl. Since the lake was initially filled in April, 1915, it has recorded a median lake level of 1039.6 feet-msl, 24.6 feet below the conservation pool level. The lake reached a minimum level of 936.2 feet-msl, 128 feet below conservation pool level, in April, 1948. Historical end-of-month pool levels in Medina Lake from May, 1913 to September, 1989 are shown in Figure 4-6. Historical reservoir storage amounts over the same period are also shown in the figure.[5] Medina Lake is subject to large fluctuations; its storage dropped to near zero capacity in 1930, 1940, 1948, 1950 to 1956, and 1964. Table 4-3 shows the percent of time Medina Lake has been below various conservation storage levels. Over the 77-year period of record, the reservoir has been less than half full 46 percent of the time and less than 20 percent full nearly 20 percent of the time.

A portion of the Nueces River Basin lies in southwest Bandera County and is made up of four primary streams: the Sabinal River, Seco Creek, Hondo Creek, and Verde Creek. The watershed area for these streams accounts for approximately 25 percent (192 square miles) of the total area of Bandera County (Figure 4-5). Generally, the streams flow directly south from Bandera County into Medina and Uvalde counties where a significant portion of their base flow recharges the Edwards-San Antonio Aquifer.

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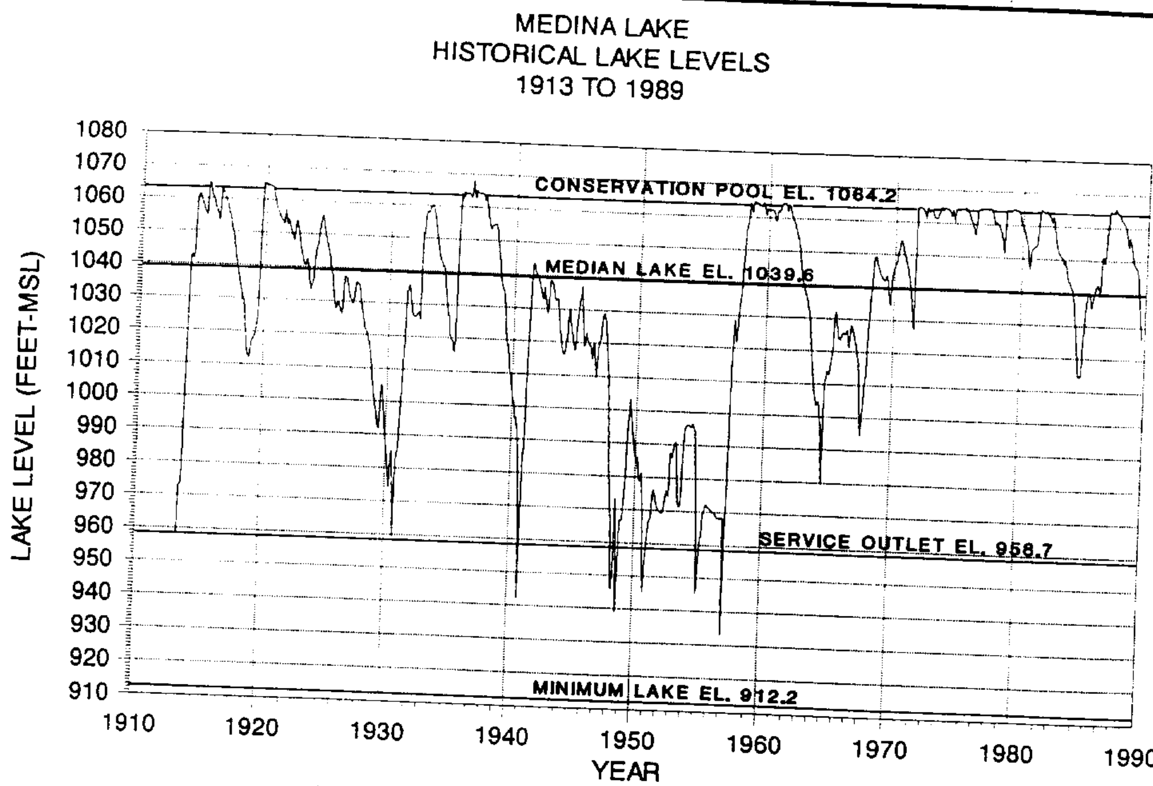
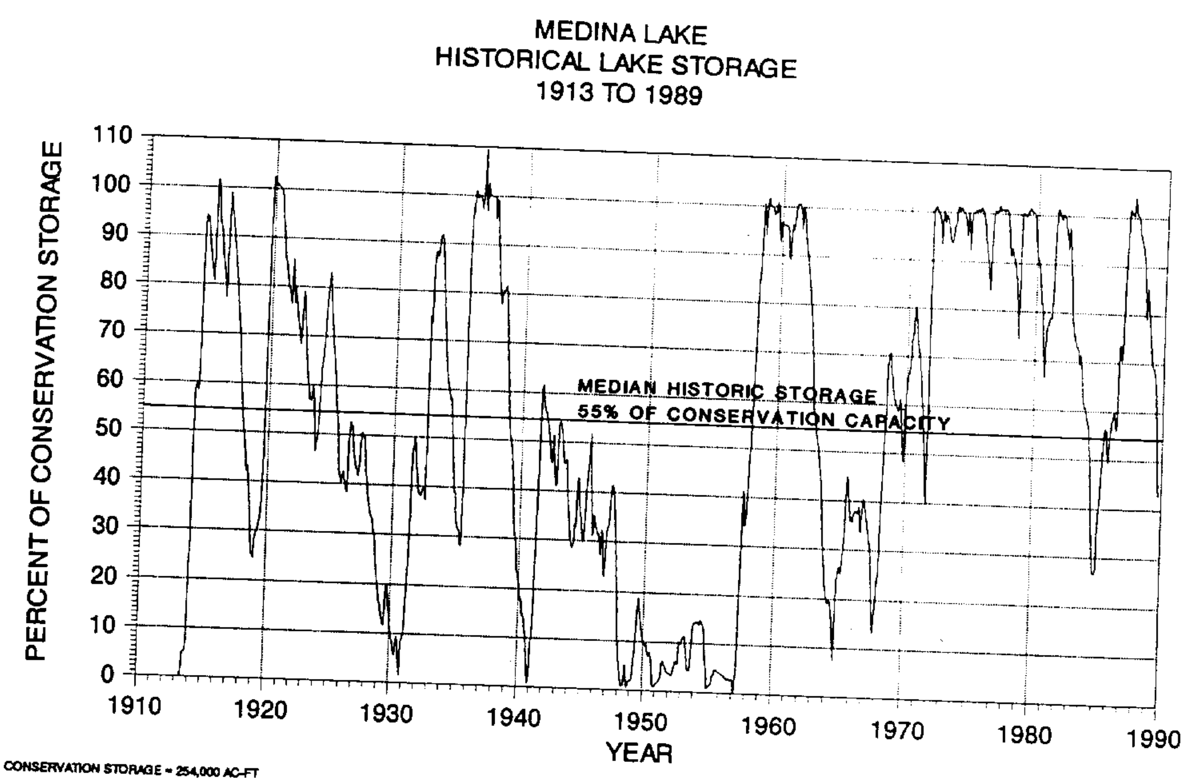
[5] Ibid.





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REGIONAL WATER SUPPLY STUDY

HDR Engineering, Inc.

MEDINA LAKE
HISTORICAL LAKE LEVELS
AND STORAGE

FIGURE 4-6

TABLE 4-3 Medina Lake Storage Levels Period of Record 1913-1989			
Percent of Conservation Storage Capacity	Reservoir Storage Volume (acre-feet)	Lake Level (feet-msl)	Percent of Time Below Storage Level
0	0	912.2	0
5	12,700	972.7	7
10	25,400	986.9	12
20	50,800	1004.9	19
30	76,200	1017.7	24
40	101,600	1027.7	35
50	127,000	1035.7	46
60	152,400	1042.8	54
70	177,800	1048.8	60
80	203,200	1054.4	69
90	228,600	1059.3	76
100	254,000	1064.2	100.0

The average annual natural flow in the Sabinal River at a gaged site 9.5 miles downstream of the Bandera/Uvalde County line has been computed to be 37,461 acre-feet per year.[6] Natural flow is defined as the amount of flow that would have occurred if no flow had been diverted or stored upstream. A minimum annual natural flow volume of 653 acre-feet was computed at the Sabinal River gage in 1955. U.S. Geological Survey gage records exist at this location for the period of 1942 to 1989. The drainage area at this gage is 206 square miles.

[6] Texas Water Commission, Water Availability Model for the Nueces River Basin. Period of record modeled is 1940 to 1978.

The average annual natural flow in Seco Creek at a gaged site near Utopia has been computed to be 9,492 acre-feet per year.[7] A minimum annual natural flow volume of 208 acre-feet was computed at the Seco Creek gage in 1956. U.S. Geological Survey gage records exist at this site, located 4 miles south of the Bandera/Medina County line, for the period of 1961 to 1989. The drainage area at this gage is 45 square miles.

The average annual natural flow in Hondo Creek at a gaged site near Tarpley has been computed to be 25,597 acre-feet per year.[8] A minimum annual natural flow volume of 414 acre-feet was computed at the Hondo Creek gage in 1956. U.S. Geological Survey gage records exist at this site, located 4 miles south of the Bandera/Medina County line, for the period of 1952 to 1989. The drainage area at this gage is 96 square miles.

Middle Verde Creek, located just east of Hondo Creek, has a relatively small watershed in Bandera County. Gage records are not available for Middle Verde Creek above the Edwards-San Antonio recharge zone. Natural flows were computed using a regression analysis for the period of 1934 to 1989 at a potential reservoir site three miles south of the Bandera/Medina County line below where the West and Middle Verde Creeks join.[9] The average annual natural flow was computed to be 13,499 acre-feet per year. The minimum annual natural flow volume was computed to be 675 acre-feet in 1954. This site has a drainage area of approximately 55 square miles.

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[7] Ibid.

[8] Ibid.

[9] HDR Engineering, Inc., "Regional Water Supply Planning Study, Nueces River Basin," May, 1991.

A very small portion (approximately two percent) of northern Bandera County lies in the Verde Creek watershed of the Guadalupe River Basin (Figure 4-5). Although annual flow in Verde Creek near the Bandera/Kerr County line is insignificant, flow volumes in the Guadalupe River north of the Bandera County are substantial. Gage records for the Guadalupe River near Comfort indicate an average annual flow of 147,100 acre-feet per year for the period of 1939 to 1989. A minimum annual flow volume of 7,860 acre-feet was recorded during the drought in 1956.[10]

4.6 Surface Water Availability

4.6.1 San Antonio River Basin

The Medina River watershed in the San Antonio River Basin contains the predominant volume of streamflow in Bandera County. However, because of existing downstream water rights, virtually all of the flow in the Medina River upstream of Medina Lake has been "appropiated" to downstream demands outside of the county. A listing of the water rights permits in Bandera County upstream of Medina Lake is provided in Table 4-4. A summary of the number of water rights by river basin and use is presented in Table 4-5. A large portion (84 percent) of the water rights in the county are for irrigation and recreation water use. The total annual permitted diversion volume in the San Antonio River Basin within Bandera County is 1,279 acre-feet. Of this total, 877 acre-feet is for irrigation, 223 acre-feet is used for recreational purposes, and 179 acre-feet is for municipal purposes. Of the 179 acre-feet permitted for municipal purposes, 170 acre-feet was obtained

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[10] U.S. Geological Survey, "Water Resources Data, Texas," Annual Volumes.

TABLE 4-4
Water Rights in Bandera County

STATE MASTER NO.	RIVER BASIN	RIVER ORDER NO.	PERMIT NO.	NAME	STREAM	USE	AUTHORIZED DIVERSION (AC-FT/YR)	IRRIGATED ACRES	RESERVOIR CAPACITY (AC-FT)	DATE FILED	REMARKS
003184	NUECES	2675000000		H B LIVELY	SPRING CREEK	IRRIGATION	10	5	42	19631231	
003179	NUECES	2825000000		JOHN K HARRELL	SABINAL RIVER	IRRIGATION	13	25		19631014	
003179	NUECES	2825000000		JOHN K HARRELL	SABINAL RIVER	IRRIGATION	24	100		19651204	
005204	NUECES	2840000000	005204	ROGER E. CANTER ET UX	SABINAL R	IRRIGATION	60	20		19881026	
003176	NUECES	2851020000		TEXAS PARKS & WILDLIFE DEPT	CAN CREEK	MUNICIPAL	7			19780123	
005186	NUECES	2824000000	005186	HILL COUNTRY SPRING WATER TX	SPRING/UNNAME	MUNICIPAL	161			19880621	TRIB SABINAL R, BOTTLED WATER,049 RES
003181	NUECES	2793800000		BRUCE L BOSWELL ET UX	W SABINAL R	IRRIGATION	400	200		19770117	ALSO CO 232, EXP 12/31/99
003177	NUECES	2850500000		JOE K LEIGHTON	SABINAL RIVER	MUNICIPAL	4			19121231	
003176	NUECES	2851020000		TEXAS PARKS & WILDLIFE DEPT	CAN CREEK	IRRIGATION	0	3		19780123	
003178	NUECES	2850000000		KING & JEWEL FISHER	SABINAL	IRRIGATION	10	56	2	19530709	
003185	NUECES	2651700000		W H THOMPSON, JR	WILLIAMS CREEK	IRRIGATION	15	5	2	19690626	
003187	NUECES	2651000000		BRIAN WEINER	WILLIAMS CREEK	IRRIGATION	23	21	15	19670331	
003186	NUECES	2651500000		DOROTHY BAIRD BEAN	WILLIAMS CREEK	IRRIGATION	128	88	73	19631231	
003188	NUECES	2650000000		W J SCHMIDT	HONDO CREEK	IRRIGATION	24	47	16	19560220	
003944	SAN ANTONIO	5887120000	003653	CONOCO INCORPORATED	UNNAMED OF	RECREATION	0		100	19781127	MEDINA RIVER, 2 DAMS
002126	SAN ANTONIO	5887105000		WILLIAM S THOMPSON ET UX	MEDINA	IRRIGATION	47	36		19551231	
002110	SAN ANTONIO	5897000000		DONALD F & MARTHA M MEAD	N PR MEDINA	IRRIGATION	21	12		19630431	
002127	SAN ANTONIO	5887100000		JERRY B PARKER ET AL	MEDINA	IRRIGATION	16	8		19621231	
003853	SAN ANTONIO	5888230000	003559	JOHN THOMAS STEEN	SPIRES CR	RECREATION	0		1322	19780130	SC EXPIRES IN 20 YEARS
002136	SAN ANTONIO	5659000000		KITTIE NELSON FERGUSON	UNNAMED	IRRIGATION	6	3	10	19631231	TRIB SAN GERONIMO CR-OUT OF 536.5 AC TR
005097	SAN ANTONIO	5890300000	005097	L KENNETH EVANS	W PR MEDINA	IRRIGATION	20	72		19860916	EXP 2/2/2016 UPON CONTRACT 1610
002129	SAN ANTONIO	5887000000		JOE H BERRY	PRIVILEGE CR	IRRIGATION	40	33	110	19670220	
002128	SAN ANTONIO	5887050000		JOE H BERRY	SADDLE CREEK	IRRIGATION	14	12	3	19611231	
002111	SAN ANTONIO	5896000000		TEXAS PETROLEUM COMPANY TR EST	COLLINS CR	IRRIGATION	4	2	16	19641231	
002117	SAN ANTONIO	5889000000		MAX E JOHNSON M D	MEDINA	IRRIGATION	7	7		19391231	OUT OF A 175.5 ACRE TRACT
001203	SAN ANTONIO	5700000000	0021306	MEDINA DEVELOPMENT CO	MEDINA	MUNICIPAL	170				MEDINA LAKE
002112	SAN ANTONIO	5894500000		MRS MARY WINKENHOWER	ELAM CREEK	IRRIGATION	27	27		19631231	OUT OF A 204 ACRE TRACT
002123	SAN ANTONIO	5887150000		DON F TOBIN	MEDINA	IRRIGATION	152	61		19471231	OUT OF A 452 ACRE TRACT
002124	SAN ANTONIO	5887130000		EVANGELINE RATCLIFFE WILSON	SAN JULIAN CR	IRRIGATION	3	5		19570721	
002107	SAN ANTONIO	5901100000		ROBERT WADE PAYNE JR	N PR MEDINA	IRRIGATION	19	25		19451231	OUT OF A 1666.5 ACRE TRACT
003693	SAN ANTONIO	5887260000	003446	GERALD H PERSYN	UNNAMED OF	RECREATION	0		11	19761115	BANDERA CREEK
002116	SAN ANTONIO	5891000000		P L GARRISON ET AL	W PR MEDINA	IRRIGATION	51	51	162	19670808	
002109A	SAN ANTONIO	5897200000		NEVIN MARR	N PR MEDINA	IRRIGATION	2	10		19631231	AMEND 1-21-83 INCREASE ACRES
002120A	SAN ANTONIO	5888051000		BANDERA ELECTRIC COOP INC	MEDINA	IRRIGATION	2	4		19181231	7/8/82 ADD DIV PT
002121	SAN ANTONIO	5888087000		ANN DARTHULA MAULDIN ET AL	INDIAN CREEK	IRRIGATION	150	40		19620701	OUT OF A 107.96 ACRE TRACT
002114	SAN ANTONIO	5892000000		PHIL A GROTHUES ET AL	UNNAMED	IRRIGATION	16	58		19670631	TRIB OF BAUERLEIN CR-OUT OF A 886.7 ACTR
003909	SAN ANTONIO	5888150000	003616	MAUDEEN M MARKS	MONTAGUE HOLLW	RECREATION	0		500	19780905	DOMESTIC, LIVESTOCK & REC
004026	SAN ANTONIO	5887125000	003736	HILL COUNTRY MANAGEMENT CORP	SAN JULIAN	RECREATION	0		3	19800225	ALSO DOM & LIVESTOCK
002118	SAN ANTONIO	5888870000		DAVID J BRASK	UNNAMED	IRRIGATION	16	16		19631231	TRIB OF LAXSON CR, TRIB MEDINA
002119	SAN ANTONIO	5888090000		RAYMOND HICKS	MEDINA	IRRIGATION	3	8		19181231	
002113	SAN ANTONIO	5894000000		SUSAN CRAWFORD TRACY	W PR MEDINA	IRRIGATION	35	45		19351231	OUT OF A 156 ACRE TRACT
001610	SAN ANTONIO	5700000000	0021306	L KEN EVANS	MEDINA	IRRIGATION	20			19860203	LAKE MEDINA, EXP 2016
003949	SAN ANTONIO	5886550000	003696	CASTLE LAND & LIVESTOCK CO INC	BEAR CREEK	RECREATION	33		33	19791204	DOM & LIVESTOCK - SC
002125	SAN ANTONIO	5887129000		RUTH ANN RATCLIFFE TIPS	SAN JULIAN CR	IRRIGATION	18	30		19570721	
003824	SAN ANTONIO	5887295000	003541	CITY OF BANDERA	MEDINA	RECREATION	0		22	19771017	
002115	SAN ANTONIO	5891500000		DAVID R SCHMIDT MD ET AL	BAUERLEIN CR	IRRIGATION	15	16		19331231	
002103	SAN ANTONIO	5903000000		O S PETTY	HONEY CR	IRRIGATION	96	38		19241231	
002106	SAN ANTONIO	5901450000		BREWINGTON LAKE RANCH ASSOC	BREWINGTON CR	RECREATION	190		190	19641231	
002122	SAN ANTONIO	5887330000		DON HICKS	MEDINA	MUNICIPAL	9			19451231	
002108	SAN ANTONIO	5900100000		BOYCE H GASKIN	ROCKY CREEK	IRRIGATION	44	32		19660431	ALSO KERR CO, OUT OF 675 AC/TR
002104B	SAN ANTONIO	5902000000		CLARENCE E LAUTZENHEISER	N PR MEDINA	IRRIGATION	20	24		19610630	AMEND 9/29/88, 8/22/89
002105	SAN ANTONIO	5901500000		STEVEN L PRICHARD TRUSTEE ETAL	MICKLE & N MED	IRRIGATION	13	19	5	19671231	
002028	GUADALUPE	7750000000		HOWARD E BUTT	PALMER CREEK	RECREATION	0		30	19400719	
002027	GUADALUPE	7720000000		ROBERT L PARKER SR ET AL	VERDE CREEK	IRRIGATION	8	3		19181231	
003825	GUADALUPE	7718000000	003567	ROBERT L PARKER SR ET AL	VERDE CREEK	RECREATION	0		277	19771017	
				TOTALS			2,166	1,267	3,024		

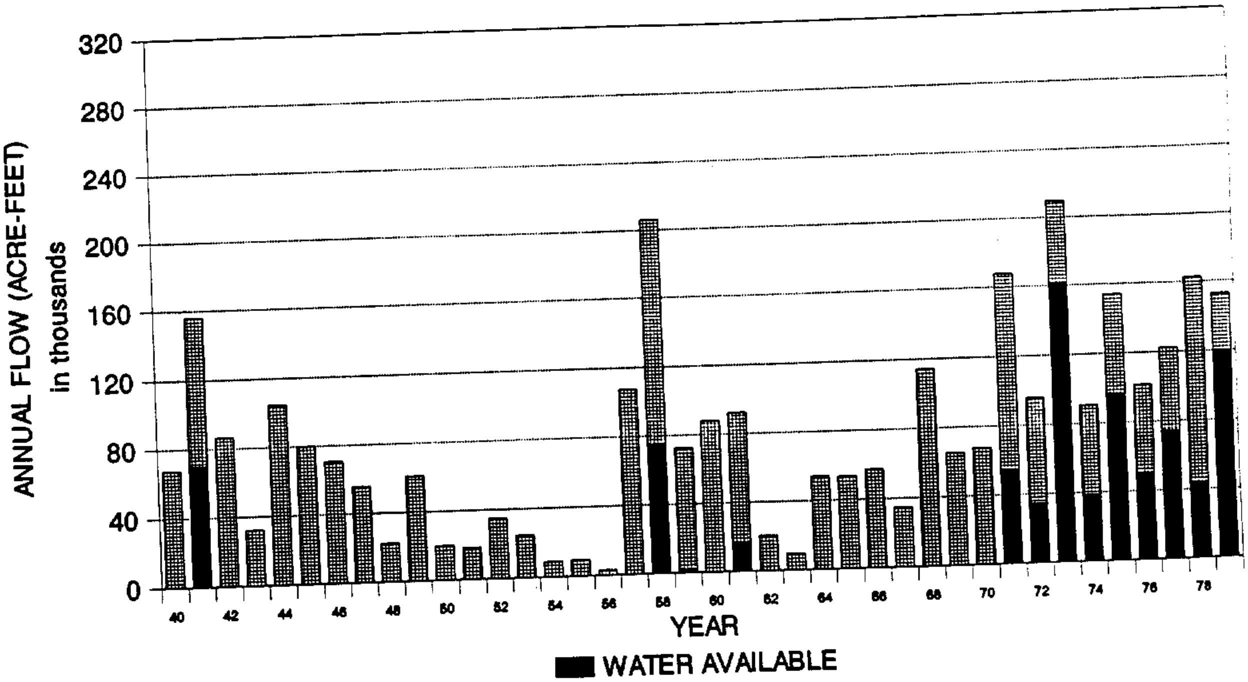
TABLE 4-5 Summary of Bandera County Water Rights			
	River Basin		
Permitted Use	Guadalupe	San Antonio	Nueces
Municipal			
No. of Rights	0	2	3
Diversion (ac-ft/yr)	0	179	172
Irrigation			
No. of Rights	1	28	11
Diversion (ac-ft/yr)	8	877	707
Irrigated Acreage	3	697	570
Recreation			
No. of Rights	2	8	0
Diversion (ac-ft/yr)	0	223	0

through a contract agreement with BMA for water allocated by permit from Medina Lake.

Total annual naturalized flow in the Medina River along with the annual volume of unappropriated water (i.e., water available for new users) for the period of 1940 to 1979 are shown in Figure 4-7 for two locations (City of Bandera and near the community of Medina).[11] For 28 of the 40 years shown, there is no water available for new diversions at either location. The lack of unappropriated water in the Medina River in Bandera County can be attributed primarily to the annual irrigation right (66,000 acre-feet) owned by BMA for water out of Medina Lake.

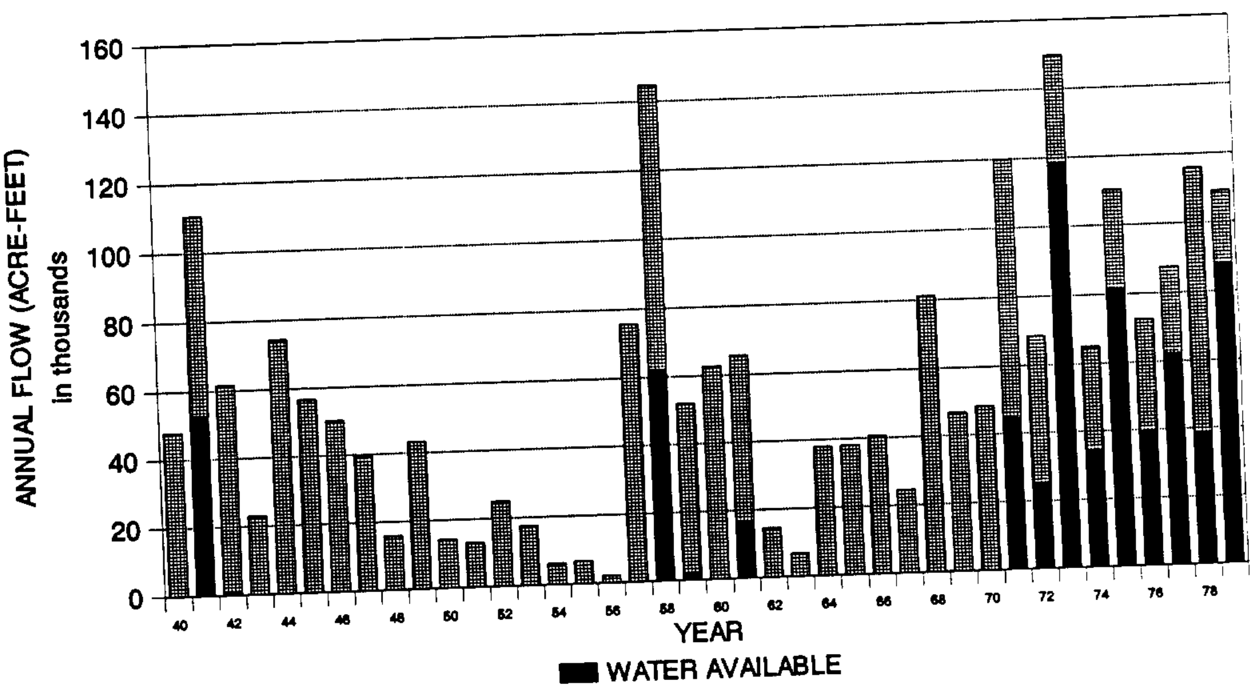
[11] Texas Water Commission, Water Availability Model for the Guadalupe/San Antonio River Basin. Period of record modeled is 1940 to 1979.

NATURALIZED FLOW IN MEDINA RIVER AT CITY OF BANDERA



BASED ON THE TEXAS WATER COMMISSION'S WATER AVAILABILITY MODEL FOR THE GUADALUPE/SAN ANTIONO RIVER BASIN

NATURALIZED FLOW IN MEDINA RIVER NEAR COMMUNITY OF MEDINA



BASED ON THE TEXAS WATER COMMISSION'S WATER AVAILABILITY MODEL FOR THE GUADALUPE/SAN ANTIONO RIVER BASIN

SPRINGHILLS W.M.D.
REGIONAL WATER SUPPLY STUDY

NATURALIZED FLOWS IN MEDINA RIVER

HDR

HDR Engineering, Inc.

FIGURE 4-7

4.6.2 Nueces River Basin

Existing permitted annual diversions from the Nueces River Basin in Bandera County total 879 acre-feet. Irrigation permits account for 707 acre-feet per year, while municipal permits total 172 acre-feet. Of the 172 acre-feet permitted for municipal purposes, 160 acre-feet is for a bottled water operation owned by Hill Country Spring Water.

Total annual naturalized flow and the annual volume of unappropriated water for the period of 1940 to 1978 for the Sabinal River, Seco Creek, and Hondo Creek are shown in Figure 4-8.[12] Total annual naturalized flow for the same period for Middle Verde Creek is also shown in Figure 4-8.

Analysis of flow data for Middle Verde Creek near Bandera County is hampered by the absence of gage records above the Edwards-San Antonio recharge zone. It is expected that flows in the creek upstream of the recharge zone would be similar to those at the adjacent gaged sites in Hondo and Seco Creeks. The natural flows shown in Figure 4-8 for Middle Verde Creek at the proposed reservoir site were derived using the adjacent Hondo Creek gage above the recharge zone.[13]

Determination of water available for appropriation in the headwaters of the Nueces River Basin is complicated by the Edwards-San Antonio recharge zone. The TWC's water availability model for the Nueces River Basin does not recognize natural recharge as a water right protected from further appropriation. Thus, the TWC flow data shown in Figure 4-8

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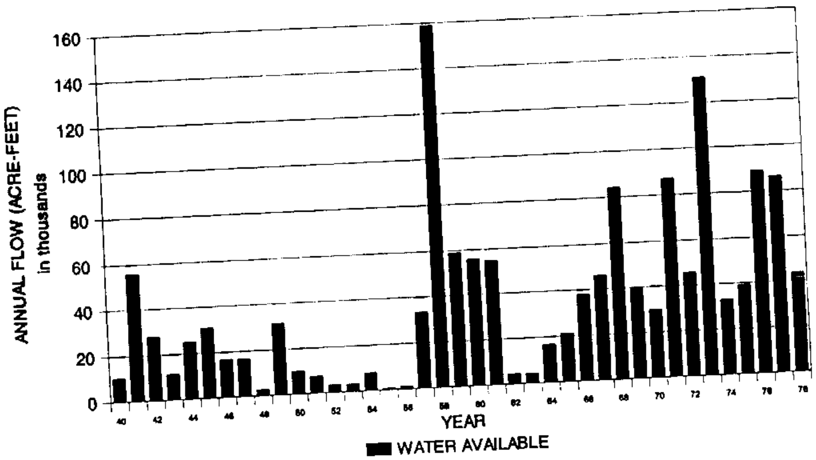
[12]Texas Water Commission, Water Availability Model for the Nueces River Basin. Period of record modeled is 1940 to 1978.

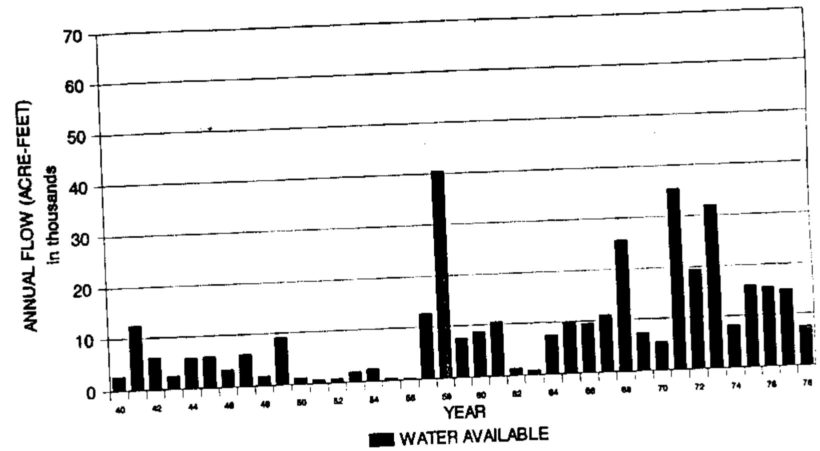
[13]HDR Engineering, Inc." Regional Water Supply Planning Study, Nueces River Basin," May, 1991.

NATURALIZED FLOW IN SABINAL RIVER
AT USGS GAGE 08198000



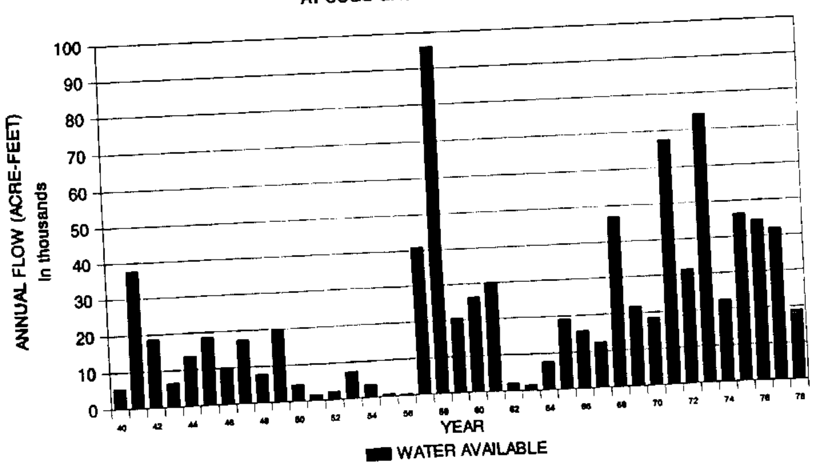
BASED ON THE TEXAS WATER COMMISSION'S WATER AVAILABILITY MODEL FOR THE NUECES RIVER BASIN

NATURALIZED FLOW IN SECO CREEK
AT USGS GAGE 08201500



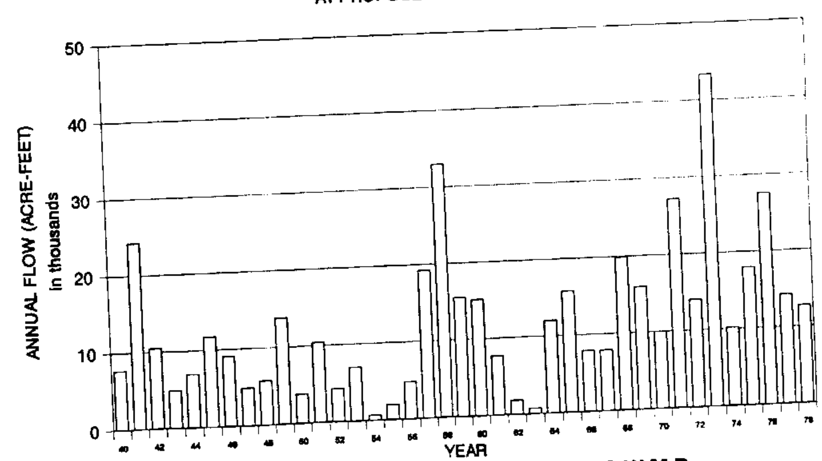
BASED ON THE TEXAS WATER COMMISSION'S WATER AVAILABILITY MODEL FOR THE NUECES RIVER BASIN

NATURALIZED FLOW IN HONDO CREEK
AT USGS GAGE 08200000



BASED ON THE TEXAS WATER COMMISSION'S WATER AVAILABILITY MODEL FOR THE NUECES RIVER BASIN

NATURALIZED FLOW IN MIDDLE VERDE CREEK
AT PROPOSED DAM SITE



SOURCE: HDR Engineering, Inc. "Regional Water Supply Planning Study, Nueces River Basin", May 1991.

SPRINGHILLS W.M.D.
REGIONAL WATER SUPPLY STUDY

HDR Engineering, Inc.

NATURALIZED FLOWS IN SABINAL RIVER AND HONDO, SECO, AND MIDDLE VERDE CREEKS

FIGURE 4-8

indicates the majority of the flow in the Nueces River Basin above the recharge zone is available for appropriation.

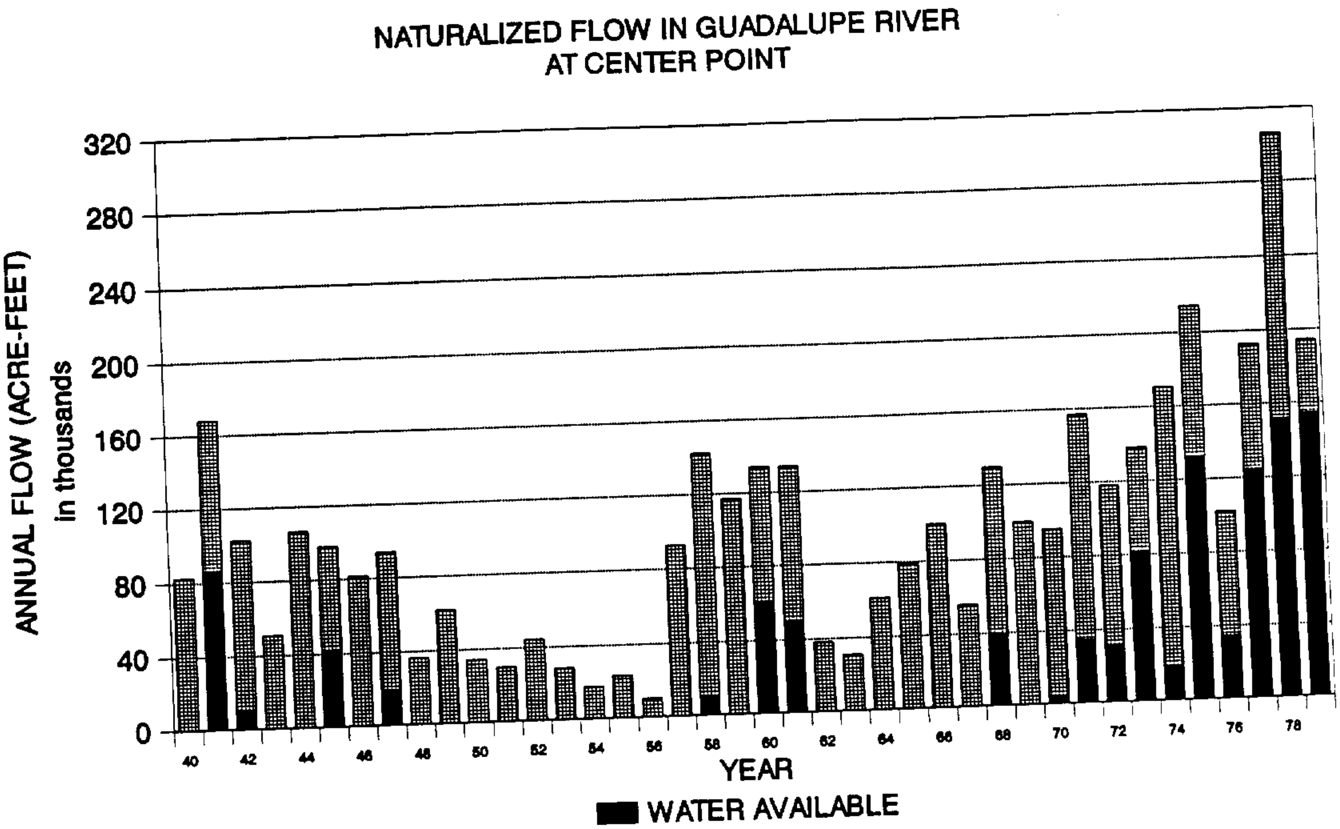
Further complicating the potential for securing water from the Nueces River Basin is the fact that the Edwards Underground Water District (EUWD) is currently evaluating sites for recharge reservoirs in Medina and Uvalde County to enhance recharge to the Edwards-San Antonio Aquifer. Additionally, the Guadalupe-Blanco River Authority (GBRA) has filed a lawsuit against the State of Texas contending that water flowing in the Edwards-San Antonio Aquifer should be considered an underground river and subject to appropriation by the state. Finally, diversion of water from the Nueces River Basin into the areas of need in Bandera County (San Antonio River Basin) would require an inter-basin transfer permit from the Texas Water Commission. Successfully securing water rights out of the Nueces River Basin would potentially be a very time consuming and expensive process.

4.6.3 Guadalupe River Basin

Existing water rights from the Guadalupe River Basin in Bandera County are limited. Three water rights exist, two of which are recreation rights, while the other is an irrigation right. The total annual permitted diversion is 8 acre-feet, which is accounted for by the irrigation right.

Total annual natural flow and the annual volume of unappropriated water for the period of 1940 to 1979 for the Guadalupe River at Center Point are shown in Figure 4-9.[14]

[14] Texas Water Commission, Water Availability Model for the Guadalupe/San Antonio River Basin. Period of record modeled is 1940 to 1979.



BASED ON THE TEXAS WATER COMMISSION'S WATER AVAILABILITY MODEL FOR THE GUADALUPE/SAN ANTIONO RIVER BASIN

SPRINGHILLS W.M.D.
REGIONAL WATER SUPPLY STUDY

NATURALIZED FLOWS IN GUADALUPE RIVER

HDR

HDR Engineering, Inc.

FIGURE 4-9

The flows of the Guadalupe River and its tributaries upstream of Canyon Lake are fully appropriated virtually all of the time under hydropower rights held by GBRA under Certificates of Adjudication 18-5488 and 18-5172, other rights held by GBRA (including 18-2074C authorizing Canyon Lake), and water rights held by others[15].

Under an existing program operated by GBRA, upstream users are allowed (for a price) to divert and use flows of the Guadalupe River upstream of Canyon Lake. The net result is a decrease in water utilized by GBRA for hydropower generation; however, water is made available to users upstream who otherwise would be unable to divert water to meet their needs. To date, a total of 27 users (permitted for a total of 2,709 acre-feet per year) have been supplied by this means, and it is anticipated that this program will continue[16]. Water diverted from the Guadalupe River above Canyon Lake into the San Antonio River Basin would require negotiating a contract with GBRA and may require an inter-basin transfer permit from the Texas Water Commission.

4.7 Surface Water Quality

The various surface water sources in Bandera County have good water quality for use as drinking water. However, like the groundwater, the surface water is highly mineralized with calcium bicarbonate and is characterized as being very hard. The total dissolved solids, however, are lower than those in the groundwater. More importantly, none of the measured constituents exceed TDH primary or secondary standards. Because of the lower dissolved

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[15] Guadalupe-Blanco River Authority and HDR Engineering, Inc., "Regional Water Plan for the Guadalupe River Basin," January, 1991.

[16] Ibid.

solids, sulfates, and other ions, the water should not have a salty taste like some of the groundwater. Water quality data for the major surface water sources in Bandera County are summarized in Tables 4-6 and 4-7.

Currently, only Holiday Water Service Company, located near Medina Lake, utilizes surface water for a drinking water supply in Bandera County. The quality of their treated water diverted from Medina Lake is shown in Table 4-6. The pH values vary somewhat, but are generally 8 or above. This is indicative of water that is scale forming and is saturated with calcium bicarbonate. Holiday's water treatment plant uses a conventional process with disinfection, mixing, coagulation, settling, and filtration. The limiting factor in utilizing water from Medina Lake is the accessibility of the water due to the wide fluctuations in the water levels and the fact that the lake will go dry during a repeat of the 1950's drought.

The Medina River near Bandera is a potential source of surface water for the county, provided contractual arrangements could be reached with BMA. As the main source of water to Medina Lake, its water quality is very similar to the lake. Because of the City of Bandera's wastewater discharge, the part of the river downstream of Bandera experiences higher loadings of fecal coliform bacteria. In assessing sources as possible drinking water supplies, this must be considered since the possibility of disease transmission is much greater with the presence of fecal coliform bacteria.

Water in the Sabinal River is also of good quality and would be easily treatable for a public drinking water supply. The river experiences some changes in pH similar to Medina Lake. If the treated water pH is not adjusted up to near 8, the water with lower pH values may become corrosive instead of scale-forming, and can cause periodic leaching

TABLE 4-6
Surface Water Quality in Bandera County

Constituent	Texas Department of Health Standard for Treated Water	Medina Lake **	Medina River at Bandera ***	Sabinal River near Sabinal (Uvalde Co.) ***	Hondo Creek near Tarpley ***	Seco Creek near Utopia (Medina Co.) ***
pH	≥7.0	8.2	8.1	8.0	7.8	8.4
Color	15*	-	7	3	1	2
Turbidity	>1	-	1.0	0.3	0.5	0.3
Coliform (fecal) (cols/100 ml)	0	-	21	70	25	37
Calcium (mg/l as Ca)	-	65	79	64	55	57
Chloride (mg/l)	300*	27	13	16	11	14
Fluoride (mg/l)	2.0*	0.2	0.3	0.2	0.2	0.2
Magnesium (mg/l as Mg)	-	17	22	14	11	13
Nitrate (mg/l as N)	10	0.07	<0.1	<0.1	<0.1	<0.1
Sodium (mg/l)	-	9	9	11	7.2	8.0
Sulfate (mg/l)	300*	90	130	35	51	66
Total Hardness (mg/l as $CaCO_3$)	-	230	290	220	180	200
Non-Carbonate Hardness (mg/l as $CaCO_3$)	-	-	130	38	53	75
Total Alkalinity (mg/l as $CaCO_3$)	-	117	157	180	130	121
P. Alkalinity (mg/l as $CaCO_3$)	-	0	-			
Carbonate (mg/l)	-	0	-			
Bicarbonate (mg/l)	-	143	-			
Total Dissolved Solids (mg/l)	1000*	280	363	266	224	241
Total Organic Carbon (mg/l)	-	-	1.8	2.4	1.2	1.9
Arsenic (mg/l)	0.05	<0.010	<0.001	<0.001	<0.001	<0.001
Barium (mg/l)	1.0	<0.50	0.036	0.036	0.023	0.024
Cadmium (mg/l)	0.01	<0.005	<0.001	<0.001	<0.001	<0.001
Chromium (mg/l)	0.05	<0.02	<0.001	0.001	<0.001	0.010
Copper (mg/l)	1.0*	<0.02	<0.001	0.001	<0.001	<0.001
Iron (mg/l)	0.3*	0.02	<0.003	0.006	0.007	0.011
Lead (mg/l)	0.05	<0.02	<0.001	<0.001	<0.005	<0.005
Manganese (mg/l)	0.05	<0.02	0.002	0.003	0.002	<0.001
Mercury (mg/l)	0.002	<0.002	<0.0001	<0.0001	<0.0001	<0.0001
Selenium (mg/l)	0.01	<0.002	<0.001	<0.001	<0.001	<0.001
Silver (mg/l)	0.05	<0.01	<0.001	<0.001	<0.001	0.001
Zinc (mg/l)	5.0*	0.06	0.003	0.008	0.005	0.046

*Secondary Standard
**Treated Medina Lake water from Holiday Water Service Plant; Water Analysis Report - Texas Department of Health; 9/25/86
***Raw Water; Water Resources Data - Texas; U.S. Geological Survey Water-Data Report, TX-89-3; Aug. 1989 - Medina River, Sabinal River Jan. 1989 - Hondo Creek, Seco Creek

TABLE 4-7 Summary of Springhills WMD's Monthly Water Quality Data from May 1988 to October 1990					
	Ranges of Constituents				
Constituents	**Medina Lake**	**Medina River near Bandera**	**Sabinal River along Hwy. 187**	**Hondo Creek near Hwy. 462**	**Seco Creek near Hwy. 470**
Dissolved Oxygen (mg/l)	6.0-11.8	7.0-11.8	6.2-11.2	7.5-14.8	5.6-10.2
Temperature (°C)	8.0-30.5	6.5-28.0	9.0-33.5	2.0-32.0	11.0-28.0
Nitrate (mg/l as N)	0.1-0.7	<0.1-6.4	0.1-3.2	0.04-1.2	<0.1-1.3
Chloride (mg/l)	12.0-18.0	<0.1-58.0	1.0-26.0	0.8-23.0	0.8-18.0
pH	6.8-8.7	7.4-8.4	7.1-8.6	7.9-8.5	7.3-8.2
Fecal Coliform (cols/100 ml)	1-420	4-3827	4-740	2-386	1-724

of iron, copper, and lead into the water from pipes. The changes in pH are often caused by temperature changes, heavy rainfall events, and changes in dissolved gasses. The pH can easily be adjusted in a treatment plant using lime or caustic soda.

Water in Hondo Creek is very hard and has a mineral content similar to some of the groundwaters. This reflects runoff from rocks and soils similar to the conditions encountered by the water that percolates through the aquifers. The quality is also influenced by springs which discharge in the creek drainage area. Runoff from the limestone and thin, vegetated topsoils along with the springs give the water in Hondo Creek very low turbidity. This indicates that there are very few suspended particles and is generally a sign of good water quality.

Seco Creek's water quality is similar to that of the other surface water sources. It exhibits periodic increases in fecal coliform concentrations, as do the other sources. Unlike the Medina River, which has a domestic wastewater discharge, the increased fecal coliform concentrations in Seco Creek are probably caused by non-point source runoff such as livestock areas and septic tanks.

SECTION 5

5.0 WATER SUPPLY NEEDS

5.1 Quantity

Groundwater provides virtually all of the municipal water needs in Bandera County. Groundwater resources include the Trinity Group Aquifer, which underlies the entire county, and the Edwards Plateau Aquifer, which exists in the higher elevations of northwestern Bandera County. As presented in Section 4.0, the quantity of groundwater which can be safely withdrawn (or "duty") from the Trinity Group Aquifer is approximately 8.5 acre-feet per square mile per year, while the Edwards Plateau Aquifer can provide a duty of approximately four acre-feet per square mile per year. Based on these figures, the groundwater duty for the entire county is estimated to be 7,200 acre-feet per year, of which 6,500 acre-feet is available from the Trinity Group Aquifer and 700 acre-feet is available from the Edwards Plateau Aquifer.

On the surface, this duty appears to be sufficient to meet Bandera County's projected municipal water demand of 5,629 acre-feet in the year 2040. However, based on existing population concentrations and projected population growth, the current and projected municipal water demands are not uniformly distributed across the county. The more densely populated areas, which include the City of Bandera and eastern Bandera County, exhibit the need for additional water supply to supplement their local groundwater resources. With proper management, the less densely populated areas of western Bandera County are likely to have adequate groundwater supplies, unless more rapid growth than is projected occurs.

To put the groundwater duty estimate of 8.5 acre-feet per square mile per year into perspective, an example is provided. Assume an average family uses 10,000 gallons of water per month (roughly equal to 2.5 persons using 133 gpcd) for a total of 120,000 gallons in a year. This is equivalent to 0.37 acre-feet in a year (one acre-foot equals 325,851 gallons). If the house had a well which pumped at a rate equal to the groundwater duty, the well would need on the average about 28 acres of land to be effectively recharged at the same rate.

A comparison between the county's projected municipal water demands and the groundwater duty for each subarea is shown in Table 5-1. Water use in Subarea B (Medina Lake) and Subarea E (City of Bandera) is currently exceeding the estimated safe yield of the groundwater, resulting in declining water levels and a gradual depletion of aquifer storage in these local areas. Municipal water demands in Subareas A and D are projected to exceed the groundwater duty by the year 2000, and the groundwater duty in Subarea F is projected to be exceeded by the year 2010. The municipal water demands listed in Table 5-1 do not include projected agricultural water demands for irrigation and livestock, which are assumed to be largely met by existing surface water rights, stock tanks, and existing wells. The majority of the agricultural water demand is in the larger western subareas of the county where projected municipal water demands are relatively low (See Section 2.0). Subareas in which the municipal water demand is projected to exceed the groundwater duty by the years 2000 and 2040 are shown in Figure 5-1. Eastern portions of Bandera County, which include the City of Bandera, the area north of Medina Lake, and the areas bordering S.H. 16, have the greatest need for additional water supply during the 50-year planning period. With proper management, the western portion of Bandera County will likely continue to have adequate groundwater resources to the year 2040.

TABLE 5-1
Municipal Water Demands and Groundwater Supply Summary
Bandera County

Subarea	Area (acres)	Groundwater Duty (ac-ft/yr)	Municipal Water Demand (ac-ft/yr)					
			1990	2000	2010	2020	2030	2040
A	34,601	458	193	555	897	1,199	1,455	1,767
B	5,215	69	227	408	502	569	619	673
C	23,118	306	92	99	106	112	110	125
D	14,172	187	115	300	456	588	697	826
E	553	7	207	201	194	197	201	205
F	43,372	573	251	511	676	800	897	1,004
G	35,933	475	191	259	307	341	365	391
H	44,577	590	113	118	123	128	132	137
I	251,332	4,024	152	215	261	293	317	343
J	38,647	511	53	85	110	128	142	158
TOTAL	491,520	7,200	1,594	2,851	3,632	4,355	4,935	5,629

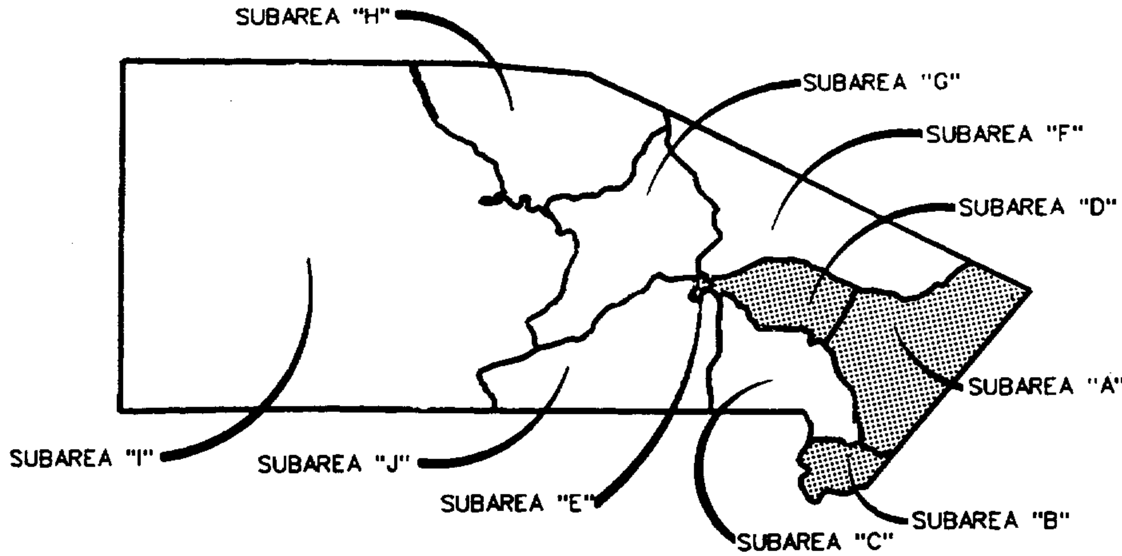
Notes:

1. Groundwater duty is the annual sustained yield that can be withdrawn from an aquifer which will prevent adverse long-term water level declines and related adverse encroachment of poor quality water. Total groundwater duty for the county is estimated to be 7,200 acre-feet/year (700 acre-feet for the Edwards Plateau Aquifer and 6,500 acre-feet/year for the Trinity Group Aquifer).

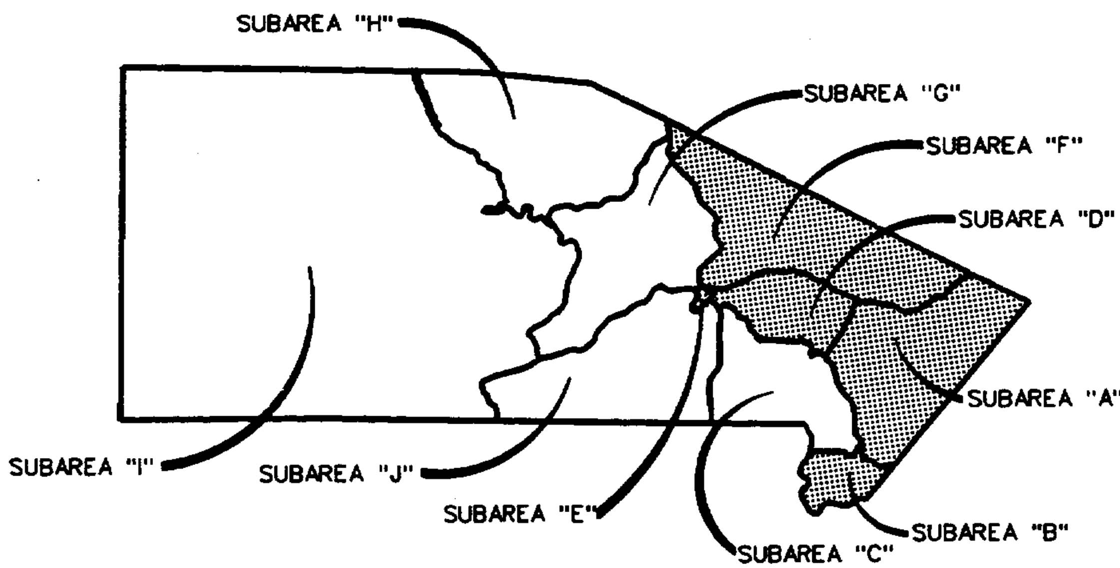
2. Groundwater duty for Subarea I includes an estimated duty of 700 acre-feet/year for the Edwards Plateau Aquifer and 3,324 acre-feet/year for the Trinity Group Aquifer.

3. Shading indicates municipal water demand exceeds groundwater duty available.

The analysis shown in Table 5-1 and Figure 5-1 is based on the census subarea boundaries used to estimate future population and water use. These boundaries largely consist of major roadways and other easily identifiable physical features in the county.



1990 - 2000



2010 - 2040

SUBAREAS REQUIRING ADDITIONAL WATER SUPPLY

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WATER SUPPLY NEEDS BY SUBAREA

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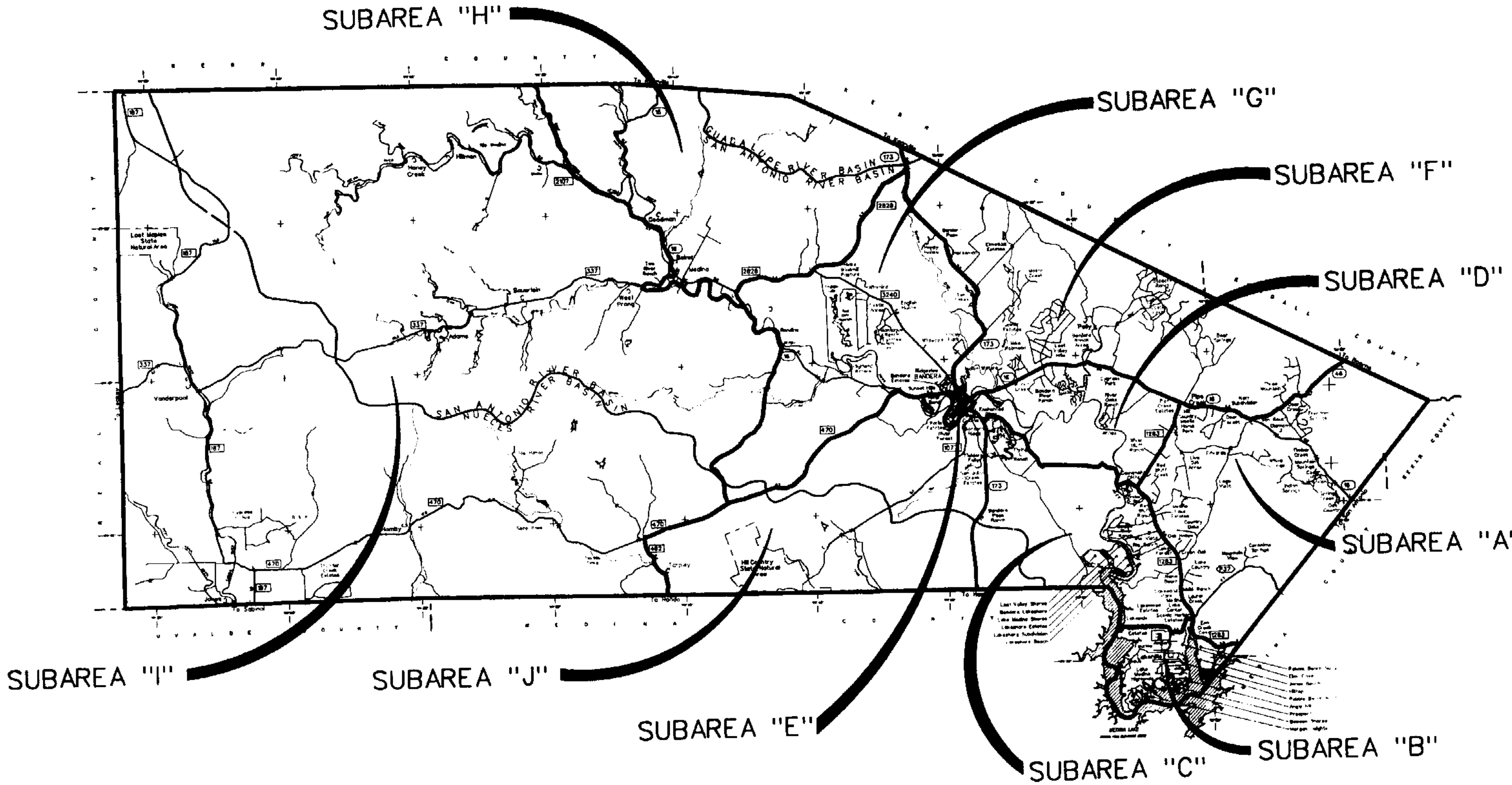
FIGURE 5-1

Based on existing trends, future growth is likely to occur along the major roadways and areas which adjoin rivers and streams. The existing platted residential developments in Bandera County are shown in Figure 5-2. Subdivisions shown in green are served by a public water system. The others, in red, are virtually all using individual wells for water supply. Nearly all of the residential development is occurring in the eastern half of the county, particularly near Medina Lake, along the Medina River, and adjacent to S.H. 16 and FM 1283. Ignoring the subarea boundaries, an interpretation was made of areas in the county that will need additional water supply during the planning period. This interpretation, shown in Figure 5-3, illustrates that approximately 23 percent of the county (177 square miles) is considered to be in an area designated as having a "critical" need for additional water supply, 9 percent (69 square miles) is in an area designated as having a "marginal" water supply, and 68 percent (522 square miles) is designated as having an "adequate" water supply.

A summary of municipal water needs in excess of the groundwater duty using the figures from Table 5-1 is provided in Table 5-2. It is these municipal demands which will need to be satisfied by a new water supply source to avoid further mining and potential quality deterioration of the existing groundwater supply.



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SUBDIVISION DEVELOPMENT IN
BANDERA COUNTY

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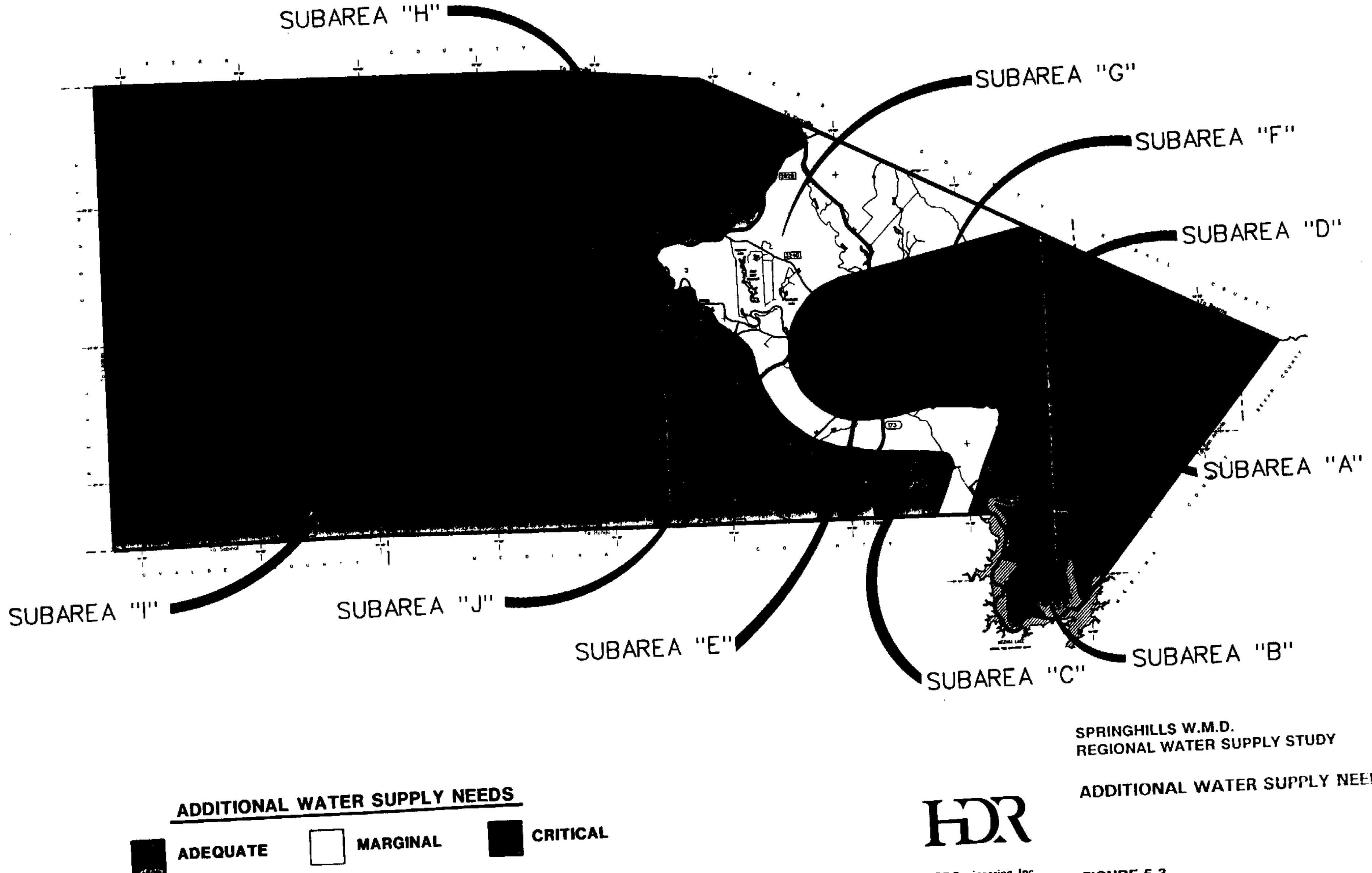
FIGURE 5-2



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ADDITIONAL WATER SUPPLY NEEDS

FIGURE 5-3

TABLE 5-2 Municipal Water Needs in Excess of Groundwater Duty	
Year	**Need (ac-ft/yr)**
1990	358
2000	743
2010	1,431
2020	2,059
2030	2,575
2040	3,181

5.2 Quality

In addition to projected water deficiency in eastern Bandera County, water quality problems also exist. Public water systems located in eastern Bandera County, primarily within Subarea A, are producing very poor quality water from the Trinity Group Aquifer (See Table 4-2). As groundwater pumpage continues in these areas, water quality will likely deteriorate further due to vertical leakage of poor quality water and increasing concentrations of sulfates and total dissolved solids. Therefore, in addition to a projected water supply deficiency, eastern Bandera County may also face additional water quality problems, thereby furthering the need for a good quality supplemental water supply.

SECTION 6

6.0 ALTERNATIVE WATER SUPPLY SOURCES

6.1 Background

A total of 10 water supply alternatives capable of meeting the future water demands of Bandera County were investigated. These include both groundwater and surface water alternatives. The criteria used for sizing, phasing of project components, and cost estimating were the same for each alternative, providing a consistent basis for comparison. Estimates of total project costs, annual power and operation and maintenance costs, and annual water purchases were made for each alternative. To provide a common economic basis for comparison, monthly cost increases per connection and the cost of water per 1,000 gallons produced were calculated for each alternative.

Each alternative was sized to supply the average annual municipal water demand in excess of the groundwater duty for the county's critical areas of need. Two phases were examined for each water supply alternative: Phase I covers the 25-year period from 1995 to 2020; and Phase II covers the 20-year period from 2020 to 2040. The estimated average annual municipal water demand in excess of the safe groundwater supply for these two phases is approximately 2,000 acre-feet per year for Phase I and 3,200 acre-feet per year ofr Phase II (Table 5-2). Sizing the alternatives in this manner reduces the capacity requirements and minimizes costs by assuming that temporary demands for water in excess of the new system's capacity will be provided from groundwater. This temporary use of the groundwater supply is acceptable as long as the average annual groundwater usage does not exceed the estimated safe duty of the aquifer, which is the case.

The water supply alternatives presented herein were formulated with consistent sizing of system components. Water treatment plants, distribution piping, and numbers of wells were sized to meet the average annual municipal demand at the end of each phase. River intakes and pump stations were sized to deliver approximately 1.5 times the average annual pumping requirement to allow for flexibility in delivering raw water to storage reservoirs. Consideration was also given to leaving minimum flows for fish and wildlife in the Medina and Guadalupe Rivers. Reservoirs on major tributaries were sized at their ultimate (2040) storage capacity in Phase I and off-channel reservoirs on minor tributaries were sized to provide the required storage at the end of each phase. Sizing of termination storage facilities and local distribution system improvements were not included because of the uncertainty of predicting the configuration of future systems and because some distribution systems with adequate storage are already in place. However, a regional water distribution system was included along major roadways, and is described in Section 6.2.

The selection of potential reservoir sites was based on proximity to existing and expected demands, topographic suitability for construction, proximity to potential diversion locations for supplemental water, and potential relocations. Suitable geologic conditions were assumed to occur at each reservoir site.

The estimated construction costs for Phase I and II for each alternative were based on estimated 1991 construction cost information obtained from data on similar type projects which have recently been bid. Detailed studies and cost estimates will be required to refine the costs prior to design, financing, and implementation of the selected projects. The cost estimates prepared for this report are considered to be preliminary; they are appropriate only for comparing alternatives, and are subject to change as more detailed information becomes available.

Total project cost estimates include right-of-way and relocation costs, 15 percent for construction contingencies, and 20 percent for permitting, engineering, legal, and financial services. Estimates of environmental mitigation costs for reservoir sites, river diversions, and river crossings were also included (Appendix B). The annual debt service factor was calculated assuming financing at an interest rate of 7.5 percent for 25 years in Phase I and 20 years in Phase II. The debt service for each phase is assumed to be retired at the end of that phase. The interest rate currently being offered by the Texas Water Development Board (TWDB) is 7.2 percent.

Power costs were calculated using $0.07 per kilowatt-hour and an average gradient over the length of each phase (i.e., 25 years for Phase I and 20 years for Phase II). The gradient was then used to calculate the present worth of the power at the beginning of each phase. This present worth amount was then annualized using 7.5 percent over the length of each phase to determine an average annual power cost.

Annual operation and maintenance (O&M) costs were estimated as one percent of the total construction cost, except for water treatment plants and dams. For the water treatment plants, annual O&M costs were set at $0.30 per 1,000 gallons of treated water, or a minimum of $75,000. For the dams, the annual O&M cost was assumed to be $30,000.

Because of the lack of unappropriated surface water in Bandera County, water diverted from the Medina Lake watershed will impact downstream water rights, necessitating compensation for this impact. For the purposes of this study, it was assumed that the

District will negotiate a water contract with the Bexar-Medina-Atascosa Water Control Improvement District No. 1 (BMA), and that the water will be paid for on a "pay-for-use" basis at a rate of $0.17 per 1,000 gallons ($56 per acre-foot) used. This cost is based on two existing contracts which BMA has negotiated for municipal water use in Bandera County (Table 4-4).

For water supply alternatives that involve diverting water from the Guadalupe River into Bandera County, it was assumed that a water contract will be negotiated with the Guadalupe-Blanco River Authority (GBRA). Based on discussions with GBRA, it was assumed that water will be paid for on a "take-or-pay" basis at a rate of $0.16 per 1,000 gallons ($53 per acre-foot).

For the water supply alternative which diverts water from Middle Verde Creek in the Nueces River Basin, it was assumed that unappropriated water is available for diversion. Actually, this may not be the case (as discussed in Section 4.6.2); however, this assumption provided the lowest possible cost for this alternative for comparison with the others.

For the water supply alternative which consists of purchasing treated water from the City of Boerne, a rate of $1.70 per 1,000 gallons was assumed. This rate was based on Boerne's current water rate structure, and an anticipated increase that would have to be paid for expanding Boerne's supply and treatment capabilities so it can use water diverted from the Guadalupe River to Boerne Lake.

Total annual costs were computed by adding the individual annual costs for debt service, power, O&M, and water purchases. To compare alternatives on a similar economic basis, the estimated monthly cost increase per connection and the cost of producing 1,000 gallons of water were determined for each alternative. The alternatives are compared at three separate points in time: 1995 (initial); 2020; and 2040. The number of connections to be served by the new water supply system in each of these years was calculated based on the projected population divided by an average of 2.5 people per connection. This resulted in 2,300, 7,400, and 9,900 connections in the years 1995, 2020, and 2040, respectively. The cost per 1,000 gallons was calculated based on projected average annual municipal usage of the new system of 550, 2,000, and 3,200 acre-feet per year in 1995, 2020, and 2040, respectively.

An introduction to the 10 water supply alternatives and a summary of the Phase I and II costs are provided in Table 6-1. Detailed listings of project component cost, and annual costs for construction, power, O&M, and water for Phases I and II of each alternative are included in Appendix C. A description of each alternative is provided in Section 6.3.

6.2 Water Distribution System

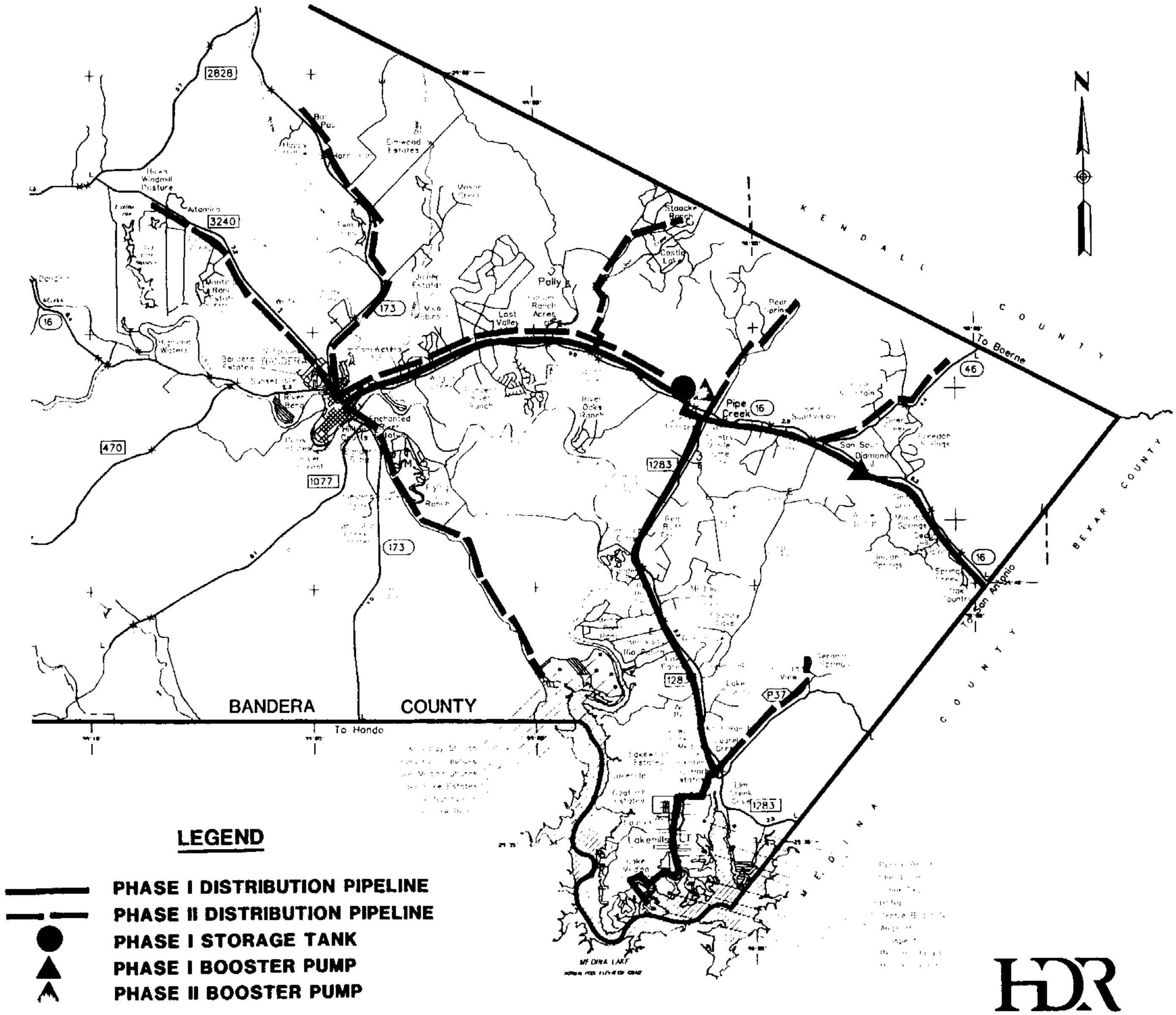
A distribution system to deliver the new water supply is a common element to each alternative. This distribution system, shown in Figure 6-1, would deliver either groundwater or treated surface water, depending on the water supply source.

The initial distribution system would provide water to the major existing public supply entities within the critical areas of need (Figure 5-3) including: all of Subareas A, B, D, and E; the eastern portion of Subarea C near Medina Lake; and the southern portion of Subarea F along S. H. 16. Holiday Water Service Company was not connected to the Phase I distribution system. Holiday serves the subdivisions west of Medina Lake in

TABLE 6-1
Summary of Water Supply Alternatives

Alternative	Phase I				Phase II			
	Initial		2020		2020		2040	
	$/1000	$/Month	$/1000	$/Month	$/1000	$/Month	$/1000	$/Month
1. Groundwater Pumping from West	7.27	47.17	2.05	15.03	1.92	14.12	1.28	11.24
2. Town Mtn. Dam w/Pumping from Medina River	7.04	45.70	2.26	16.60	2.12	15.58	1.53	13.43
3. Bandera Creek Dam w/Pumping from Medina River	7.77	50.46	2.43	17.84	1.62	11.86	1.22	10.70
4. Bandera Creek Dam w/Pumping from Guadalupe River	8.89	57.75	2.63	19.31	1.88	13.77	1.37	12.05
5. Mason Creek Dam w/Pumping from Medina River	9.31	60.48	2.86	21.01	1.88	13.76	1.39	12.19
6. Mason Creek Dam w/Pumping from Guadalupe River	10.28	66.76	3.01	22.11	2.03	14.92	1.48	12.96
7. Upper Privilege Creek Dam w/Pumping from Medina River	9.43	61.21	2.90	21.30	1.91	14.03	1.41	12.40
8. Lower Privilege Creek Dam - w/Pumping from Medina River	10.69	69.42	3.24	23.80	1.77	12.98	1.32	11.54
9. Middle Verde Creek Dam - Nueces River Basin	9.75	63.32	2.87	21.04	1.81	13.27	1.29	11.32
10. Purchase Treated Water from City of Boerne	6.98	45.33	3.15	23.13	3.08	22.57	2.61	22.91

Notes:
1. Cost per 1,000 gallons for Phase I initial (1995) conditions based on average annual demand of 550 acre-feet per year. Monthly cost per connection based on 2,300 connections served.
2. Cost per 1,000 gallons for end of Phase I and start of Phase II in 2020 based on average annual demand of 2,000 acre-feet per year. Monthly cost per connection based on 7,400 connections served.
3. Cost per 1,000 gallons for end of Phase II in 2040 based on average annual demand of 3,200 acre-feet per year. Monthly cost per connection based on 9,900 connections served.
4. Costs based on 1991 dollars.



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WATER DISTRIBUTION SYSTEM

FIGURE 6-1

Subarea C and presently has the capability to utilize 170 acre-feet of surface water annually from Medina Lake. It was assumed that this source, in addition to their groundwater supply, would satisfy their water needs until 2020, at which time Phase II of the distribution system would be extended to provide Holiday with additional water. Phase I of the distribution system was sized assuming the projected average day municipal water demand of 2,000 acre-feet per year in 2020 is distributed uniformly along the length of the pipelines.

Phase II of the distribution system would provide supply lines north from S.H. 16 into northern Subarea F, northwest of the City of Bandera along S.H. 173 and F.M. 3240 into Subarea G, southeast of the City of Bandera along F.M. 3240 through Subarea C, and northeast from the intersection of F.M. 1283 and Park Road 37 into Subarea A. Sizing of the Phase II distribution system assumed that the projected average day municipal water demand of 3,200 acre-feet per year in 2040 is distributed uniformly along the length of the pipelines. This would necessitate paralleling the Phase I main trunk line between the City of Bandera and the storage tank near Pipe Creek, as well as adding a booster pump station to the storage tank.

Piping for the distribution system ranges from four to 12 inches in diameter, and was sized to maintain flow velocity below four feet per second (fps) and pressures less than 200 pounds per square inch (psi). A two million gallon storage tank was included west of Pipe Creek to provide system flexibility and maintain at least one day of storage. A 20-foot easement width was assumed for all pipelines, except where a line would be paralleled in the future, in which case a 30-foot easement was used. A small pump station would be required east of S.H. 46 to boost water over Cedar Hill to serve areas near the eastern edge of the county.

The total project cost estimate for the Phase I distribution system is $5,000,000 in 1991 dollars. Phase II of the distribution system is estimated to have a total cost of $3,056,000 in 1991 dollars. As previously discussed, the distribution system is a common element to each water supply alternative, and must be added to the water supply and treatment components to obtain the total estimated project cost for Phases I and II of each alternative.

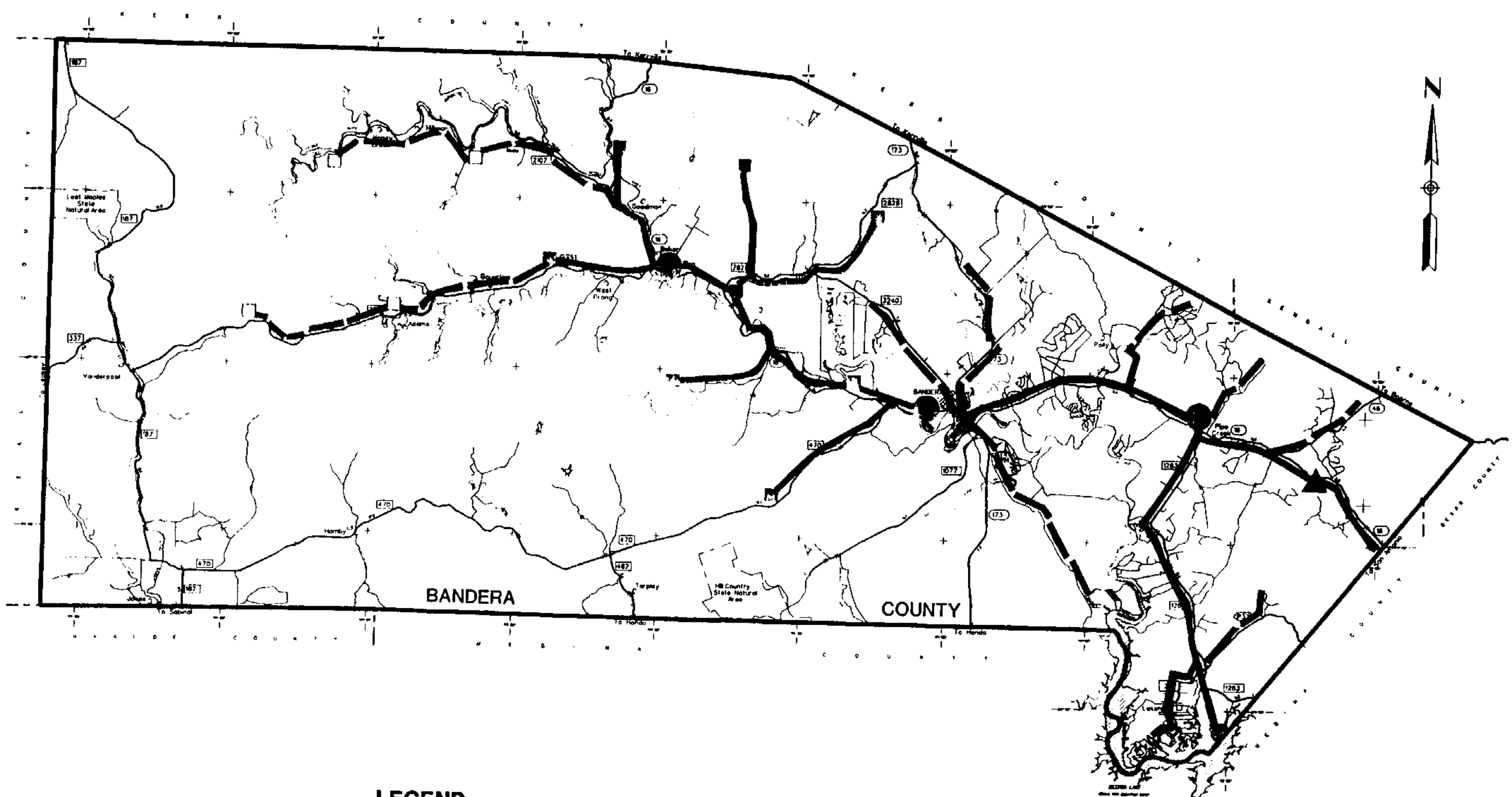
6.3 Description of Water Supply Alternatives

Following are descriptions of all 10 water supply alternatives investigated in this study. All costs are presented in 1991 dollars.

6.3.1 Alternative No. 1 - Groundwater Pumping from the West

For the study planning period, available groundwater will exceed the projected municipal water demand in the northern and western subareas of the county, based on the estimated safe groundwater duty (Table 5-1). Alternative No. 1 consists of installing large diameter production wells in Subareas G, H, and I to pump and deliver groundwater to the areas of need in eastern Bandera County.

Groundwater wells would be drilled into the Lower Trinity Aquifer approximately five to six miles apart along the major and secondary roads northwest and west of the City of Bandera as shown in Figure 6-2. This spacing assumes that each well is pumped at a



LEGEND

- PHASE I WELL
- PHASE II WELL
- BOOSTER PUMP
- PHASE I DELIVERY PIPELINE
- PHASE II DELIVERY PIPELINE
- STORAGE TANK W/BOOSTER PUMP
- PHASE I DISTRIBUTION PIPELINE
- PHASE II DISTRIBUTION PIPELINE

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ALTERNATIVE NO. 1
GROUNDWATER PUMPING
FROM WEST

FIGURE 6-2

sustained capacity of 150 to 170 gallons per minute (gpm). Phase I would consist of eight wells and Phase II would require an additional four wells to supply the projected demands.

The total project cost for Phase I is estimated to be $12,605,000. This cost includes: (1) test wells and a geohydrologic study; (2) piping ranging from six to 12 inches in diameter; (3) eight wells drilled approximately 1,000 feet deep; (4) chlorination at each well head; (5) a 500,000 gallon storage tank and pump station in Medina; (6) a 500,000 gallon storage tank near Bandera; and (7) the Phase I distribution system. The cost for pumping water from the Bandera storage tank into the distribution system is included in the cost of the distribution system. The total project cost for Phase II is estimated to be an additional $9,528,000, which includes: (1) additional piping ranging from six to 10 inches in diameter; (2) four wells; (3) modifications to the initial pump station at Medina; and (4) the Phase II distribution system.

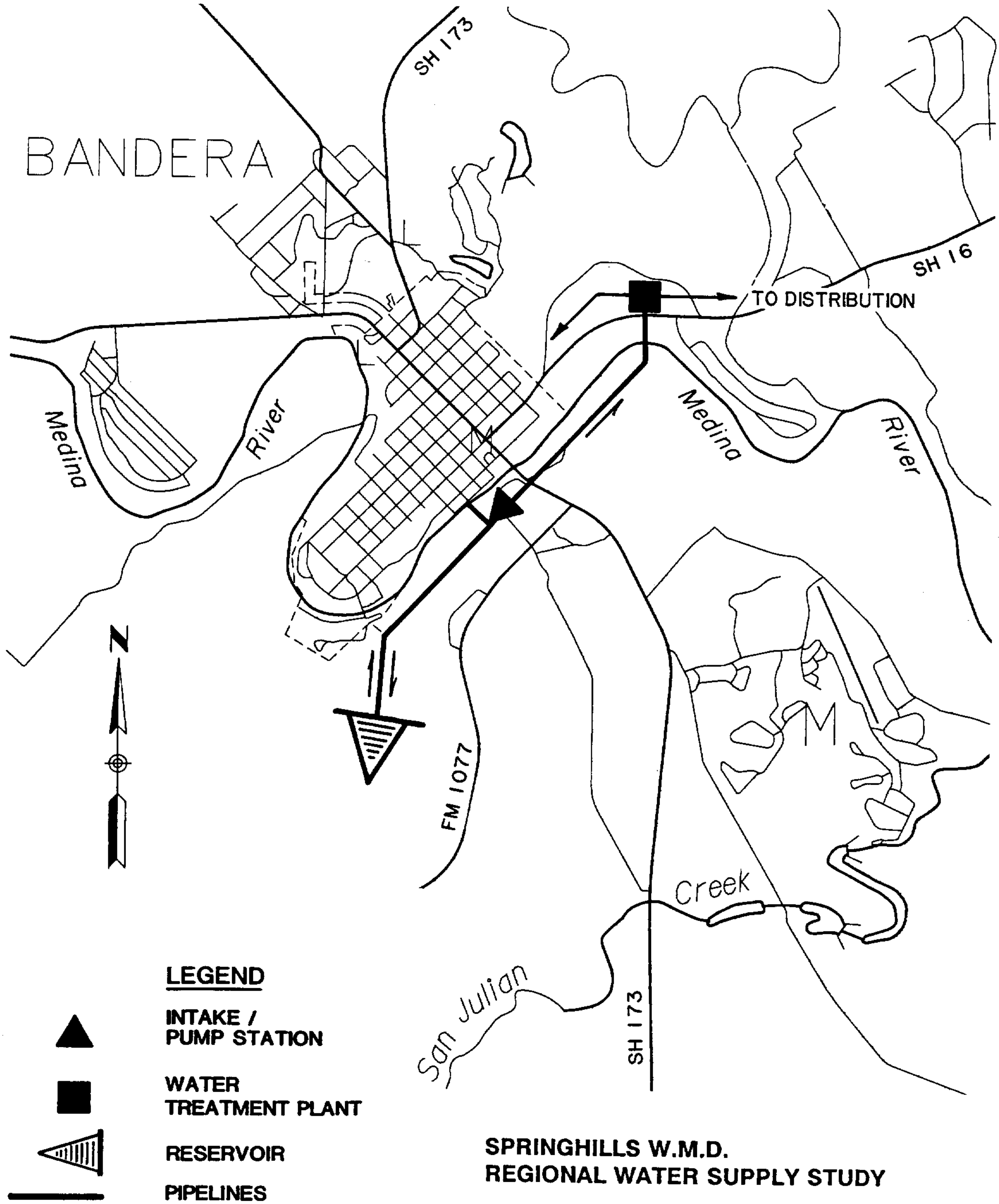
This alternative assumes that no other wells of significant capacity would be installed within the estimated five- to six-mile diameter of influence of each production well. Regulations would need to be established to ensure that the production wells are protected. This alternative also assumes that no water treatment, other than chlorination at the well head, would be required.

6.3.2 Alternative No. 2 - Town Mountain Dam with Pumping from Medina River

This alternative would provide treated surface water to the distribution system in eastern Bandera County. It consists of an off-channel dam and reservoir on an unnamed creek east of Town Mountain, a pump station on the Medina River at City Park Lake, and a package-type water treatment plant just east of the City of Bandera. Pipelines would connect each of these major components (Figure 6-3).

The concept of the off-channel dam and storage reservoir is to pump water from the Medina River when it is plentiful and then store it to satisfy demands during dry periods. The drainage area above the dam is very small and, therefore, natural inflows to the reservoir would not contribute significantly to the yield of the system. Because of the relatively small natural inflow, spillway requirements are minimal. The pump station and storage volume are sized for each phase to provide the average annual demand through the worst drought of record (in this case, a repeat of the 1950's drought). Additionally, it is assumed that a minimum flow of one cubic foot per second (cfs) will need to be maintained in the Medina River below City Park Lake for fish and wildlife considerations. Construction of the dam would be staged to provide only the maximum storage needed for each of the phases. Similarly, the pump station would be modified as needed in Phase II by installing larger and/or additional pumps. The pipelines connecting the major components are sized initially to accommodate Phase II flow rates.

The water treatment plant is anticipated to be a modular- or package-type plant. Package plants are built at a factory, skid-mounted, and transported virtually assembled to the operation site. They are typically used to treat small community water supplies that have consistently low to moderate turbidity levels. Their advantages include cost-effectiveness for small capacities when compared to conventional plants, compact size, ease of staging, relative ease of operation for consistent raw water, and capability for unattended operations utilizing automatic controls. For Phase I, the plant capacity is set at two million



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ALTERNATIVE NO. 2
TOWN MOUNTAIN DAM WITH PUMPING FROM MEDINA RIVER

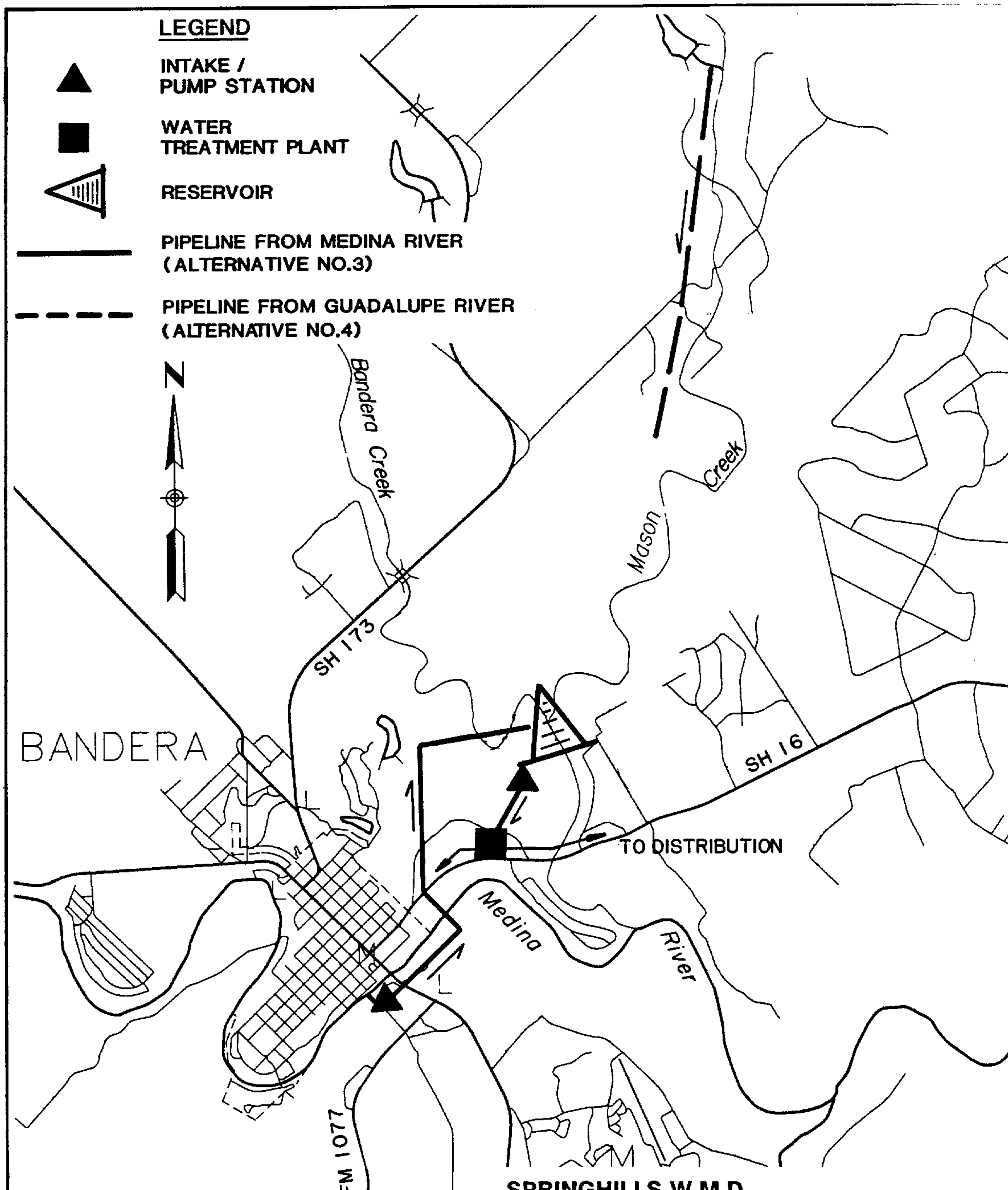
FIGURE 6-3

gallons per day (mgd). Additional treatment units would be installed in the plant to obtain a total capacity of 3.5 mgd for Phase II.

The total project cost for the Town Mountain alternative is estimated to be $11,341,700 for Phase I. This includes: (1) the initial stage of the dam; (2) a pump station at City Park Lake with a pipeline to the new reservoir; (3) a pipeline from the pump station site to the water treatment plant; (4) a two mgd water treatment plant; and (5) the Phase I distribution system. The Phase II total project cost is estimated to be $8,798,500, which includes: (1) raising the dam; (2) modifying the pump station; (3) expanding the treatment plant capacity to 3.5 mgd; and (4) installing the Phase II distribution system.

6.3.3 Alternative No. 3 - Bandera Creek Dam with Pumping from Medina River

The main difference between this alternative and the Town Mountain Dam alternative is that the storage reservoir is located on Bandera Creek, a major tributary of the Medina River just east of the City of Bandera (Figure 6-4). Natural inflows to the reservoir from the 56- square mile drainage area above the dam will help to reduce the amount of water that will need to be pumped from the Medina River to meet demands. Tributary reservoirs like Bandera Creek are sized to optimize the yield produced by just the reservoir in order to minimize pumping from the Medina River. Given their relatively large drainage areas compared to an off-channel site, tributary sites generally require more spillway capacity to pass large floods. This requirement makes it difficult to stage or enlarge tributary dams in the future. Therefore, tributary reservoirs are sized based on the ultimate



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ALTERNATIVES NO. 3 AND 4
BANDERA CREEK DAM WITH PUMPING FROM MEDINA OR GUADALUPE RIVERS

HDR

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FIGURE 6-4

(2040) average annual demand that would need to be provided by the reservoir. Only the average annual pumping rates to and from the reservoir change between Phases I and II.

Alternative No. 3 consists of the dam and reservoir on Bandera Creek; a pump station and pipeline from the Medina River at City Park Lake to deliver water to the new reservoir; a package-type water treatment plant; and a pump station and pipeline at the dam to supply the water treatment plant. Pumping rates from the Medina River were established assuming that a minimum flow of one cfs is maintained in the river. Pumping rates from the reservoir to supply the treatment plant were set equal to the average daily demand. The basic configuration of the system is the same for Phases I and II. The only difference is that for Phase II, the pump stations capacities are increased and the pipelines paralleled. For Phase II, additional treatment units would also be installed in the plant to obtain a total capacity of 3.5 mgd.

The total project cost for Alternative No. 3 is estimated to be $12,212,200 for Phase I. This includes: (1) the dam and reservoir, (2) a pump station at City Park Lake with a pipeline to the new lake; (3) a pump station at the dam with a pipeline to the treatment plant; (4) a two mgd water treatment plant; and (5) the Phase I distribution system. The Phase II total project cost is estimated to be $5,103,400, which includes: (1) modifying both pump stations; (2) paralleling each pipeline; (3) expanding the treatment plant; and (4) the Phase II distribution system.

6.3.4 Alternative No. 4 - Bandera Creek Dam with Pumping from Guadalupe River

This alternative is identical to the previous, except supplemental water is pumped from the Guadalupe River rather than from the Medina River. The pump station, located at an existing channel dam in Center Point, lifts water from the Guadalupe River over the basin divide and discharges it into the headwaters of Mason Creek in Bandera County. The water is then transported via the creek into the reservoir located on Bandera Creek below the confluence with Mason Creek (Figure 6-4). The amount of water which must be pumped from the Guadalupe River on an average annual basis is virtually identical to that which must be pumped from the Medina River in Alternative No. 3. Pumping rates from the Guadalupe River were established assuming that a minimum flow of two cfs is maintained in the river.

The total project cost for this alternative is estimated to be $13,272,900 for Phase I. The cost increase above Alternative No. 3 is due solely to the higher cost to pump and transport water from the Guadalupe River. All other components are identical. The estimated Phase II total project cost is $6,110,800. As with the previous alternative, Phase II will require modifying both pump stations, paralleling the pipelines, and expanding the water treatment plant.

6.3.5 Alternative No. 5 - Mason Creek Dam with Pumping from Medina River

This alternative is identical to Alternative No. 3, except that the storage reservoir is located on Mason Creek above the confluence with Bandera Creek (Figure 6-5). Topographically, this appears to be a favorable site. However, modelling indicates that the amount of supplemental pumping into the reservoir necessary to meet the 2040 average annual demand is greater than that required for the Bandera Creek site. This is primarily due to a decrease in the natural inflow contribution from a smaller drainage area (29 square miles rather than 56 square miles).

The total Phase I project cost for this alternative is estimated to be $14,820,100. The main items contributing to the cost increase above Alternative No. 3 are a higher dam cost and the increased pumping head and distance from the pump station at City Park Lake to the dam. The estimated Phase II total project cost is $6,014,200. Again, the initial pump stations would be modified, the pipelines paralleled, and the treatment plant expanded to provide the Phase II capacity.

6.3.6 Alternative No. 6 - Mason Creek Dam with Pumping from Guadalupe River

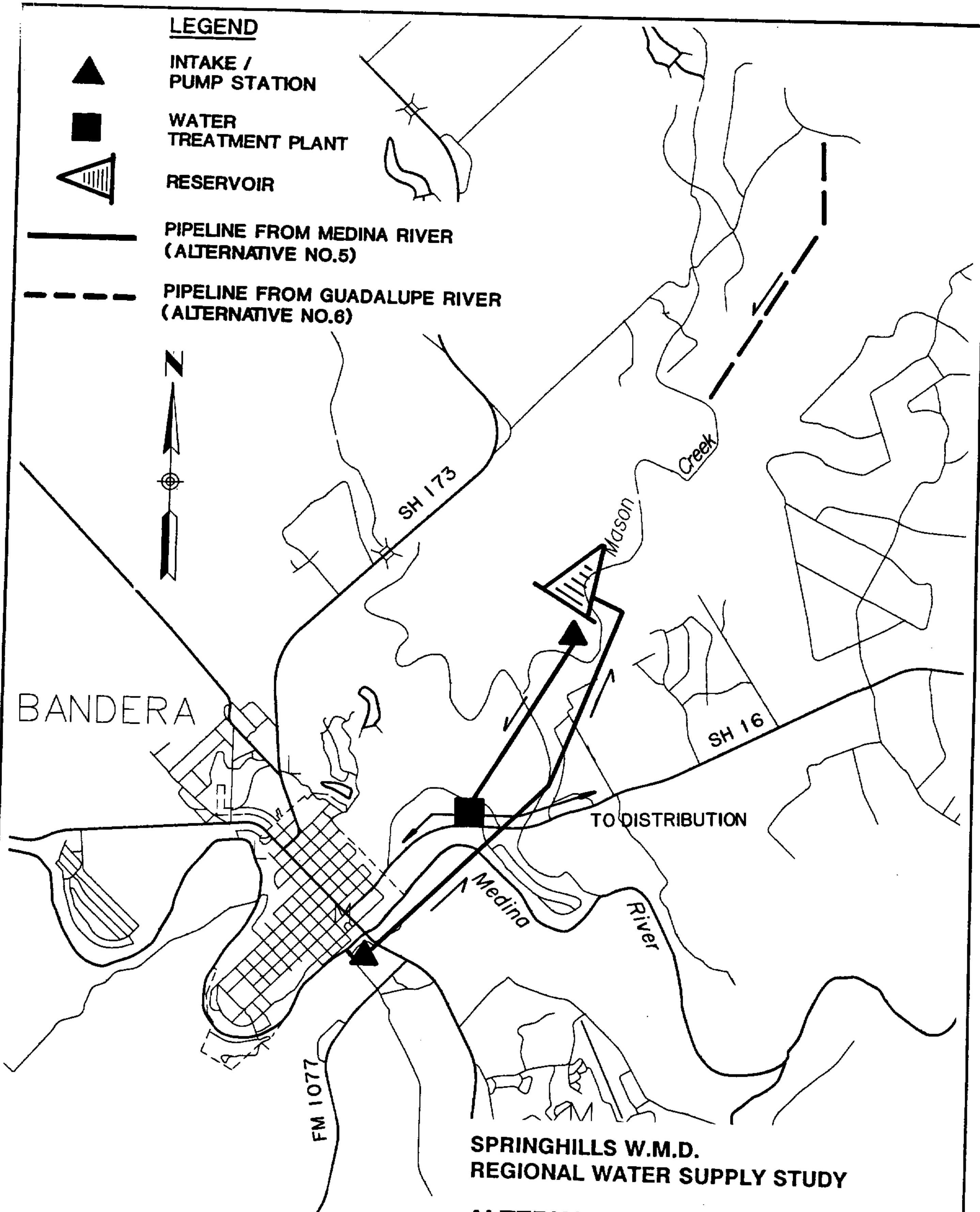
This alternative is identical to the previous alternative, except supplemental water is pumped from the Guadalupe River (Figure 6-5). The pumping operations and delivery point into Mason Creek are the same as for the Bandera Creek site, Alternative No. 4.

The total project cost for this alternative is estimated to be $15,602,600 for Phase I. The cost increase above Alternative No. 5 is attributed to the larger pump station and pipeline needed to deliver water from the Guadalupe. All other project components are identical. The estimated Phase II total project cost is $6,494,400. As with the previous alternatives, the pump stations would be modified, the pipelines paralleled, and the treatment plant expanded to provide the additional Phase II capacity.

6.3.7 Alternative No. 7 - Upper Privilege Creek Dam with Pumping from the Medina River

Alternative No. 7 consists of a small tributary reservoir on Privilege Creek above the confluence with Bear Creek. Natural flows from the 18-square mile drainage area at this site would be supplemented by pumping from the Medina River below the confluence with Privilege Creek (Figure 6-6). This would necessitate constructing a new low-head diversion dam across the Medina River to provide pump submergence and suction head. Again, pumping rates were set assuming that a minimum flow of one cfs is maintained in the river. A pipeline was provided northward from the river pump station along an existing road to the east side of the dam. A pump station at the dam and pipeline would supply raw water to the treatment plant. For this alternative, the water treatment plant is located on the north side of S.H. 16 about one mile east of the Privilege Creek crossing. Minor modifications to the distribution system would be required with the treatment plant at this location. However, the total cost would not change significantly and is assumed to be the same for the purposes of this report.

The total project cost for Phase I of this alternative is estimated to be $15,237,300. This includes: (1) the dam and reservoir on Privilege Creek; (2) the diversion dam across the Medina River; (3) a pump station at the diversion dam with a pipeline to the reservoir; (4) a pump station at the dam with a pipeline to the treatment plant; (5) a two mgd water treatment plant; and (6) the Phase I distribution system. The cost increase above the previous alternatives is primarily due to a more expensive dam, the need for a diversion dam, and the increased pumping head and distance. The estimated Phase II total project



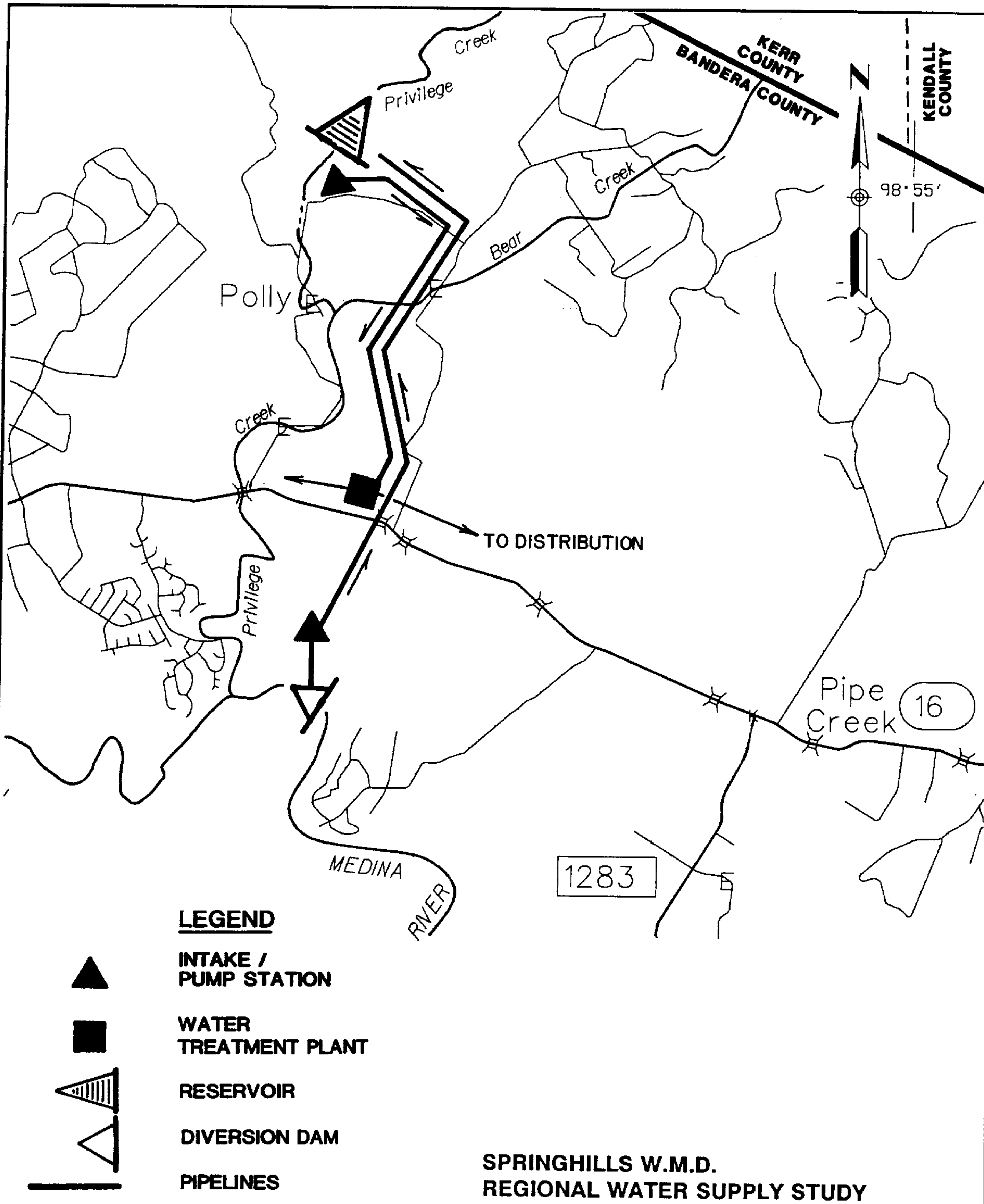
SPRINGHILLS W.M.D.
REGIONAL WATER SUPPLY STUDY

**ALTERNATIVES NO. 5 AND 6
MASON CREEK DAM WITH
PUMPING FROM MEDINA OR
GUADALUPE RIVERS**

HDR

HDR Engineering, Inc.

FIGURE 6-5



HDR Engineering, Inc.

SPRINGHILLS W.M.D.
REGIONAL WATER SUPPLY STUDY

ALTERNATIVE NO. 7
UPPER PRIVILEGE CREEK DAM WITH PUMPING FROM MEDINA RIVER

FIGURE 6-6

cost is $6,165,950, which includes: (1) modifying both pump stations; (2) paralleling each pipeline; (3) expanding the water treatment plant; and (4) the Phase II distribution system.

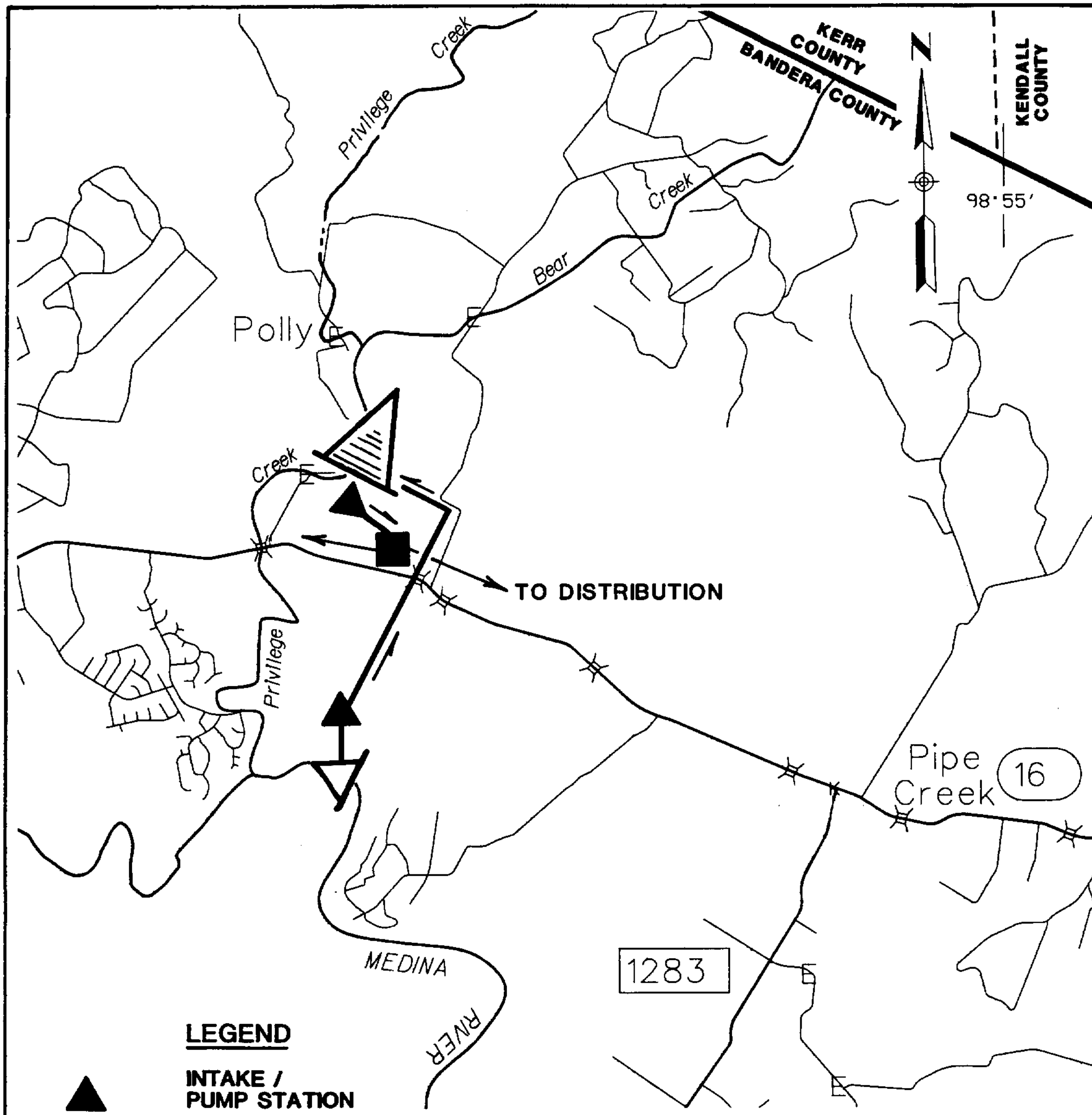
6.3.8. Alternative No. 8 - Lower Privilege Creek Dam with Pumping from the Medina River

This alternative is similar to the previous alternative, except the dam site is located downstream of the Bear Creek confluence to enhance the natural drainage area contribution (Figure 6-7). The total drainage area at this site is approximately 38 square miles. Although the natural flow contribution to the system's yield would be greater than the Upper Privilege Creek site, evaporation would also be greater because of the increased surface area of the lake. The net result would be only a slightly lower required supplemental pumping volume to meet the 2040 demand; this is not enough to offset a much higher dam cost.

The total project cost for Phase I of this alternative is estimated to be $17,574,600. The dam cost alone at this site is over $9,000,000. The Phase II total project cost is $5,183,400. Phase II of this alternative is less costly than Phase II of the Upper Privilege Creek site because it is closer to the Medina River and water treatment plant site.

6.3.9 Alternative No. 9 - Middle Verde Creek Dam - Nueces River Basin

This alternative consists of constructing a dam and reservoir on Middle Verde Creek below its confluence with West Verde Creek near S.H. 173 in Medina County just south of the Bandera County line (Figure 6-8). Based on the naturalized flow data presented in Section 4.5 for Middle Verde Creek, a reservoir could be built at this site to yield the total



LEGEND

INTAKE / PUMP STATION

WATER TREATMENT PLANT

RESERVOIR

DIVERSION DAM

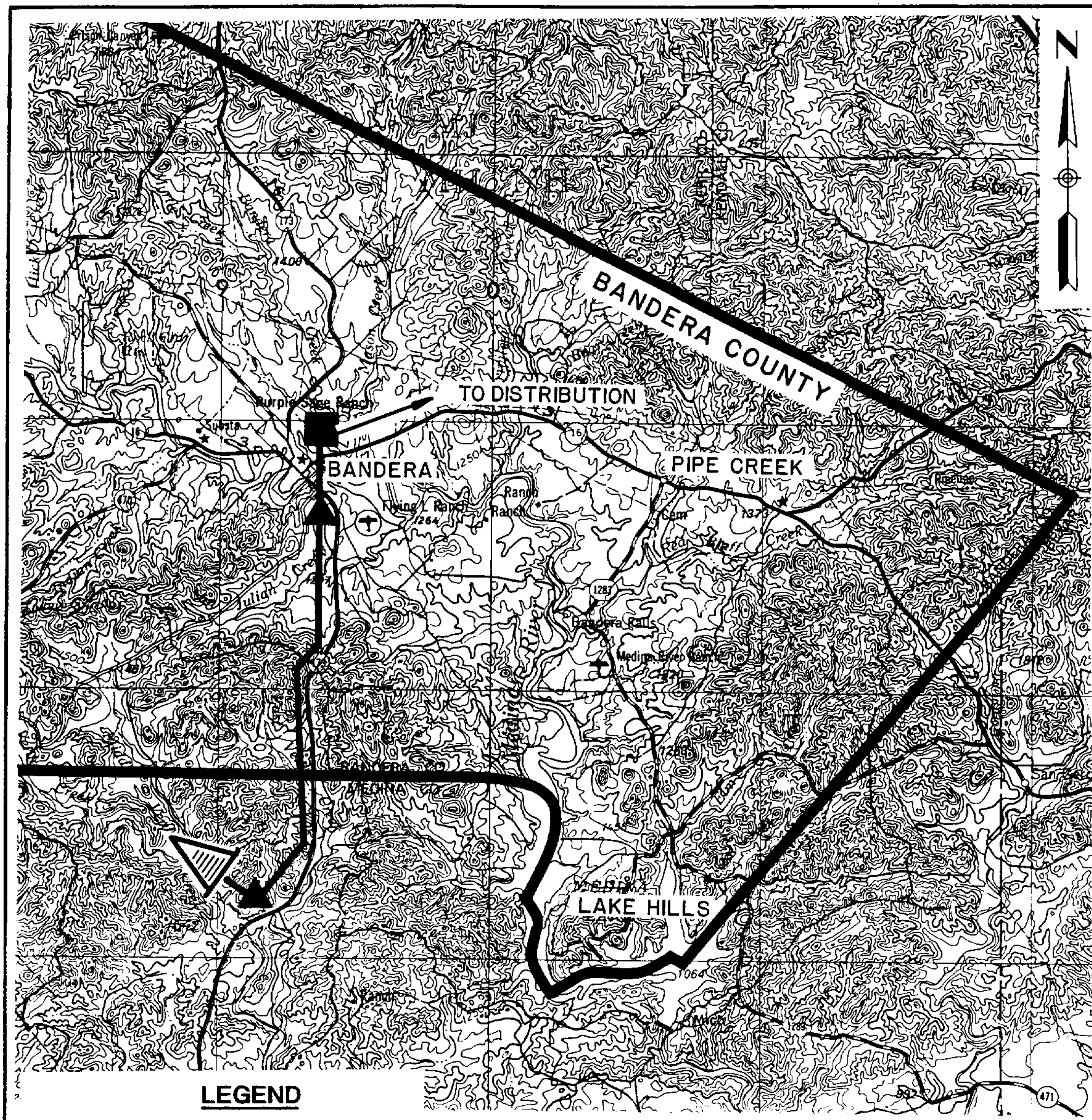
PIPELINES

HDR Engineering, Inc.

SPRINGHILLS W.M.D.
REGIONAL WATER SUPPLY STUDY

ALTERNATIVE NO. 8
LOWER PRIVILEGE CREEK DAM WITH PUMPING FROM MEDINA RIVER

FIGURE 6-7



LEGEND

PUMP/
BOOSTER STATION

WATER
TREATMENT PLANT

RESERVOIR

PIPELINE

HDR

HDR Engineering, Inc.

SPRINGHILLS W.M.D.
REGIONAL WATER SUPPLY STUDY

ALTERNATIVE NO. 9
MIDDLE VERDE CREEK DAM
NUECES RIVER BASIN

FIGURE 6-8

2040 average annual demand of 3,200 acre-feet per year. In other words, no supplemental pumping into this reservoir would be required to enhance the yield. Raw water would be delivered from the reservoir over the basin divide to the water treatment plant in Bandera via a main pump station at the dam, 13.5 miles of pipeline, and a booster pump station near the Medina River. Phase II of this alternative includes enlarging the main and booster pump stations, paralleling the pipeline, and expanding the treatment plant.

The total project cost for this alternative is estimated to be $16,757,000 for Phase I. The major cost component other than the dam ($6,667,900) is the pumping works and pipeline ($3,489,100). The Phase II total project cost is estimated to be $6,988,400, with a major additional component being the pump station modifications and parallel pipeline.

6.3.10 Alternative No. 10 - Purchase Treated Water from the City of Boerne

The nearest surface water treatment system to eastern Bandera County is at the City of Boerne. Presently, Boerne's treatment system has a maximum capacity to produce 1.5 mgd and would not be adequate to serve the anticipated demands of both Boerne and eastern Bandera County.[1] This alternative assumes that either the City of Boerne or the District would enter into an agreement with GBRA to divert water from the Guadalupe River to supplement their existing lake and expand their water treatment plant capacity. Bandera County would negotiate a contract with the City of Boerne to supply treated water to the distribution system in eastern Bandera County.

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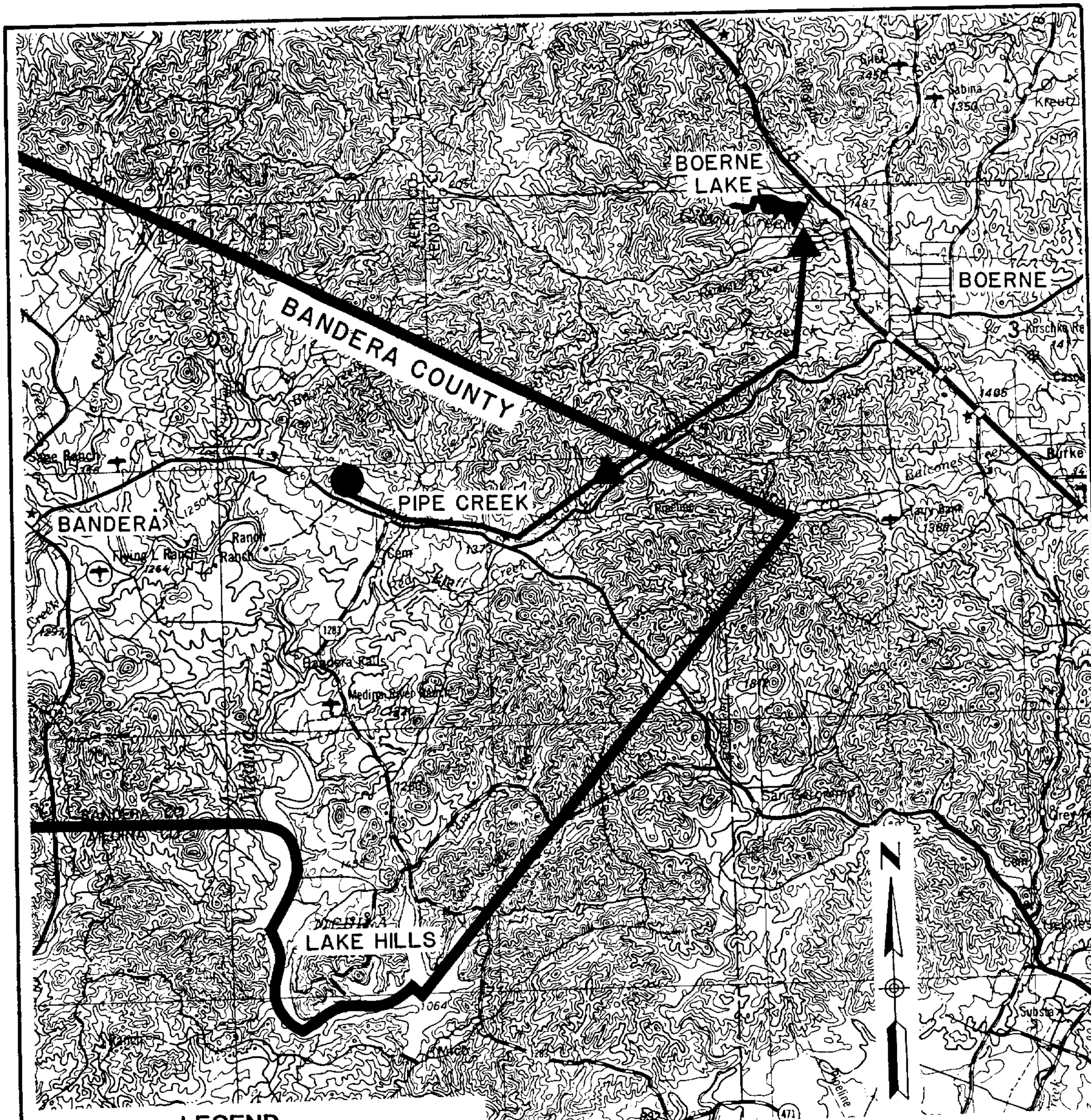
[1]City of Boerne, Personal communications with Director of Public Works and Water Treatment Plant Operator.

In addition to purchasing the treated water and constructing a distribution system, this alternative requires installing approximately 16 miles of pipeline and constructing two pump stations to deliver the treated water from Boerne to the two million gallon storage tank near Pipe Creek (Figure 6-9). A main pump station would be located at Boerne's plant and a booster pump station would be required along the pipeline near Red Bluff Creek. The pipeline route would follow S.H. 46 to S.H. 16, then westward to Pipe Creek.

The total project cost for the Phase I pumping, transmission, and distribution works associated with this alternative is estimated to be $8,877,800. For Phase II, the pump stations would be modified, the pipeline paralleled, and the Phase II distribution system built. The total project cost for Phase II is $6,150,000. Although these total project costs seem low compared to the previous alternatives, the annual cost of this alternative is driven by the purchase of treated water from the City of Boerne (Table 6-1 and Appendix C).

6.4 Groundwater Recharge Considerations

Recharge of groundwater aquifers occurs naturally when rainfall or runoff contacts the exposed areas of the aquifer at the ground surface. Artificial recharge is the process of transferring additional surface water into the groundwater aquifer. The recharge of an aquifer can sometimes be enhanced by either spreading ponds or injection wells, depending on the characteristics of the aquifer. Groundwater injection/recovery is sometimes possible depending on the aquifers ability to receive and store water. Under this process, treated drinking water would be stored underground in a suitable aquifer using recharge wells during periods of lower demand, and withdrawn during periods of peak water demands using



LEGEND

PUMP/
BOOSTER STATION

DISTRIBUTION SYSTEM
STORAGE TANK

TREATED WATER PIPELINE

SPRINGHILLS W.M.D.
REGIONAL WATER SUPPLY STUDY

ALTERNATIVE NO. 10
PURCHASE TREATED WATER
FROM CITY OF BOERNE

HDR

HDR Engineering, Inc.

FIGURE 6-9

recovery wells. A surface water source is required to provide the supply for any method of artificial recharge.

6.4.1 Artificial Recharge Using Spreading Ponds or Injection Wells

Spreading ponds capture surface water in detention basins to enhance infiltration into a highly permeable zone of an aquifer at the location of an outcrop. Direct recharge to the Hensel Sand and Cow Creek Limestone formations of the Middle Trinity Aquifer and the Hosston Sand and Sligo Limestone members of the Lower Trinity Aquifer does not occur in Bandera County since these formations do not out crop. Direct recharge in Bandera County is limited to the upper and lower members of the Glen Rose Limestone formation. Artificial recharge of the lower units of the Middle Trinity Aquifer and the Lower Trinity Aquifer in Bandera County would have to be performed using injection wells.

Four major factors must be addressed when considering the use of artificial recharge to enhance existing groundwater supplies:

1) Precipitation levels and the availability of runoff to the recharge zones;
2) Hydraulic characteristics of the aquifer;
3) Treatment requirements for the recharge water; and
4) Recoverability and ownership of the recharge water.

Bandera County is located in a semiarid region of Texas and receives approximately 25 to 30 inches of annual rainfall. A major portion of this water either runs off rapidly due to the impervious nature of the rocky landscape, or is consumed by evapotranspiration through vegetation. In addition, rainfall events are not uniformly distributed throughout the year; relatively long dry spells broken by high intensity rainfall events are common in this part of the state.

The effectiveness of artificial recharge using either spreading ponds or injection wells, and the ability of an aquifer to function as an underground distribution system, is directly dependent on the hydraulic characteristics of the aquifer. These include such factors as porosity, transmissivity, storativity (confined aquifer), and specific yield (unconfined aquifer). Transmissivity values range from 150 to 25,000 gallons per day per foot (gpd/ft) for the Lower Trinity Aquifer and 600 to 9,300 gpd/ft for the Middle Trinity Aquifer. Transmissivity of the Upper Trinity Aquifer (upper Glen Rose Limestone formation) is estimated to be 1,500 gpd/ft.[2] Transmissivities greater than 100,000 gpd/ft represent good aquifers for water well exploration.[3] The hydraulic characteristics of the Trinity Group Aquifers are inherently deficient. These deficiencies result in most Trinity Group Aquifer wells experiencing unusually large drawdowns, serious reductions in well yields, and relatively poor water-level recovery during and after extended periods of pumping.[4]

The Trinity Group Aquifer is not expected to readily accept or distribute ponded or injected surface water over extensive areas. For any type of artificial recharge project to be successful, it would require implementation directly in the area of need (i.e., eastern

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[2]Texas Water Development Board, "Evaluation of the Ground-Water Resources of the Paleozoic and Cretaceous Aquifers in the Hill Country of Central Texas," October 1990 (Manuscript Draft).

[3]Freeze, R.A. and Cherry, J.A., Groundwater, Prentice-Hall, Inc., 1979.

[4]Texas Water Development Board, "Evaluation of the Ground-Water Resources of the Paleozoic and Cretaceous Aquifers in the Hill Country of Central Texas," October 1990 (Manuscript Draft).

Bandera County).[5] As discussed previously, the estimated countywide groundwater duty of the Trinity Group Aquifer is 6,500 acre-feet per year. Assuming this duty represents the approximate annual natural recharge to this aquifer, any artificial recharge operation would need to increase this amount by about 50 percent countywide to meet the year 2040 additional municipal demand of 3,200 acre-feet. Even if this were attainable, a question still exists regarding the available storage space or porosity in the formation to contain this volume of water over an extended period of time.

Artificial recharge using injection wells would require securing permits for the wells from the state (probably the newly created Texas Natural Resources Conservation Commission). Additionally, the quality of the water injected into the ground must be at least equivalent to the minimum requirements for potable water. Therefore, treatment to Safe Drinking Water Act (SDWA) standards using a conventional surface water treatment plant would be required. Following treatment, the pH and temperature of the water would have to be adjusted to eliminate the possibility of undesirable precipitates forming in the injection well when surface water and groundwater are combined.

If spreading pond techniques are used for artificial recharge, the captured water would probably not need to be treated to SDWA standards and permits would not be required. As development continues throughout the county and runoff increases due to more impervious cover, issues such as stormwater runoff and nonpoint pollution will need to be addressed. Small detention basins could be constructed locally to capture stormwater runoff as a potential source of groundwater recharge. These catchment basins could be

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[5]Texas Water Development Board, Personal communications with Director of Planning.

strategically located over obvious recharge zones; however, water quality issues related to nonpoint pollution sources would have to be investigated.

Use of artificial recharge to supplement groundwater raises legal questions pertaining to ownership of the captured surface waters. Recharge projects which divert or capture surface water flows that would have otherwise reached a stream course would require a permit from the Texas Water Commission. Given that virtually no unappropriated water exists in Bandera County, it is not likely that such a permit would be granted.

Approximately five percent of the total rainfall volume is estimated to be available as natural recharge to the Trinity Group Aquifer by infiltration and seepage of streamflow in the outcrop areas. Much of the recharge received by the aquifers is discharged as spring flow, which provides a large part of the base flow to the county's rivers and streams. Artificially recharged surface water may be subject to the same fate. The storage volume available for recharged water before it "overflows" and escapes through springs is unknown.

Extensive geohydrologic studies and pilot testing will be required to assess the technical and economic feasibility of artificial recharge to supplement local groundwater supplies and the use of the aquifer as an underground distribution system. The potential use of the local aquifers for recharge and distribution could be explored as a short-term solution. However, supplemental water supplies, storage, and transmission pipelines will be needed to meet the long-term needs of Bandera County.[6]

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[6]Ibid.

6.4.2 Groundwater Injection/Recovery

A groundwater injection/recovery project is only one component of a water supply system and has to be operated in conjunction with existing surface water treatment facilities. The concept of injection/recovery is to recharge treated water to an aquifer during periods of low demand and recover the water from the aquifer during peak demand. This allows the water provider to operate the surface water treatment plant at a base level and inject when production exceeds demand or recover when demand exceeds production. In the case of an existing plant which may be nearing its peak capacity, an injection/recovery project could defer the need for plant expansion.

A pilot injection/recovery project is presently in operation at the City of Kerrville. The Upper Guadalupe River Authority (UGRA) is using treated water from the Guadalupe River and injecting it into the Hosston Sand formation for temporary storage to meet peaking needs.[7,8] Initially, the project was developed to delay expansion of UGRA's water treatment plant; however, preliminary results indicate that the project could also allow UGRA to postpone the development of additional surface water supplies.[9]

If Bandera County were to develop an injection/recovery project (assuming aquifer testing showed it to be feasible), the first step would be development of a surface water source and construction of a treatment plant. However, extensive geohydrologic studies and

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[7]CH2M Hill, "Aquifer Storage Recovery Feasibility Investigation, Phase I-Preliminary Assessment," Upper Guadalupe River Authority, Kerrville, Texas, April, 1988.

[8]CH2M Hill, "Aquifer Storage Recovery Feasibility Investigation, Phase IIA, Monitoring Well PZ-1, Volumes I and II," Upper Guadalupe River Authority, Kerrville, Texas, December 1989.

[9]Upper Guadalupe River Authority, Personal communications with General Manager.

pilot testing would be required to determine the viability of an injection/recovery project in Bandera County. A more likely application of an injection/recovery project could be implemention of such a concept in Phase II to possibly reduce the size of the treatment plant expansion.

6.5 Effects of Brush Control on Water Supply

Approximately 90 percent of Bandera County is used for range, seven percent for farms, and two percent for other purposes. The remainder consists of inland water, primarily Medina Lake.[10] Much of the rangeland consists of rolling hills with gentle to steep rocky slopes that support juniper oak woodlands of varying density.

It has been observed, and in some cases measurement has shown, that after brush control was applied to watersheds, springs and creeks of local and neighboring areas began to flow. Among the notable examples are Rocky Creek in Tom Green and Irion Counties, the Bridgeford Ranch in Nolan County, the Chaparrosa Ranch in Zavala County, and on ranches in the Fredericksberg/Kerrville area.[11] Quantitative information about potential changes in aquifer recharge and streamflows resulting from brush management programs is not adequate to determine whether or not brush management is a viable water development tool for Bandera County. In order to obtain such information, the Texas Water Development Board, Texas A&M University, the Texas State Soil and Water Conservation Board, the U.S. Soil Conservation Service, the Edwards Underground Water

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[10]U.S. Department of Agriculture, Soil Conservation Service, "Soil Survey of Bandera County, Texas," 1977.

[11]Texas Water Development Board, "Water Yield Improvement from Rangeland Watersheds," January, 1988.

District, and others are funding studies to measure the effects of brush management on water yield from rangeland watersheds. Two of the study sites are located within the Nueces River Basin south of Bandera County. One is located at Lyles Ranch about 18.6 miles southwest of Uvalde, and the other at Annadale Ranch about 19.8 miles northeast of Uvalde near Concan. A third site is located at the LaCopita Ranch near Alice in Jim Wells County within the Nueces-Rio Grande Coastal Basin.

The study sites were chosen to obtain information about the effects of management of different species of brush upon water yields. At the Lyles Ranch, the species being studied are honey mesquite and blackbrush. In this study, 0.6 hectare plots within nine watersheds have been equipped with instruments to measure precipitation, soil moisture, runoff, and sediment transport from the experimental plots. By comparing the results from treated and untreated plots, estimates can be made of the effects of treatment. The study is presently in the data collection phase and will require several years of observation before conclusions can be reached.

At the Annadale Ranch near Concan, nine watersheds ranging in size from four to six hectare have been instrumented to measure precipitation, runoff, and sediment loss. The species of interest at this site are live oak and ash juniper. As in the case of the Lyles Ranch, this study is in the data collection state.

At the LaCopita Ranch, the first year of water budget data indicates that runoff and deep percolation may increase by 1.18 inches when mesquite-dominated mixed brush complexes are replaced with herb-dominated species.[12]

Limited observations indicate a beneficial relationship between brush management and water yield in Texas, including the Nueces and adjacent Nueces-Rio Grande Coastal Basin. The results of the studies mentioned above should soon provide useful quantitative information about the potential quantities of water that might be expected per unit of watershed treated.

6.6 Recommended Alternative

The recommended water supply alternative to meet Bandera County's future municipal water needs is Alternative No. 2 - Town Mountain Dam with Pumping from the Medina River. Although comparable in cost, Alternative No. 1 - Groundwater Pumping from the West is not recommended because of uncertainties regarding reliability of continued pumping from the Lower Trinity Aquifer. Additionally, regulations which would be necessary to protect the groundwater production wells by restricting drilling of new wells within the zone of influence would be difficult, if not impossible, to implement and enforce. Alternative No. 3 - Bandera Creek Dam with Pumping from the Medina River should also be given consideration, since this reservoir would provide recreational benefits for the county.

[12]Texas A&M University, Department of Range Science, "Water Yield Improvement from Rangeland Watersheds," Annual Progress Report, Texas Water Development Board Contract No. IAC (86-87) 0940, January, 1988.

The recommended alternative (No. 2) consists of an earth/rock fill dam on an unnamed drainage east of Town Mountain which is southwest of the City of Bandera. Phase I of the dam would impound a storage reservoir with a capacity of approximately 1,600 acre-feet. A pump station on the Medina River on the south side of City Park Lake would deliver water through an 18-inch diameter pipeline to the reservoir. The pump station would also be able to divert water directly to a two mgd package water treatment plant located on the eastern edge of the City of Bandera. Water from storage in the reservoir would be delivered by gravity through a 14-inch pipeline to the treatment plant. Treated water would be delivered to the customers from the plant via the Phase I distribution system. A contract for diverting water from the Medina River at City Park Lake would need to be negotiated with BMA. This would necessitate amending BMA's water rights permit and examining the quantity of water available in the Medina River at the point of diversion.

Phase II of the Town Mountain water supply project would require raising the dam to impound a storage reservoir with a capacity of about 4,200 acre-feet. The pump station would be modified by enlarging and/or installing additional pumps to deliver higher flow rates to the reservoir. Pipelines installed during Phase I to connect the system components would be able to accommodate the Phase II flow rates. Additional treatment units would be installed in the water plant to obtain a 3.5 mgd capacity, and treated water would be delivered via the Phase II distribution system.

6.7 Staging Plan for Implementation of Recommended Alternative

The recommended water supply alternative could be implemented in stages to lower the initial financial impact. This would be accomplished by initially constructing only the

Medina River pump station with a pipeline to deliver water directly to a 0.5 mgd package water treatment plant. The initial stage would be considered a "wet weather" system. In other words, the storage reservoir to provide water during drought conditions would be constructed at some point in the future as demand, available water supplies, and long-term weather conditions dictate. In the meantime, during extremely low-flow conditions on the Medina River, groundwater wells would be used to meet temporary peak demands.

It is assumed that this initial system (estimated to be constructed in 1995) would provide an average annual supply of 0.3 mgd to 1,000 connections (current number of City of Bandera connections is 762). Five miles of distribution system piping is included to serve additional connections around the City and east along S.H. 16. The total project cost, annual debt service, annual power, O&M, and water costs are provided in Table 6-2. The cost to produce 1,000 gallons of treated water and estimated monthly increase in cost per connection are also presented in the table.

The initial stage of the Town Mountain water supply project is easily expanded by extending the distribution system into developing areas, installing additional treatment units, and modifying the pump station to increase pump capacity. Conjunctive use of surface and groundwater would continue until the storage reservoir is required. During the initial stage of the project, detailed hydrogeologic studies could be undertaken to: (1) assess the merits of a groundwater injection/recovery project to meet peak water demands; and (2) explore using the groundwater aquifer as a distribution system to deliver water to the rapidly developing eastern areas of the county.

TABLE 6-2
Stage I of Town Mountain Water Supply Project

Project Components	Cost of Project Components	Annual Costs					Cost Per 1000 Gallons	Monthly Cost Per Connection
		Construction	Power	O&M	Water	Total		
Water Pumped from Medina River at City Park Lake to Water Treatment Plant								
Pumping Works - Medina River Pump Station	$276,000	$24,760	$5,000	$8,000	$30,800	$68,560		
Pipeline - Pump Station to Treatment Plant	$345,000	$30,950	$0	$2,000	$0	$32,950		
0.5 MGD Treatment Plant	$690,000	$61,900	$0	$75,000	$0	$136,900		
Storage and Distribution System	$690,000	$61,900	$5,000	$10,000	$0	$76,900		
TOTAL	$2,001,000	$179,510	$10,000	$95,000	$30,800	$315,310	$2.88	$26.28

NOTES:
1. Cost of project components includes: 15% contingencies; right-of-way costs; and 20% for permitting, engineering, legal, and financing.
2. Annual cost for construction calculated using debt service factor of 7.5% for 25 years.
3. Average annual power cost calculated using $0.07 Per kwh.
4. Annual cost of water equal to 550 acre-feet per year times $56 per acre-foot from BMA WCID No. 1.
5. Cost per 1000 gallons calculated based on an initial average annual demand of 300,000 gallons per day.
6. Monthly cost per connection based on 1,000 connections served.
7. Costs based on 1991 dollars.

A water supply system to serve Subarea B (north side of Medina Lake) using water directly from Medina Lake was considered as a possible additional initial stage to the Phase I regional system. However, Medina Lake is not considered as reliable a source as diverting water from the river upstream of the lake. This is because of the wide lake level fluctuations and extended periods of virtually no storage during the drought. It was assumed that a floating-type intake could be utilized for normal operations and a deep well(s) could serve as an intake during drought conditions. In either case, a contract for diverting water from the lake would need to be negotiated with BMA. The intake (or well) would deliver raw water to a 0.5 mgd package-type water treatment plant which would supply an extensive distribution system to serve the Lake Hills area. A main trunk line would be included to supply treated water to Bandera Fresh Water Supply District's present system serving the Pebble Beach area. Assuming a total of about 750 connections and an average use of 0.3 mgd, the cost per 1000 gallons for this system was calculated to be $4.45 or about $50.00 per month per connection. At this time, there does not appear to be an entity established to pursue the development of this system. Constructing two separate water supply systems, one at the City of Bandera and another at Medina Lake, would have a tendency to fragment the regional system and make it more difficult to phase over time.

6.8 Water Supply Financing Options

There are five major sources of financing for public water supply projects, including: (1) Bond Market; (2) Texas Water Development Fund; (3) State Participation Fund; (4)

Community Development Block Grants; and (5) Farmer's Home Administration Grants and Loans. Each source is discussed below.

6.8.1 Bond Market

Public agencies borrow funds in the financial markets through the issuance of bonds, then use the proceeds to construct public works projects such as water supply reservoirs, water wells, pipelines, treatment plants, pump stations, storage tanks, and associated capital equipment. The bond holders are repaid with interest, using revenues and/or fees collected from those who receive water, from taxes levied on property in the water service area, or from a combination of revenues, fees, and taxes. In cases where public entities issue bonds to supply water to the public, the bonds are classified under federal tax laws as "tax exempt." On tax exempt bonds, the interest paid to bond holders is not classified as ordinary income; therefore, the bond holder does not have to pay income tax on the earnings from these investments. As a result, individuals and other investors are willing to lend their capital to governmental entities at lower interest rates than would be the case if the interest on those loans (bonds) were taxed by the federal government.

6.8.2 Texas Water Development Fund

The Texas Water Development Board (TWDB) has authority granted by Texas Constitutional Amendments and State Statutes to issue State of Texas General Obligation Bonds for providing loans to political subdivisions and special purpose districts for the construction of water supply, sewer, and flood control projects. The TWDB uses the proceeds of its bond sales to purchase the bonds (either general obligation or revenue) of cities and local water districts and authorities, which in turn use the borrowed funds to pay for the construction of local projects. The local district or city repays the TWDB, with interest equal to the rate that the TWDB must pay on its bonds plus 0.5 percent, which the TWDB uses to retire the bonds it issued. The 0.5 percent assists the state in paying the cost of administering the loan program. This State of Texas water resources loan program enables some cities and local districts, especially smaller entities that do not have a credit rating, to utilize the credit of the state in financing projects and thereby obtain financing at lower interest rates than if they sold their bonds on the open bond market. The current interest rate on TWDB bonds is 6.7 percent plus the 0.5 percent for a total rate of 7.2 percent.

To be eligible to borrow from the Texas Water Development Fund, applicants must have: (1) authority to supply water; (2) a source of water; and (3) a water conservation plan, unless the applicant is exempted from this requirement. The conditions for exemption from a conservation plan are: 1) in cases of emergency; 2) for applications of $500,000 or less; or 3) if the applicant demonstrates, and the TWDB finds, that a conservation plan is not necessary to facilitate conservation. However, if the application is filed as an emergency case and is for a loan in excess of $500,000, a conservation plan must be developed and implemented within six months of the date of the TWDB's approval of the loan.

In the case of individual cities and individual special purpose districts and authorities, the applicants must be classified as "hardship cases." In order to be classified as a "hardship case," the TWDB must determine that the applicant cannot secure financing in the open market or elsewhere at a reasonable rate of interest. Smaller districts that do not have a credit history and a credit rating usually meet the "hardship" criteria. However, the applicant must present evidence that it can repay the loan for which it is applying.

If the project for which the loan is needed is regional (i.e., serves more than one entity or serves an area involving more than one county, city, special district, or other political subdivision), then the hardship requirement does not apply. In other words, water supply loans can be obtained for regional water supply projects even though the members are not classified as hardship cases. Likewise, a surface water supply system which is developed to replace groundwater in critical groundwater areas can be financed with a loan from the TWDB even though the members are not classified as hardship cases. Thus, it appears that surface water supply projects for all or parts of Bandera County would be eligible for loans from the TWDB for financing of up to 100 percent of the costs of such projects. Groundwater supply projects to serve two or more cities and/or water utilities of a regional system would also be eligible.

6.8.3 State Participation Fund

The concept of State Participation as it applies to water supply projects is as follows. A local area, such as eastern Bandera County, needs an additional water source, transmission lines, storage tanks, and treatment plant to meet present and future water supply needs. However, the area's existing customer base can only support monthly rates required to repay loans for a project sized to meet present needs. However, if a project is built to only meet present needs, it may soon be inadequate. Thus, through the State

Participation Fund, the local entity could plan a larger project, with phased construction of the separate elements to the extent possible, and apply to the TWDB for state participation in the project. Under this arrangement, the TWDB would become a "silent partner" in the project by entering into an agreement with the local entity to pay up to half of the project costs initially. The TWDB would hold the remaining project share until a future date, at which time the local entity would be required to buy the TWDB's share.

The terms and conditions of such an agreement are negotiated for each case. Typically, local entities are required to pay simple interest on the TWDB's share of the project cost from the beginning, and to begin buying the TWDB's share, including accumulated interest, at a specified future date, usually within eight to 12 years of project completion. By lending the state's credit to local areas an optimal development plan for growing areas can be implemented at lower costs. However, the local beneficiaries of the program will be required to repay the TWDB, including interest and other financing costs incurred. It is emphasized, however, that state participation is appropriate and reasonable only for additional project capacities that will be needed within the foreseeable future.

6.8.4 Community Development Block Grants

The Community Development Block Grant (CDBG) program was created by Congress in 1974. It is administered at the federal level through the U.S. Department of Housing and Urban Development (HUD). The program funding is divided into two major categories: (1) entitlement (cities over 50,000 and qualifying counties over 200,000 in population) and (2) non-entitlement (cities under 50,000 in population and counties not eligible for entitlement status). In the State of Texas, there are 47 entitlement cities, 5 entitlement counties, and approximately 1,313 non-entitlement cities and counties. Entitlement entities receive an annual allocation of funds directly from HUD for eligible activities, whereas non-entitlement localities generally have to compete on a statewide basis for funding.

In 1981, Congress transferred the responsibilities of administering several federal block grant programs to the states. This new law authorized the states to administer the non-entitlement portion of the CDBG program. The State of Texas assumed administration of this program in federal fiscal year 1983. It is administered by the Texas Department of Commerce. The Texas Community Development Program provides grants and loans on a competitive basis to non-entitlement cities and counties in Texas. Thus, an application for such funding would need to be made by Bandera County or a city within the county for a relevant part of the regional water supply plan. Among the threshold requirements of applicants, there must be a particular problem that poses a serious and immediate threat to the health and safety of the public and the applicant must have the ability to levy a local property tax and/or a local sales tax.

The Community Development Fund is the major funding category (about two-thirds of the total funding) under the Texas Community Development Program, and is the only category through which water supply projects for the Bandera County area could be eligible. Typical types of public works projects requested and funded include water and sewer improvements, street and drainage improvements, community and senior centers, and handicapped accessibility projects. An annual competition, divided into regional allocations for eligible cities and counties in each of the state's 24 planning regions, is held.[13] An application for the 1991 program from Bandera County would need to be filed with the Alamo Area Council of Governments by August 30, 1991. The applications are reviewed by Texas Department of Commerce staff, and the Alamo Area Council of Governments regional advisory committee. The committee, which is comprised of 12 locally elected officials appointed by the Governor for two-year terms of office, would meet publicly to review and score applications in accordance with previously established scoring criteria. Award recommendations are made to the Department of Commerce's Executive Director on the basis of the scores of the regional review committee. The Executive Director makes final funding decisions on the basis of these recommendations.

Since the Texas Community Development program is available only to cities and/or counties having taxing authority, and competition for available funding is high, this source of funding appears to be quite limited as far as implementation of water supplies for Bandera County. However, it could perhaps be useful in the funding of subregional water supplies where there may be a threat to public health.

6.8.5 Farmer's Home Administration Grants and Loans

The Farmer's Home Administration (FmHA) of the U.S. Department of Agriculture is authorized to provide financial assistance, in the form of loans and grants, for water supply development in rural areas and towns with populations of 10,000 or less. Public entities, including cities, special purpose districts, and nonprofit corporations, are eligible

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[13] "Programs Available Through the 1991 Texas Community Development Program and Texas Rental Rehabilitation Program." Texas Department of Commerce, Austin, Texas, March, 1991.

for such assistance to restore a deteriorating water supply or to enlarge an inadequate water system. Preference is given to entities in areas smaller than 5,500 people, to areas wanting to merge small facilities, and to serve low-income communities.[14] To qualify for FmHA financing, applicants must: (1) be unable to obtain funds elsewhere at reasonable rates and terms, (2) have legal authority to borrow and repay loans and operate water facilities, and (3) have a financially sound project based on revenues, fees, taxes, or other sources of income. Water systems must be consistent with state water development plans and comply with all local, state, and federal laws.

Funds from FmHA for water systems may be used for construction or modification of facilities such as reservoirs, pipelines, wells, and pump stations; acquisition of water rights or water supplies; legal and engineering fees required for the project; rights-of-way and easements; and relocations of roads and utilities. FmHA funds may be used in conjunction with funds from other sources, such as loans from the Texas Water Development Fund or bonds sold on the open bond market.

The maximum length or term of FmHA loans is 40 years, the statutory limitations of the organization borrowing funds, or the useful life of the project, whichever is less. Interest rates are set periodically, in accordance with law, and as of August, 1991, rates were 5.875 percent.

Grants may be made for up to 75 percent of eligible project costs for facilities serving low-income areas. FmHA staff will advise applicants as to how to assembly information and file both grant and loan applications. Such applications are filed with the local FmHA

[14] U.S. Department of Agriculture, Farmer's Home Administrator, Program Aid Number 1203, "Water and Waste Disposal Loans and Grants," P. O. Box 830, Seguin, Texas, Revised August, 1987.

district office, which for Bandera County is located in Seguin, Texas (512/372-1043). Preapplications to the district office are reviewed by the local area Council of Governments, and upon favorable review, a formal application together with an environmental assessment is filed through the local district office to the state office in Temple, Texas. Preapplication conferences with FmHA staff are recommended to obtain specific details about making application for funds.

The FmHA grants and loans program appears to be a viable financing option for water supply facilities needed in the immediate future for the rapidly growing areas of Bandera County. This source of funding could perhaps be combined with Texas Water Development Board funding, particularly the State Participation program described in Section 6.8.2, to secure water supplies for areas with the most urgent needs.

SECTION 7

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Bandera County was the ninth-fastest growing county in the State of Texas during the decade of the 1980's, with a total growth rate of 49.1 percent. An estimated 10,562 people resided in the county in 1990. Continued migration into the county by retirement settlers and people relocating from San Antonio and other areas is expected to increase population to as much as 16,220 by the end of the century, to 25,484 by 2020, and to 32,745 by the end of the 50-year planning period in 2040.

The objectives of this study were to delineate methods to conserve existing water supplies and to evaluate the feasibility of developing and securing a long-term dependable water supply for Bandera County. Water conservation efforts are considered to be a very important part of the overall water development plan, and a goal of 10 percent reduction in per capita water use between 1990 and 2010 was established.

Projections of municipal and agricultural water use were made for the county at each decade of the 50-year planning period. Total municipal water demands by 2040 are projected to be 5,629 acre-feet per year, assuming conservation practices have been implemented and drought water use conditions exist. Municipal water requirements in 1990 were approximately 1,355 acre-feet. Total agricultural water demands by 2040 are projected to be 2,070 acre-feet per year. Consideration has been given to the developing apple orchard and horse racing industries in the county. Current levels of agricultural water demand are approximately 1,500 acre-feet per year.

Bandera County presently derives nearly all of its water supply from groundwater sources, primarily the Trinity Group Aquifer. This aquifer is being mined, and based on current trends in water level declines, compounded with increasing future demand, the long-term outlook for these aquifers is not favorable. The estimated safe yield of the Trinity Group Aquifer beneath Bandera County is 6,500 acre-feet per year. Unfortunately, the demands on the groundwater supply are not distributed uniformly throughout the county. In fact, 80 percent of the projected 2040 municipal demand exists in the eastern 25 percent of the county. Municipal demands are projected to exceed the safe groundwater supply by 2,000 acre-feet per year in 2020 and by 3,200 acre-feet per year by the end of the 50-year planning period. It is expected that agricultural demands for water, which exist primarily in the central and western areas of the county, will continue to be met using existing surface water rights and groundwater wells.

Practically all of the surface water in Bandera County has been appropriated to downstream water rights permits. Development of a surface water supply in the Medina River watershed within the county will require negotiating a contract for water purchases with the Bexar-Medina-Atascosa Water Control Improvement District No. 1 (BMA). It may also be possible to negotiate a contract with the Guadalupe-Blanco River Authority (GBRA) for water from the Guadalupe River. The availability of unappropriated surface water from the Nueces River Basin is complicated by issues related to the Edwards-San Antonio Aquifer and inter-basin permitting requirements.

7.2 Recommendations

Ten specific water development alternatives for Bandera County were evaluated in detail in this study. Each of the alternatives could reliably provide at least the 50-year municipal water needs in excess of the groundwater duty for the county. The most attractive water supply alternative appears to be an off-channel dam on a small drainage southwest of the City of Bandera near Town Mountain. Water would be pumped from the Medina River at City Park Lake either directly to a treatment plant or to the storage reservoir for use during periods of extremely low flow in the river. This alternative also offers benefits in terms of staging construction over time as water demands increase.

Based on the findings and conclusions of this study, the following recommendations are made to the Springhills Water Management District:

1. Due to the long time frame required to develop a surface water supply project, complex surface water rights issues, and the current level of interest in Medina Lake, Springhills WMD should take immediate steps towards securing a contract with BMA for water under BMA's Medina Lake permit;

2. Adopt the Water Conservation Plan and actively promote water conservation practices;

3. Continue to develop and enforce sound groundwater management practices, including proper well construction techniques, plugging abandoned wells, and implementing a well-head protection program in the vicinity of all public supply wells;

4. Pursue implementation of Stage I of the Town Mountain water supply project by seeking support from the City of Bandera and other local sponsors;

5. Following development of a surface water treatment facility, consider performing detailed geohydrologic studies of the Lower Trinity Aquifer to assess the feasibility of groundwater injection/recovery and the use of the aquifer as an underground distribution system.

APPENDIX A

WATER CONSERVATION AND DROUGHT CONTINGENCY PLANS

A.0 WATER CONSERVATION AND DROUGHT CONTINGENCY PLANS

A.1 Purpose

Water used in residential and commercial sectors of Bandera County involves day-to-day living and business activities, and includes water used for drinking, bathing, cooking, toilet flushing, fire protection, lawn watering, swimming pools, laundry, dish washing, food preparation, car washing, and sanitation. The objective of water conservation is to establish a permanent reduction in the quantity of water required for each activity through efficient water supply and water use practices. The area to which this municipal water conservation plan applies is Bandera County. Major communities in the county are Bandera, Medina, Lakehills, Pipe Creek, Tarpley, and Vanderpool. Including the City of Bandera, there are 16 public water systems within the planning area, having a total of 1,853 water service connections (Table A-1). In addition, there are 95 platted subdivisions in which the residences presumably obtain water from individual wells.

The drought contingency plan provides procedures for both voluntary and mandatory actions to temporarily reduce water usage during a water shortage crisis. Drought contingency procedures may include water conservation and prohibition of certain uses. Both procedures are tools that officials and individuals will have available to effectively operate public water supply systems during a wide range of conditions.

A.2 Water Conservation Goals for Per Capita Water Use

The quantity of water needed in an area depends on both the number of people who live there and the number of gallons each person uses per day, commonly referred to as per

TABLE A-1 List of Public Water Systems in Bandera County		
Water System	**Water Source**	**Number of Connections***
1. City of Bandera	Trinity Sands	762
2. Holiday Water Service, Inc.	Lake Medina/Trinity	201
3. Bandera River Ranch No. 1	Trinity Group	45
4. Cedar Hill Subdivision	Not Known	3
5. Comanche Cliffs*	Not Known	8
6. Elmwood Estates**	Glen Rose	11
7. Enchanted River Estates***	Glen Rose	35
8. Flying L Ranch P.U.D.	Edwards-Trinity	35
9. Hill Country Mobile Home	Edwards-Trinity	16
10. Medina Highlands	Glen Rose	14
11. Lakewood Water**	Glen Rose	37
12. Medina WSC	Trinity	160
13. Blue Medina WSC	Glen Rose	48
14. Bandera County F.W.S.D. #1	Trinity Sands	430
15. River Bend Estates***	Glen Rose	45
16. San Julian Creek Estates**	Not Known	3
17. Bandina, Inc.	Not Known	30
Total		1,883

Source: Texas Department of Health

*May 1990
**Operated by Hill Country Utilities
***Operated by Bandera Water Company

capita water use. In the following discussion, information about per capita water use in Bandera and neighboring areas is presented (Table A-2).

TABLE A-2
Per Capita Water Use for Bandera, Neighboring Cities, and Statewide*

City		Without Conservation	
		Average Use	Drought Use
1.	Converse	130	165
2.	Devine	155	179
3.	**Bandera**	**156**	**179**
4.	Rock Springs	158	190
5.	Boerne	162	182
6.	**Statewide**	**165**	**194**
7.	Blanco	166	191
8.	Kerrville	179	197
9.	San Antonio	185	208
10.	Sabinal	203	246
11.	Hondo	233	291
12.	Uvalde	267	302
13.	Castroville	284	320
	Bandera Rural	**112**	**133**
	State Rural	**110**	**130**

*Source: Texas Water Development Board water planning data. Average use is for 1977-1986. Drought use is for four driest years of the 1977-1986 period.

Average daily water use within the county ranges between 112 gallons per person per day in rural areas to 156 gallons per person per day for the City of Bandera. Under dry weather conditions, per capita water use is 15 percent to 18 percent higher than the average, and ranges between 133 and 179 gallons per person per day.

In the 1990 Texas Water Plan, the Texas Water Development Board (TWDB) established a water conservation goal of reducing per capita water use by 15 percent by 2020. In the Texas Water Plan, this goal would be achieved in increments of five percent per decade between 1990 and 2020. Per capita water use under average conditions in the City of Bandera between 1977 and 1986 was 156 gallons per person per day, which is 94 percent of the statewide average of 165 gallons per person per day (Table A-2). This rate is also one of the lowest compared to neighboring cities. (1977-1986 period was used as the base period in the 1990 Texas Water Plan.) Therefore, because Bandera's rate is already less than the statewide average, it is recommended the water conservation goal for the Springhills WMD study be established at 10 percent reduction in per capita water use for the City of Bandera to be phased in at five percent per decade between 1990 and 2010. This results in ultimate water use rates for the City of Bandera (Subarea E) of 140 gallons per person per day for average conditions and 161 gallons per person per day for drought conditions.

Per capita water use for the rural subareas (C, G, H, I, and J) of Bandera County was set at 110 gallons per person per day for average conditions and 130 gallons per person per day for drought conditions. These are the rates used by the TWDB for rural areas in the 1990 Texas Water Plan, and are nearly identical to existing rural water use rates in the county. For the rural areas, water use rates were held constant through the 50-year planning period. However, the water conservation programs described herein should be implemented to keep per capita water use rates from rising as development occurs and the subareas take on the characteristics of urban communities, which typically exhibit higher per capita water use than rural areas.

For the rapidly growing subareas (A, B, D, and F) of Bandera County, per capita water use can be expected to increase in comparison to the historic rural levels as public water systems are developed and the communities become more urban in their water using characteristics. For example, additional water will be needed for fire protection, sanitation, landscaping, and commercial establishments. For these rapidly growing subareas, per capita water use goals should be established at the ultimate conservation rates of the City of Bandera. This recommendation is based on the idea that efficient plumbing fixtures will be installed in new homes, native plants will be used in landscaping, and a water conservation rate structure will be established.

Projected per capita water use rates for each subarea for the 1990-2040 planning period are shown in Table 3-2 of the report. These rates are used in the study for projecting the future water requirements for each subarea in the county.

A.3 Water Conservation Methods

The objective of water conservation is to establish a permanent reduction in the quantity of water required for day-to-day living and business activities. The TWDB's recommended water saving methods are listed below.[1]

A.3.1 Bathroom

1. Take a shower instead of filling the tub and taking a bath. Showers usually use less water than tub baths.

2. Install a low-flow shower head which restricts the quantity of flow at 60 psi to no more than 2.75 gallons per minute.

[1]Texas Water Development Board, Austin, Texas.

3. Take short showers and install a cutoff valve or turn the water off while soaping and back on again only to rinse.

4. Do not use hot water when cold will do. Water and energy can be saved by washing hands with soap and cold water, hot water should only be added when hands are especially dirty.

5. Reduce the level of the water being used in a bath tub by one or two inches if a shower is not available.

6. Turn water off when brushing teeth until it is time to rinse.

7. Do not let water run when washing hands. Instead, hands should be wet, and water should be turned off while soaping and scrubbing and turned on again to rinse. A cutoff valve may also be installed on the faucet.

8. Shampoo hair in the shower. Shampooing in the shower takes only a little more water than is used to shampoo hair during a bath and much less than shampooing and bathing separately.

9. Hold hot water in the basin when shaving instead of letting the faucet continue to run.

10. Test toilets for leaks. To test for a leak, a few drops of food coloring can be added to the water in the tank. The toilet should not be flushed. The customer can then watch to see if the coloring appears in the bowl within a few minutes. If it does, the fixture needs adjustment or repair.

11. Use a toilet tank displacement device. A one-gallon plastic milk bottle can be filled with stones or with water, recapped, and placed in the toilet tank. This will reduce the amount of water in the tank but still providing enough for flushing. (Bricks which some people use for this purpose are not recommended since they crumble eventually and could damage the working mechanism, necessitating a call to the plumber).

12. Install faucet aerators to reduce water consumption.

13. Never use the toilet to dispose of cleaning tissues, cigarette butts, or other trash. This can waste a great deal of water and also places an unnecessary load on the sewage treatment plant or septic tank.

14. Install a new low-volume flush toilet that uses 1.6 gallons or less per flush when building a new home or remodeling a bathroom.

A.3.2 Kitchen

1. Use a pan of water (or place a stopper in the sink) for rinsing pots and pans and cooking implements when cooking rather than turning on the water faucet each time a rinse is needed.

2. Never run the dishwasher without a full load. In addition to saving water, expensive detergent will last longer and a significant energy savings will appear on the utility bill.

3. Use the sink disposal sparingly, and never use it for just a few scraps.

4. Keep a container of drinking water in the refrigerator. Running water from the tap until it is cool is wasteful. Better still, both water and energy can be saved by keeping cold water in a picnic jug on a kitchen counter to avoid opening the refrigerator door frequently.

5. Use a small pan of cold water when cleaning vegetables rather than letting the faucet run.

6. Use only a little water in the pot and put a lid on it for cooking most food. Not only does this method save water, but food is more nutritious since vitamins and minerals are not poured down the drain with the extra cooking water.

7. Use a pan of water for rinsing when hand washing dishes rather than a running faucet.

8. Always keep water conservation in mind, and think of other ways to save in the kitchen. Small kitchen savings from not making too much coffee or letting ice cubes melt in a sink can add up in a year's time.

A.3.3 Laundry

1. Wash only a full load when using an automatic washing machine.

2. Use the lowest water level setting on the washing machine for light loads whenever possible.

3. Use cold water as often as possible to save energy and to conserve the hot water for uses which cold water cannot serve. (This is also better for clothing made of today's synthetic fabrics.)

A.3.4 Appliances and Plumbing

1. Check water requirements of various models and brands when considering purchasing any new appliance that uses water. Some use less water than others.

2. Check all water line connections and faucets for leaks. If the cost of water is $1.00 per 1,000 gallons, one could be paying a large bill for water that simply goes down the drain because of leakage. A slow drip can waste as much as 170 gallons of water EACH DAY, or 5,000 gallons per month, and can add as much as $10.00 per month to the water bill.

3. Learn to replace faucet washers so that drips can be corrected promptly. It is easy to do, costs very little, and can represent a substantial amount saved in plumbing and water bills.

4. Check for water leakage that the customer may be entirely unaware of, such as a leak between the water meter and the house. To check, all indoor and outdoor faucets should be turned off, and the water meter should be checked. If it continues to run or turn, a leak probably exists and needs to be located.

5. Insulate all hot water pipes to avoid the delays (and wasted water) experienced while waiting for the water to "run hot".

6. Be sure the hot water heater thermostat is not set too high. Extremely hot settings waste water and energy because the water often has to be cooled with cold water before it can be used.

7. Use a moisture meter to determine when house plants need water. More plants die from over-watering than from being too dry.

A.3.5 Out-Of-Door Uses

1. Water lawns early in the morning during the hotter summer months. Much of the water used on the lawn can simply evaporate between the sprinkler and the grass.

2. Use a sprinkler that produces large drops of water, rather than a fine mist, to avoid evaporation.

3. Turn soaker hoses so the holes are on the bottom to avoid evaporation.

4. Water slowly for better absorption, and never water on windy days.

5. Forget about watering the street or walks or driveways. They will never grow a thing.

6. Condition the soil with compost before planting grass or flower beds so that water will soak in rather than run off.

7. Fertilize lawns at least twice a year for root stimulation. Grass with a good root system makes better use of less water.

8. Learn to know when grass needs watering. If it has turned a dull grey-green or if footprints remain visible, it is time to water.

9. Do not water too frequently. Too much water can overload the soil so that air cannot get to the roots and can encourage plant diseases.

10. Do not over-water. Soil can absorb only so much moisture and the rest simply runs off. A timer will help, and either a kitchen timer or an alarm clock will do. An inch and one-half of water applied once a week will keep most Texas grasses alive and healthy.

11. Operate automatic sprinkler systems only when the demand on the town's water supply is lowest. Set the system to operate between four and six a.m.

12. Do not scalp lawns when mowing during hot weather. Taller grass holds moisture better. Rather, grass should be cut fairly often, so that only 1/2 to 3/4 inch is trimmed off. A better looking lawn will result.

13. Use a watering can or hand water with the hose in small areas of the lawn that need more frequent watering (those near walks or driveways or in especially hot, sunny spots).

14. Learn what types of grass, shrubbery, and plants do best in the area and in which parts of the lawn, and then plant accordingly. If one has a heavily shaded yard, no amount of water will make roses bloom. In especially dry sections of the state, attractive arrangements of plants that are adapted to arid or semi-arid climates should be chosen.

15. Consider decorating areas of the lawn with rocks, gravel, wood chips, or other materials now available that require no water at all.

16. Do not "sweep" walks and driveways with the hose. Use a broom or rake instead.

17. Use a bucket of soapy water and use the hose only for rinsing when washing the car.

Estimates of potential water savings through water conservation actions range from 1.0 gallon per person per day for public information to 9.5 gallons per person per day for water conserving toilets (Table A-3):

TABLE A-3
Water Conservation Potentials

Conservation Action	Water Savings (gpcd)*
Public Information/Education	1.0
Water Conserving Plumbing	
Toilets (1.6 gal/flush)	9.5
Showerheads (3 gpm)	6.7
Faucets (2 gpm)	0.5
Pipe Insulation	2.0
Water Efficient Dishwasher (13 gal/cycle)	2.0
Water Conserving Rate Structure	3.5
TOTAL	25.2

*gpcd = gallons per capita per day

Source: Hays County Water and Wastewater Study, Hays County Water Development Board, HDR Engineering, Inc., Austin, Texas, May 1989.

A.4 Water Conservation Plan

The TWDB Water Conservation Planning Guidelines contain nine major water conservation methods. This water conservation plan addresses each of the nine methods: (1) public information and education; (2) recommended water conserving plumbing fixtures; (3) water conservation retrofit programs; (4) water conservation-oriented rate structures; (5) metering and meter testing; (6) water conserving landscaping; (7) leak detection and water audits; (8) wastewater reuse and recycling; and (9) implementation and enforcement. Each method is explained below, and in Section A.4.9, implementation procedures and associated costs are presented.

A.4.1 Public Information and Education

The Springhills WMD will organize and operate an ongoing program to:

- Provide qualified individuals to speak at institutions, organizations, and groups throughout the area at regular intervals;
- Conduct or sponsor exhibits on conservation, water saving devices, and other methods to promote water conservation and efficiency;
- Provide and distribute brochures and other materials to the citizens of the area. Materials available from agencies such as the Texas Agricultural Extension Service and the TWDB can be used;
- Work in cooperation with builders, developers, and governmental agencies to provide exhibits of xeriscape landscaping for new homes;
- Work in cooperation with schools to establish an education program within these institutions and to provide them with landscape videos, brochures, and other training aids; and
- Develop welcome packages for new citizens to educate them in the benefits of conservation and inform them of water efficient plumbing fixtures and water efficient plants, trees, shrubs, and grasses best suited to this area.

A.4.2 Water-Conserving Plumbing Fixtures

The Springhills WMD will inform cities, communities, water utilities, and the public about the existence of water-conserving plumbing fixtures, and will encourage the use of such fixtures in new homes, new commercial and public buildings, and when replacing fixtures in existing homes and commercial and public buildings. City and water utility plumbing codes should require the use of water-conserving plumbing fixtures. The fixtures listed below are water-conserving fixtures which meet new state water conservation standards, as specified in Senate Bill 587, 1991 Regular Session, Texas Legislature:

- Toilets: Wall mounted, flushometer types that have a maximum flush of 2.0 gallons, with all other types having a maximum flush that does not exceed 1.6 gallons of water;
- Urinals: Maximum flush of one gallon of water;
- Showerheads: Maximum flow rate of 2.75 gallons per minute at 80 psi (pounds per square inch), except where necessary for safety reasons;
- Faucets: Maximum flow rate of 2.2 gallons per minute at 60 psi for all lavatory, kitchen, and bar sink faucets;
- Drinking Water Fountains: Must be self closing; and
- Hot Water Piping: All hot water lines not in or under a concrete slab should be insulated.

A.4.3 Water Conservation Retrofit Program

The Springhills WMD will encourage the retrofit of existing plumbing fixtures through the voluntary efforts of individual consumers for their homes and businesses. Adoption of a water conservation plumbing code (as described in Section A.4.2) will provide a gradual up-grading of plumbing fixtures in existing structures.

A.4.4 Water Conservation - Oriented Rate Structure

The Springhills WMD will encourage and promote cities and water utilities to adopt either a uniform or an increasing block rate structure to encourage water users to reduce water use and thereby increase water conservation. With an increasing block rate, the price per 1,000 gallons of water increases as the quantity used increases, thereby discouraging excessive and wasteful water use.

A.4.5 Metering and Meter Testing

The purpose of metering is to measure the quantity of water being distributed to customers throughout the system to account for all water being produced and to accurately bill for the quantity of water delivered to each customer. A recommended schedule for testing meters is as follows:

- Production or master meters, test once per year;
- Meters large than 1", test once every three years; and
- Meters 1" or less, test once every 10 years.

A.4.6 Water-Conserving Landscaping

The Springhills WMD will encourage water-conserving landscaping through public information and education. Well-designed and properly maintained demonstration landscapes located in parks and other highly visible areas will be encouraged to promote the water-conserving landscape concept.

A.4.7 Leak Detection and Water Audits

The Springhills WMD will encourage cities and water utilities to perform leak detection studies and water audits. Technical assistance can be obtained from the TWDB at no cost to the water utility. Leak detection and repair of leaks will reduce the quantity of water that must be pumped from aquifers and/or obtained from surface water sources.

A.4.8 Wastewater Reuse and Recycling

The Springhills WMD will encourage reuse and recycling whenever it is found to be fiscally, environmentally, and institutionally feasible. The leading potential types of water reuse projects are:

- Use of the City of Bandera's wastewater effluent for irrigation of parks and/or golf courses;
- Transmission of the City of Bandera's wastewater effluent to a surface water reservoir project for treatment and reuse as a public water supply;
- Installation of gray water (water from the washing machines, showers, and bath tubs) tanks in homes for lawn and landscape watering; and
- Installation of central sewers and wastewater treatment systems as subdivisions expand and grow into cities. Treated effluent could then be used to irrigate parks, golf courses, public areas, and perhaps forage production for livestock.

A.4.9 Means of Implementation and Enforcement

The water conservation plan will be implemented and enforced through cooperative efforts among the Springhills WMD, cities, communities, water utilities, and other public entities in Bandera County. Methods and costs of implementation are described below.

Public Information and Education: The Springhills WMD will make presentations of the water conservation plan at public meetings and will print and distribute copies of the plan, including copies of water conservation methods, to cities, communities, water utilities, and other groups upon request. As a part of its water conservation public information program, the Springhills WMD will purchase and distribute the following list of water conservation literature from the TWDB. The method of distribution will be to provide copies to cities and water utilities for inclusion as bill stuffers. In addition, copies will be distributed at public meetings and placed in businesses such as banks, laundries, and restaurants for customers. Also, copies will be given to the local newspaper for use in writing water conservation articles.

Water Conservation Plumbing Fixtures: In 1991, the Texas Legislature adopted legislation which sets water conservation standards for plumbing fixtures sold within Texas. These standards are listed in Section A.4.2. With these standards in place, water-conserving plumbing fixtures will be phased into use as new homes and commercial buildings are built. Thus, there is no need for Springhills WMD action other than that of an information

Water Conservation Literature			
Title	**Number of Copies Annually**	**Cost per Copy ($)**	**Total Cost ($)**
Water...Half-A Hundred Ways To Save It: TWDB WC-1, Pamphlet, 8 pp.	3,000	$0.04	$120
A Homeowner's Guide to Water Use and Water Conservation: TWDB WC-3, Booklet, 22 pp.	2,000	$0.25	$500
How to Save Water Inside the Home: TWDB WC-4, Pamphlet, 8 pp.	3,000	$0.07	$210
Water Saving Ideas for Business and Industry: TWDB WC-5, Pamphlet, 8 pp.	250	$0.04	$10
How to Save Water Outside the Home: TWDB WC-6, Pamphlet, 8 pp.	3,000	$0.07	$210
Lawn Watering Guide: TWDB WC-12 Card, 3.5"x5"	3,000	$0.04	$120
Drip Irrigation: TWDB WC-8, Pamphlet, 6 pp.	250	$0.10	$ 25
A Directory of Water Saving Plants and Trees for Texas: TWDB WC-13, Booklet, 42 pp.	250	$0.55	$138
Xeriscape-Principles, Benefits: TWDB WC-14A, Pamphlet, 4 pp., Size 3.5"x7.5".	3,000	$0.07	$210
			$1,543

water-conserving action is included in the budget for public information and education. It is anticipated that costs to water utilities will be offset by more accurate accounting and billing of customers.

Water-Conserving Landscaping: Through its public information and education program, the Springhills WMD will encourage water-conserving landscaping, including the use of plants and shrubs that are native to the area. The budget for this activity is included in the budget for public information and education. A small xeriscape demonstration project could be implemented in a high-visibility area of the county at a cost of about $1,500.

Leak Detection and Water Audits: The Springhills WMD will encourage cities and water utilities to perform leak detection and water audits, and to repair leaks to save water and reduce operating costs. Technical assistance to cities and water utilities for leak detection and water audits can be obtained from the TWDB at no cost. Thus, no budget is included for this water conservation activity.

Wastewater Reuse and Recycling: The use of wastewater effluent from a central sewage collection and treatment system for irrigation of parks, golf courses, or forage crops must be planned and evaluated on an individual basis. The cost to implement reuse would be borne by the entities involved; thus, the Springhills WMD water conservation plan does not include a separate budget for this water conservation action.

The use of gray water systems in homes for lawn and landscape watering is most easily installed as homes are being built. Existing homes can be retrofitted with a gray water system at a higher cost. In the case of new homes, gray water tanks, piping, and pumping equipment for a family of four would cost approximately $1,600 to install. The costs to install such a system in existing homes may be considerably higher, since piping would need to be modified and pumps added.

Through its public information and education program, the Springhills WMD will encourage water reuse and recognize that the costs of water reuse will be borne by the beneficiaries. To the extent that water reuse saves water and lowers monthly water bills, the benefits can be used to pay back the costs of reuse projects.

A.5 Drought Contingency Methods

Drought and other uncontrollable circumstances can disrupt the normal availability of water supplies from either ground or surface sources. During drought periods, consumer demand is typically 15 to 18 percent higher than under normal conditions. Limitations on the supply of either ground or surface water, or on facilities to pump, treat, store, or distribute water can also present a public water supply utility with an emergency demand management situation. The purpose of a drought contingency plan is to establish methods to be used only as long as the emergency exists. The plan includes the following:

1. Trigger conditions signaling the start of an emergency period;
2. Drought contingency measures and initiation of water demand management procedures;
3. Information and education; and
4. Termination notification actions.

A.5.1 Trigger Conditions

The water supply utility should initiate drought contingency measures upon occurrence of conditions such as those listed below:

Mild Conditions

a. Daily water demand reaches the level of 90 percent of system capacity for three consecutive days; or

b. Distribution pressure remains below normal for more than six consecutive hours.

Moderate Conditions

a. Daily water demands reach 100 percent of system capacity for three consecutive days;

b. The supply of water is continually decreasing on a daily basis and the water supply utility is advised to conserve by the Springhills WMD, the Texas Water Commission, or the Texas Department of Health; or

c. Decrease in the water pressures in the distribution system as measured by the pressure gauges and customer complaints.

Severe Conditions

a. The imminent or actual failure of a major component of the system which would cause an immediate health or safety hazard;

b. Water demand is exceeding 100 percent of system capacity for three consecutive days; or

c. The full allotment of raw water is being pumped from the system's supply source.

A.5.2 Drought Contingency Measures and Initiation of Water Demand Management Procedures

The following actions should be taken when trigger conditions are met for the area. The water utility should monitor water pressure in the distribution system and water levels in the storage tanks.

Mild Condition

a. Inform public by giving notice of a mild drought to the customers served by the system, post the notice, and notify news media of the mild drought;

b. Included in the information to the public will be the recommendation that water users look for ways to conserve water.

c. Through the news media, the public will be advised daily of the trigger conditions.

Moderate Condition

a. Inform the public through the news media that a trigger condition has been reached, and they should look for ways to voluntarily reduce water use. Specific steps which can be taken will be provided through the news media (see water saving methods in Section A.3);

b. Notify major commercial water users of the situation and request voluntary water use reductions;

c. A lawn watering schedule should be implemented: Customers may water every fifth day based on the last digit of their street address (i.e., 0 and 1 on Monday, 2 and 3 on Tuesday, etc.). Watering shall occur only between the hours of 6-10 a.m. and 8-10 p.m.; and

d. Recommend water users insulate pipes rather than running water to prevent freezing during winter months.

Severe Condition

a. Continue implementation of all relevant actions in preceding phase;

b. Car washing, window washing, and pavement washing should be prohibited except when a bucket is used;

c. The following public water uses, not essential for public health or safety, should be prohibited:

1). Street washing;
2). Water hydrant flushing;
3). Filling swimming pools;
4). Athletic field watering;

5). Park watering; and
6). Golf course watering.

d. Certain industrial and commercial water use which are not essential to the health and safety of the community should be prohibited; and

e. Through the news media, the public should be advised daily of the trigger conditions.

A.5.3 Information and Education

Once trigger conditions have been reached, the public should be informed of the conditions, and measures to be taken. The process for notifying the public includes:

1. Posting the Notice of Drought conditions at Springhills WMD, City Hall, County Courthouse, Post Office, Public Library, Senior Citizens Center, and Major Supermarkets;

2. Copy of notice to newspapers, and hold press conferences; and

3. Copy of notice to San Antonio radio and television stations.

A.5.4 Termination Notification

Termination of the drought measures should take place when the trigger conditions which initiated the drought measures have subsided, and an emergency situation no longer exists. The public can be informed of the termination of the drought measures in the same manner that they were informed of the initiation of the drought measures.

APPENDIX B

ENVIRONMENTAL CONSIDERATIONS

SPRINGHILLS WATER MANAGEMENT DISTRICT
REGIONAL WATER SUPPLY STUDY
ENVIRONMENTAL CONSIDERATIONS

Prepared for

HDR ENGINEERING, INC.

Prepared by
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August 1991

SPRINGHILLS WATER MANAGEMENT DISTRICT

REGIONAL WATER SUPPLY STUDY

ENVIRONMENTAL CONSIDERATIONS

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1.0 INTRODUCTION

1.1 Purpose and Scope

This report examines environmental features of the diversion, reservoir, and pipeline alternatives proposed to supplement the water supply system for portions of Bandera County, Texas. In addition to looking for environmental features that could render a proposed facility or site unsuitable or impractical for the proposed uses, the report characterizes important environmental features, known cultural resources, and human activities of each facility area. This is done in order to evaluate each site with respect to environmental sensitivity, mitigation liability, and the probable costs of addressing those issues.

1.2 Project Description

The proposed water supply system facilities and operation are depicted and described by HDR Engineering documents. The proposed project facilities consist of potential storage reservoir sites at Mason Creek, Bandera Creek, Town Mountain, Upper Privilege Creek, and Lower Privilege Creek. Diversion facilities are proposed on the Medina River near the mouth of Privilege Creek and at Bandera City Park Lake dam. Medina River pipeline crossings that would connect these diversion facilities and reservoirs are also addressed here.

1.3 Materials and Methods

The dam locations, maximum reservoir elevations, and surface areas of the proposed reservoirs, and the alternative diversion facility locations, obtained from HDR Engineering were used to delineate the potential area of environmental effects on topographic maps. Within the reservoir areas direct construction impacts resulting from clearing and building, and operational impacts from flooding are expected. Other direct and indirect operational effects will include changes in downstream flows below the storage reservoirs and diversions, and increased access to and use of areas that have been private. Land use and habitat types within each reservoir, diversion facility and pipeline route have been identified and evaluated using available literature sources and a variety of unpublished data file resources, including the

Texas Parks and Wildlife Department, Resources Protection Division's data and mapping files for endangered, protected and sensitive resources. Cultural Resources were identified and evaluated using a similar procedure and the resources of the Texas Archaeological Research Library. This data base is on 7.5 minute quadrangles maintained in the Springhills Water Management District data file.

2.0 ENVIRONMENTAL SETTING

2.1 Regional Description

The study area encompasses Bandera County in the Edwards Plateau region of central Texas. Bandera County is located on the Edwards Aquifer catchment area which is characterized by a surface cap of pourus Edwards Limestone that provides base flows to spring fed streams that flow downstream to the Edwards recharge zone. The topography of Bandera County typically consists of rolling hills with gentle to steep rocky slopes that support juniper oak woodlands of varying density. Stream valleys tend to be highly modified by agricultural activities, as the larger ones (ie, Privilege Creek) have flat valley floors and deeper soils than do the adjacent uplands. The climate is subtropical subhumid with mild winters and warm summers. The vegetation is live oak *(Quercus buckleyi)* and ashe juniper *(Juniperus ashei)* parks, an open shrubland with midgrasses and xeromorphic shrubs, including several bluestem species *(Schizachyrium and Andropogon spp.)*, gramas *(Bouteloua spp.)*, sumac *(Rhus spp.)* and agarito *(Berberis trifoliolata)*. Baldcypress *(Taxodium distichum)* are found along perennial streams and rivers, while pecan *(Carya illinoiensis)*, Arizona and little walnut *(Juglans marjor, J. microcarpa)*, hackberry *(Celtis laevigata)*, black willow *(Salix nigra)*, and eastern cottonwood *(Populus deltoides)* are more widely distributed in riparian areas of both perennial and intermittent streams (Texas Almanac, 1989; TPWD, 1984).

2.2 Important Species

Species considered Endangered or Threatened under the Endangered Species Act (16 USC 1536) by the U.S. Fish and Wildlife Service, and having some likelihood of being present in

Bandera County are listed in Table 2-1. Of those species most likely to be present, only the golden cheeked warbler, the tobusch fishhook cactus and, to some extent, the black-capped vireo are strongly associated with, and dependent on, specific habitats that may be in short supply. The other species tend to be winter migrants for whom non-nesting habitat is probably not limiting.

State designated protected non-game species that may occur in Bandera County are listed in Table 2-2. The species most likely to be present in aquatic or riparian habitats include the white-faced ibis, wood stork, the two salamanders and the indigo snake.

2.3 Cultural Resources

Of the cultural resources recorded in the project vicinity (Table 2-3), only the Mason Creek reservoir includes a known archaeological site (41BN59). It is a prehistoric camp of unknown extent, but probably large, that has been recommended for further testing.

3.0 SITE EVALUATIONS

3.1 Reservoir Sites

The characteristics of each proposed reservoir site in Bandera County are summarized in Table 3-1. The five sites are relatively small, with maximum surface areas ranging from 600 acres at Mason Creek to 120 acres at Town Mountain. The relatively steep site topography at Town Mountain facilitates a reservoir surface area less than a quarter the size of the next larger site at Upper Privilege Creek. The Town Mountain site has a small drainage area with relatively steep slopes. There is a gravel mining operation adjacent to the reservoir site (HDR, pers. com.), therefore, we have assumed it is significantly disturbed by mining activities.

There are no federally listed species reported within or in the vicinity of the reservoir sites, diversion sites, or pipeline corridors. State listed species, or species and resources of special concern to Texas Parks and Wildlife Department, have been reported within or in the vicinity of reservoir and diversion sites (Table 3-2). The latter species and resources are not protected by either state or federal law, but are considered to occur in only limited numbers, to have restricted distribution, or to be sensitive to disturbance. The state managed Guadalupe bass

TABLE 2-1

Endangered and Threatened Species of Bandera County, Texas Listed by the U. S. Department of the Interior
(50 CFR 17.11 & 17.12, 1 January 1990)

Taxa		Occurrence [1]
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	***
Bald Eagle	*Haliaeetus leucocephalus*	***
Black-capped Vireo	*Vireo atricapillus*	**
Golden-Cheeked Warbler	*Dendroica chrysoparia*	**
Interior Least Tern	*Sterna antillarum athalassas*	*
White-faced Ibis	*Plegadis chihi*	**
Wood Stork	*Mycteria americana*	***
Tobusch fishhook cactus	*Ancistrocactus tobuschii*	***

[1] County occurrence information from Texas Parks and Wildlife Department Endangered / Threatened species file:

***verified recent occurrence
**within general distribution of species
*periphery of known distribution

TABLE 2-2

Threatened (31 TAC Sec. 65-171-65.177) and
Endangered (31 TAC Sec. 65.181-65.184)
Species Listed by the State of Texas that are of Known or Possible Occurrence in Bandera County

Taxa		Occurrence [1]
Swallow-tailed kite	*Elanoides forficatus*	**
White-faced Ibis	*Plegadis chihi*	**
White-tailed hawk	*Buteo albicaudatus*	**
Zone-tailed hawk	*Buteo albonotatus*	**
Blind Comal salamander	*Eurycea tridentifera*	*
Cascade Cavern salamander	*Eurycea latitans*	*
Texas tortoise	*Gopherus berlandieri*	*
Reticulate collared lizard	*Crotaphytus reticulatus*	*
Texas horned lizard	*Phrynosoma cornutum*	*
Texas indigo snake	*Drymarchon corais erebennus*	*
Big red Sage	*Salvia penstemonoides*	***
Edge falls anemone	*Anemone edwardsiana var. petraea*	***
Glass mountain coral-root	*Hexalectris nitida*	***
Sabinal prairie-clover	*Dalea sabinalis*	***
Texas mock-orange	*Philadelphus texensis*	***

[1] County occurrence information from Texas Parks and Wildlife Department Endangered / Threatened species file:

***verified recent occurrence
**within general distribution of species
*periphery of known distribution

TABLE 2-3

Texas Archaeological Research Library Records for Bandera County
(Bandera, Bandera Pass, Turkey Knob, Pipe Creek, U.S. Geological Society, 1982, 7.5 Minute Quadrants)

Quadrant / Record No	Condition or Recommendation, if any
Bandera / 41BN3	Good
41BN6	Additional Survey
41BN59	Further Survey
41BN68	No further work
41BN94	Further survey
41BN96	Bad condition
41BN97	Fair to good condition
Bandera Pass/ 41BN19	Further survey
41BN73	Further survey
Turkey Knob / 41BN111	Fair, one-third eroded
41BN112	Historic site, damaged
Pipe Creek / 41BN109	No further work
41BN113	Totally excavated
41BN107	Destroyed
41BN108	Rockshelter, Damaged
41BN114	Damaged
41BN115	Poor
41BN13	No further work
41BN69	No further work
41BN70	No further work
41BN72	No further work
41BN60	No further work
41BN1	No further work
41BN116	Fair to good
41BN71	No further work

TABLE 3-1

Environmental Impacts Evaluation Matrix

	Bandera Creek	Mason Creek	Lower Privilege	Upper Privilege	Town Mountain *
Reservoir (acres)	350	600	450	350	120
Wood type	O/J C	O/J PB	O/J	O/J	O/J
Stream Flow (S,P,I)	P, S	P, S	P	I	I
Special Resources	NO	NO	NO	NO	NO
Permanent innundation	YES	YES	YES	YES	YES
Instream flow requirement	POSSIBLE	POSSIBLE	POSSIBLE	POSSIBLE	

TABLE 3-1 (Continued)

Environmental Impacts Evaluation Matrix

	Bandera City Park Lake	Privilege Crk at Medina R	Medina River Crossing [2]
Reservoir (acres)	0.25 [1]	1.0	0.25
Wood type	O/J C	O/J C, PB	O/J *
Stream Flow (S,P,I)	P	P,S	P
Special Resources	YES	NO	YES
Permanent innundation	YES	YES	YES
Instream flow requirement	POSSIBLE	POSSIBLE	POSSIBLE

TABLE 3-1 (Concluded)

* Not inspected
[1] = Urbanized area
[2] = Medina River

VEGETATION TYPE
O/J = live oak - ashe juniper woodland
C = CYPRESS
PB = PECAN BOTTOM

Perennial flow code:
S = Spring
P = Perennial
I = Intermittent
R = Recharge Zone

TABLE 3-2

IMPORTANT SPECIES AND HABITATS
REPORTED IN THE AREA OF THE PROPOSED RESERVOIRS,
DIVERSION SITES AND PIPELINE CORRIDORS
Texas Parks and Wildlife, Resource Protection Division, 1991

Taxa		Federal Status	State Status	State Rank	Reservoir * /Diversion Site
Guadalupe Bass	*Micropterus treculi*	C2		S3	Bandera City Park Lake1 / Medina River Crossing1
Buckley tridens	*Tridens buckleyanus*			S2	General Project Vicinity 3
Heller's false-gromwell	*Onosmodium helleri*			S3	General Project Vicinity 3
Texas amorpha	*Amorpha Roemerana*	3C		S3	Town Mountain 3; Bandera City Park 3
Edward Ranch Rookery [1]				Private	General Project Vicinity 3
Pete Knowls Rookery [1]				Private	General Project Vicinity 3
Tobbin Ranch Rookery [1]				Private	General Project Vicinity 3
Walter Ranch Rookery [1]				Private	Middle Verde Pipeline Corridor 1

TABLE 3-2 (Concluded)

Key to notes and codes used in Table

[1] Rookeries are great blue heron colonies, reported in creek and river bottom pecan trees at each site.

* proximity to the reservoir / diversion site or pipeline crossing:
1 = within reservoir, diversion site or pipeline corridor
3 = in vicinity of reservoir, not necessarily the drainage area
General Project Vicinity = reported from a point located on a project area 7.5 minute U.S. Geological Survey quadrant by Texas Parks and Wildlife, Resources Protection Division data file

Federal:

LE = listed as endangered

C2 = candidate category 2; under review for possible listing, but USFWS needs more information

3C = no longer under federal review for listing; either more abundant or widespread than thought.

State Status:

E = Endangered

State Rank:

S1 = less than 6 occurrences known in state; critically imperiled in state; especially vulnerable to extirpation from the state.

S2 = 6-20 known occurrences in state; imperiled because of rarity; very vulnerable to extirpation from the state.

S3 = 21-100 known state occurrences; either rare or uncommon in state.

S4 = more than 100 occurrences in state; apparently secure, though may be quite rare in some areas of state.

S5 = Demonstrably secure in state.

Private = located on privately owned land.

(*Micropterus treculi*) is a "Category 2" species that is currently under study and may at some time be listed as Endangered or Threatened by the U. S. Fish and Wildlife Service. The Guadalupe bass was reported in the Medina River at Bandera City Park.

Other important resources that are reported in the area include nesting colonies of the great blue heron (*Ardea herodias*) in the general vicinity of the reservoirs, diversion sites, and pipeline corridors (Mullins, L.M. et. al. 1982. et. seq.). The great blue heron is a versatile nesting water bird with a stable population that nests in diverse sites including cypress (*Taxodium spp.*), shrubs (*Baccharis sp*), cactus (*Opuntia sp*), channel markers and abandoned duck blinds (Texas Colonial Waterbird Society. 1982).

Bandera Creek's channels were marked by cypress tress indicating that it is spring fed. There are several road crossings including FM 173, Highway 16, and local roads between the upper reach and the Medina River. The Mason Creek reservoir site was the least accessible, least developed site. It was marked by large junipers on the upper slopes and a diversity of creek bottom hardwoods. Privilege Creek is in a broad valley that has been largely cleared for crops and pasture land except for a narrow riparian strip along the creek. There is some residential development on the terraces above the creek and recreational use of the stream. Picnicking was observed on July 26, 1991. At the Upper Privilege Creek site an upland woodland appeared to be less disturbed than at the lower site. Several pipeline routes would include crossings at the Medina River. The lower diversion site on the Medina River at the mouth of Privilege Creek has a wooded riparian corridor, and is within a residential development. A low water dam at this site would have to be built, probably above the mouth of Privilege Creek. Bandera City Park Lake is located on the Medina River upstream from the Highway 173 crossing, where there is a an existing low water dam.

3.2 Environmental Effects and Mitigation Requirements

Table 3-3 summarizes projected costs for environmental and archaeological work, and probable mitigation requirements, for each site. Environmental report costs are assumed to include baseline studies, a comprehensive Environmental Assessment, and permit support. Additional efforts such as endangered species survey and instream flows affect the environmental report costs. U.S. Army Corps of Engineers, Section 404 permits and state

TABLE 3-3

PROJECTED COSTS

Reservoir Sites	Bandera Creek	Mason Creek	Lower Privilege Creek	Upper Privilege Creek	Town Mountain
maximum elevation/ surface MSL / acres	1245/350	1300/600	1285/450	1340/350	1360/120
Environmental reports [1]	10,000	10,000	15,000	10,000	7,000
threatened/endangered species survey, Section 7 consultation	5,000	5,000		5,000	
instream flow studies	2,000	2,000	2,000	2,000	
Environmental mitigation					
habitat evaluation program & mitigation evaluation	5,000	5,000	5,000	5,000	2,000
land costs	350,000	600,000	450,000	350,000	120,000
land management ($/acre/year)	3,500	6,000	4,500	3,500	1,200
geotechnical-geomorphology	1,771	3,036	2,277	1,771	1,000
**archeological & historical survey	5,936	10,176	7,632	5,936	2,035
testing for National Register Eligibility	4,746	8,124	6,093	4,746	1,625
Cultural Resources-mitigation (404)	60,834	104,286	78,215	60,834	21,600
TOTAL COST	445,287	747,622	566,217	445,287	155,260
***ANNUAL COST**	3,500	6,000	4,500	3,500	1,200

[1] Multiple reports or reports on the entire Privilege Creek system would have some cost savings

* 50 Year Project Life

**Pipeline archaeological survey costs of $800/mile not included

TABLE 3-3 (Concluded)

PROJECTED COSTS

Diversion Sites/ Pipelines	Bandera City Park Lake	Privilege Crk at Medina R	Medina River Crossing [2]
Environmental reports [1]	2,000		2,000
threatened/endangered species survey			
Section 7 consultation			
instream flow studies	5,000	15,000	
Environmental mitigation			
habitat evaluation program & mitigation evaluation			
land costs			
*management ($/acre/year)			
geotechnical-geomorphology	1,000	1,000	1,000
**archeological & historical survey	2,800	2,400	2,400
testing for National Register Eligibility	4,000	4,000	3,000
Cultural Resources-mitigation (404)	10,000	10,000	10,000
***TOTAL COST**	24,800	32,400	16,400

[1] Multiple reports or reports on the entire Privilege Creek system would have some cost savings
[2] Typical Medina River Crossing cost
* 50 Year Project Life
**Pipeline archaeological survey costs estimated at $800/mile not included

**Pipeline archaeological survey costs of $800/mile not included water rights permits would be required for the reservoir sites. The pipeline stream crossings, intakes and outfalls are covered under a Nation-wide Section 404 permit. However, additional environmental assessment could be required for perennial stream crossings, in this case the Medina River, if potential impacts are considered substantial. Planning for erosion control, revegetation and bank stabilization will be required as part of these permits. Cultural resources surveys will be required at all reservoir sites and pipeline rights-of-way. Mitigation land costs are given only for reservoir sites as habitat replacement is unlikely to be required for pump stations, pipelines, and other small areas of disturbance. These costs are based on rural land prices in the Bandera County area for woodlands (Real Estate Center, Texas A & M University. 1990).

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APPENDIX C

COST TABLES FOR WATER SUPPLY ALTERNATIVES

SPRINGHILLS WATER MANAGEMENT DISTRICT
REGIONAL WATER SUPPLY STUDY - BANDERA COUNTY
PHASE I - WATER SUPPLY ALTERNATIVES TO MEET YEAR 2020 PROJECTED
ADDITIONAL MUNICIPAL WATER DEMAND OF 2000 ACRE-FEET PER YEAR

NO.	ALTERNATIVE	TOTAL COST OF PROJECT COMPONENTS	ANNUAL COSTS								**INITIAL**		2020	
			DEBT SERVICE	POWER	O&M (INITIAL)	O&M (2020)	WATER (INITIAL)	WATER (2020)	TOTAL (INITIAL)	TOTAL (2020)	COST PER 1000 GAL	MONTHLY COST PER CONNECT	COST PER 1000 GAL	MONTHLY COST PER CONNECT
1	GROUNDWATER PUMPING FROM WEST													
	WELL FIELDS, CHLORINATION, & TRANSMISSION	$7,605,000	$682,245	$63,600	$32,500	$65,100	$0	$0	$778,345	$810,945				
	STORAGE AND DISTRIBUTION SYSTEM	$5,000,000	$448,550	$32,100	$43,000	$43,000	$0	$0	$523,650	$523,650				
	TOTAL	$12,605,000	$1,130,795	$95,700	$75,500	$108,100	$0	$0	$1,301,995	$1,334,595	$7.27	$47.17	$2.05	$15.03
2	TOWN MOUNTAIN DAM W/PUMPING FROM MEDINA RIVER													
	TOWN MOUNTAIN DAM AND RESERVOIR	$3,804,000	$318,100	$0	$30,000	$30,000	$36,400	$128,800	$384,500	$476,900				
	PUMPING WORKS - MEDINA RIVER TO RESERVOIR	$846,600	$75,683	$15,000	$8,000	$8,000	$0	$0	$98,683	$98,683				
	PIPELINE - DAM TO TREATMENT PLANT	$349,600	$31,400	$3,100	$2,000	$2,000	$0	$0	$36,500	$36,500				
	TREATMENT PLANT	$1,600,000	$143,500	$0	$75,000	$195,500	$0	$0	$218,500	$339,000				
	STORAGE AND DISTRIBUTION SYSTEM	$5,000,000	$450,000	$30,000	$43,000	$43,000	$0	$0	$523,000	$523,000				
	TOTAL	$11,600,200	$1,018,683	$48,100	$158,000	$278,500	$36,400	$128,800	$1,261,183	$1,474,083	$7.04	$45.70	$2.26	$16.60
3	BANDERA CREEK DAM W/PUMPING FROM MEDINA RIVER													
	BANDERA CREEK DAM AND RESERVOIR	$5,037,500	$396,100	$0	$30,000	$30,000	$97,500	$168,000	$523,600	$594,100				
	PUMPING WORKS - MEDINA RIVER TO RESERVOIR	$806,800	$72,400	$6,400	$7,000	$7,000	$0	$0	$85,800	$85,800				
	PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$389,900	$35,000	$3,400	$3,500	$3,500	$0	$0	$41,900	$41,900				
	TREATMENT PLANT	$1,600,000	$143,500	$0	$75,000	$195,500	$0	$0	$218,500	$339,000				
	STORAGE AND DISTRIBUTION SYSTEM	$5,000,000	$450,000	$30,000	$43,000	$43,000	$0	$0	$523,000	$523,000				
	TOTAL	$12,834,200	$1,097,000	$39,800	$158,500	$279,000	$97,500	$168,000	$1,392,800	$1,583,800	$7.77	$50.46	$2.43	$17.84
4	BANDERA CREEK DAM W/PUMPING FROM GUADALUPE RIVER													
	BANDERA CREEK DAM AND RESERVOIR	$5,037,500	$396,100	$0	$30,000	$30,000	$97,500	$97,500	$523,600	$523,600				
	PUMPING WORKS - GUADALUPE RIVER TO RESERVOIR	$1,867,500	$167,500	$20,200	$16,200	$16,200	$83,000	$83,000	$286,900	$286,900				
	PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$389,900	$35,000	$3,400	$3,500	$3,500	$0	$0	$41,900	$41,900				
	TREATMENT PLANT	$1,600,000	$143,500	$0	$75,000	$195,500	$0	$0	$218,500	$339,000				
	STORAGE AND DISTRIBUTION SYSTEM	$5,000,000	$450,000	$30,000	$43,000	$43,000	$0	$0	$523,000	$523,000				
	TOTAL	$13,894,900	$1,192,100	$53,600	$167,700	$288,200	$180,500	$180,500	$1,593,900	$1,714,400	$8.89	$57.75	$2.63	$19.31

5 MASON CREEK DAM W/PUMPING FROM MEDINA RIVER												
MASON CREEK DAM AND RESERVOIR	$7,121,900	$548,200	$0	$30,000	$30,000	$119,800	$196,000	$698,000	$774,200			
PUMPING WORKS - MEDINA RIVER TO RESERVOIR	$1,294,900	$116,200	$12,900	$11,300	$11,300	$0	$0	$140,400	$140,400			
PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$814,200	$73,000	$9,200	$7,100	$7,100	$0	$0	$89,300	$89,300			
TREATMENT PLANT	$1,600,000	$143,500	$0	$75,000	$195,500	$0	$0	$218,500	$339,000			
STORAGE AND DISTRIBUTION SYSTEM	$5,000,000	$450,000	$30,000	$43,000	$43,000	$0	$0	$523,000	$523,000			
TOTAL	$15,831,000	$1,330,900	$52,100	$166,400	$286,900	$119,800	$196,000	$1,669,200	$1,865,900	$9.31	$60.48	$2.86	$21.01
6 MASON CREEK DAM W/PUMPING FROM GUADALUPE RIVER												
MASON CREEK DAM AND RESERVOIR	$7,121,900	$548,200	$0	$30,000	$30,000	$119,800	$119,800	$698,000	$698,000			
PUMPING WORKS - GUADALUPE RIVER TO RESERVOIR	$2,077,400	$186,400	$23,100	$18,100	$18,100	$86,200	$86,200	$313,800	$313,800			
PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$814,200	$73,000	$9,200	$7,100	$7,100	$0	$0	$89,300	$89,300			
TREATMENT PLANT	$1,600,000	$143,500	$0	$75,000	$195,500	$0	$0	$218,500	$339,000			
STORAGE AND DISTRIBUTION SYSTEM	$5,000,000	$450,000	$30,000	$43,000	$43,000	$0	$0	$523,000	$523,000			
TOTAL	$16,613,500	$1,401,100	$62,300	$173,200	$293,700	$206,000	$206,000	$1,842,600	$1,963,100	$10.28	$66.76	$3.01	$22.11
7 UPPER PRIVILEGE CREEK DAM W/PUMPING FROM MEDINA RIVER												
UPPER PRIVILEGE CREEK DAM AND RESERVOIR	$6,359,300	$515,900	$0	$30,000	$30,000	$86,800	$168,000	$632,700	$713,900			
PUMPING WORKS - MEDINA RIVER TO RESERVOIR	$2,041,000	$183,100	$25,800	$17,800	$17,800	$0	$0	$226,700	$226,700			
PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$845,300	$75,800	$5,200	$7,400	$7,400	$0	$0	$88,400	$88,400			
TREATMENT PLANT	$1,600,000	$143,500	$0	$75,000	$195,500	$0	$0	$218,500	$339,000			
STORAGE AND DISTRIBUTION SYSTEM	$5,000,000	$450,000	$30,000	$43,000	$43,000	$0	$0	$523,000	$523,000			
TOTAL	$15,845,600	$1,368,300	$61,000	$173,200	$293,700	$86,800	$168,000	$1,689,300	$1,891,000	$9.43	$61.21	$2.90	$21.30
8 LOWER PRIVILEGE CREEK DAM W/PUMPING FROM MEDINA RIVER												
LOWER PRIVILEGE CREEK DAM AND RESERVOIR	$9,983,000	$825,800	$0	$30,000	$30,000	$108,100	$184,800	$963,900	$1,040,600			
PUMPING WORKS - MEDINA RIVER TO RESERVOIR	$1,393,800	$125,000	$13,600	$27,100	$27,100	$0	$0	$165,700	$165,700			
PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$376,000	$33,700	$8,000	$3,300	$3,300	$0	$0	$45,000	$45,000			
TREATMENT PLANT	$1,600,000	$143,500	$0	$75,000	$195,500	$0	$0	$218,500	$339,000			
STORAGE AND DISTRIBUTION SYSTEM	$5,000,000	$450,000	$30,000	$43,000	$43,000	$0	$0	$523,000	$523,000			
TOTAL	$18,352,800	$1,578,000	$51,600	$178,400	$298,900	$108,100	$184,800	$1,916,100	$2,113,300	$10.69	$69.42	$3.24	$23.80

9 MIDDLE VERDE CREEK DAM - NUECES RIVER BASIN													
MIDDLE VERDE CREEK DAM AND RESERVOIR	$7,257,000	$598,200	$0	$30,000	$30,000	$0	$0	$628,200	$628,200				
PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$3,489,100	$313,000	$34,700	$30,300	$30,300	$0	$0	$378,000	$378,000				
TREATMENT PLANT	$1,600,000	$143,500	$0	$75,000	$195,500	$0	$0	$218,500	$339,000				
STORAGE AND DISTRIBUTION SYSTEM	$5,000,000	$450,000	$30,000	$43,000	$43,000	$0	$0	$523,000	$523,000				
TOTAL	$17,346,100	$1,504,700	$64,700	$178,300	$298,800	$0	$0	$1,747,700	$1,868,200	$9.75	$63.32	$2.87	$21.04
10 PURCHASE TREATED WATER FROM CITY OF BOERNE													
PURCHASE OF TREATED WATER	$0	$0	$0	$0	$0	$304,700	$1,108,000	$304,700	$1,108,000				
PUMPING WORKS-TREATED WATER-BOERNE TO BANDERA CO.	$3,877,800	$347,900	$41,700	$33,700	$33,700	$0	$0	$423,300	$423,300				
STORAGE AND DISTRIBUTION SYSTEM	$5,000,000	$450,000	$30,000	$43,000	$43,000	$0	$0	$523,000	$523,000				
TOTAL	$8,877,800	$797,900	$71,700	$76,700	$76,700	$304,700	$1,108,000	$1,251,000	$2,054,300	$6.98	$45.33	$3.15	$23.13

NOTES:

1. COST OF PROJECT COMPONENTS INCLUDES: 15% CONTINGENCIES; RIGHT-OF-WAY COSTS; AND 20% FOR PERMITTING, ENGINEERING, LEGAL, AND FINANCING.
2. ANNUAL COST FOR CONSTRUCTION CALCULATED USING DEBT SERVICE FACTOR OF 7.5% FOR 25 YEARS.
3. AVERAGE ANNUAL POWER COST CALCULATED USING CONSTANT GRADIENT OVER 25 YEARS. ENERGY COST EQUAL TO $0.07 PER KWH.
4. ANNUAL O&M COST EQUAL TO 1% OF PROJECT CONSTRUCTION COST FOR PUMPING WORKS, PIPELINES, AND DISTRIBUTION SYSTEM.
5. ANNUAL O&M COST FOR WATER TREATMENT PLANTS EQUAL TO $0.30/1000 GALLONS OR A MINIMUM OF $75,000.
6. ANNUAL O&M COST FOR DAMS SET AT $30,000.
7. COST OF WATER EQUAL TO $56 PER ACRE-FOOT FROM BMA WCID NO. 1 ON "PAY-FOR-USE" BASIS.
8. COST OF WATER EQUAL TO $53 PER ACRE-FOOT FROM GBRA ON "TAKE-OR-PAY" BASIS.
9. COST OF TREATED WATER FROM CITY OF BOERNE EQUAL TO $1.70/1000 GALLONS ($554 PER ACRE-FOOT).
10. COST PER 1000 GALLONS FOR INITIAL CONDITIONS CALCULATED BASED ON AVERAGE ANNUAL DEMAND OF 550 ACRE-FEET PER YEAR.
11. COST PER 1000 GALLONS IN 2020 CALCULATED BASED ON AVERAGE ANNUAL DEMAND OF 2000 ACRE-FEET PER YEAR.
12. MONTHLY COST PER CONNECTION FOR INITIAL CONDITIONS ASSUMES 2,300 CONNECTIONS SERVED.
13. MONTHLY COST PER CONNECTION IN 2020 ASSUMES 7,400 CONNECTIONS SERVED.
14. ALL COSTS IN 1991 DOLLARS.

SPRINGHILLS WATER MANAGEMENT DISTRICT
REGIONAL WATER SUPPLY STUDY - BANDERA COUNTY
PHASE II - WATER SUPPLY ALTERNATIVES TO MEET YEAR 2040 PROJECTED
ADDITIONAL MUNICIPAL WATER DEMAND OF 3200 ACRE-FEET PER YEAR

NO.	ALTERNATIVE	TOTAL COST OF PROJECT COMPONENTS	ANNUAL COSTS								2020		2040	
			DEBT SERVICE	POWER	O&M (2020)	O&M (2040)	WATER (2020)	WATER (2040)	TOTAL (2020)	TOTAL (2040)	COST PER 1000 GAL	MONTHLY COST PER CONNECT	COST PER 1000 GAL	MONTHLY COST PER CONNECT
1	GROUNDWATER PUMPING FROM WEST													
	WELL FIELDS, CHLORINATION, & TRANSMISSION	$6,472,000	$634,903	$139,500	$65,100	$120,800	$0	$0	$839,503	$895,203				
	STORAGE AND DISTRIBUTION SYSTEM	$3,056,000	$299,794	$71,500	$43,000	$68,800	$0	$0	$414,294	$440,094				
	TOTAL	$9,528,000	$934,697	$211,000	$108,100	$189,600	$0	$0	$1,253,797	$1,335,297	$1.92	$14.12	$1.28	$11.24
2	TOWN MOUNTAIN DAM W/PUMPING FROM MEDINA RIVER													
	TOWN MOUNTAIN DAM AND RESERVOIR	$4,404,000	$432,032	$0	$30,000	$30,000	$128,800	$196,000	$590,832	$658,032				
	PUMPING WORKS - MEDINA RIVER TO RESERVOIR	$207,000	$20,307	$34,500	$8,000	$10,000	$0	$0	$62,807	$64,807				
	PIPELINE - DAM TO TREATMENT PLANT	$0	$0	$0	$2,000	$2,000	$0	$0	$2,000	$2,000				
	TREATMENT PLANT	$1,200,000	$117,720	$0	$195,500	$312,800	$0	$0	$313,220	$430,520				
	STORAGE AND DISTRIBUTION SYSTEM	$3,056,000	$299,794	$71,500	$43,000	$68,800	$0	$0	$414,294	$440,094				
	TOTAL	$8,867,000	$869,853	$106,000	$278,500	$423,600	$128,800	$196,000	$1,383,153	$1,595,453	$2.12	$15.58	$1.53	$13.43
3	BANDERA CREEK DAM W/PUMPING FROM MEDINA RIVER													
	BANDERA CREEK DAM AND RESERVOIR	$0	$0	$0	$30,000	$30,000	$168,000	$235,200	$198,000	$265,200				
	PUMPING WORKS - MEDINA RIVER TO RESERVOIR	$665,200	$65,256	$22,400	$7,000	$13,000	$0	$0	$94,656	$100,656				
	PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$182,200	$17,874	$11,900	$3,500	$5,000	$0	$0	$33,274	$34,774				
	TREATMENT PLANT	$1,200,000	$117,720	$0	$195,500	$312,800	$0	$0	$313,220	$430,520				
	STORAGE AND DISTRIBUTION SYSTEM	$3,056,000	$299,794	$71,500	$43,000	$68,800	$0	$0	$414,294	$440,094				
	TOTAL	$5,103,400	$500,644	$105,800	$279,000	$429,600	$168,000	$235,200	$1,053,444	$1,271,244	$1.62	$11.86	$1.22	$10.70
4	BANDERA CREEK DAM W/PUMPING FROM GUADALUPE RIVER													
	BANDERA CREEK DAM AND RESERVOIR	$0	$0	$0	$30,000	$30,000	$97,500	$97,500	$127,500	$127,500				
	PUMPING WORKS - GUADALUPE RIVER TO RESERVOIR	$1,672,600	$164,082	$70,900	$16,200	$30,700	$83,000	$132,500	$334,182	$398,182				
	PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$182,200	$17,874	$11,900	$3,500	$5,000	$0	$0	$33,274	$34,774				
	TREATMENT PLANT	$1,200,000	$117,720	$0	$195,500	$312,800	$0	$0	$313,220	$430,520				
	STORAGE AND DISTRIBUTION SYSTEM	$3,056,000	$299,794	$71,500	$43,000	$68,800	$0	$0	$414,294	$440,094				
	TOTAL	$6,110,800	$599,469	$154,300	$288,200	$447,300	$180,500	$230,000	$1,222,469	$1,431,069	$1.88	$13.77	$1.37	$12.05

5 MASON CREEK DAM W/PUMPING FROM MEDINA RIVER													
MASON CREEK DAM AND RESERVOIR	$0	$0	$0	$30,000	$30,000	$196,000	$263,200	$226,000	$293,200				
PUMPING WORKS - MEDINA RIVER TO RESERVOIR	$1,162,000	$113,992	$45,500	$11,300	$21,400	$0	$0	$170,792	$180,892				
PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$596,200	$58,487	$32,200	$7,100	$12,300	$0	$0	$97,787	$102,987				
TREATMENT PLANT	$1,200,000	$117,720	$0	$195,500	$312,800	$0	$0	$313,220	$430,520				
STORAGE AND DISTRIBUTION SYSTEM	$3,056,000	$299,794	$71,500	$43,000	$68,800	$0	$0	$414,294	$440,094				
TOTAL	$6,014,200	$589,993	$149,200	$286,900	$445,300	$196,000	$263,200	$1,222,093	$1,447,693	$1.88	$13.76	$1.39	$12.19
6 MASON CREEK DAM W/PUMPING FROM GUADALUPE RIVER													
MASON CREEK DAM AND RESERVOIR	$0	$0	$0	$30,000	$30,000	$119,800	$119,800	$149,800	$149,800				
PUMPING WORKS - GUADALUPE RIVER TO RESERVOIR	$1,642,200	$161,100	$84,600	$18,100	$32,400	$86,200	$137,800	$350,000	$415,900				
PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$596,200	$58,487	$32,200	$7,100	$12,300	$0	$0	$97,787	$102,987				
TREATMENT PLANT	$1,200,000	$117,720	$0	$195,500	$312,800	$0	$0	$313,220	$430,520				
STORAGE AND DISTRIBUTION SYSTEM	$3,056,000	$299,794	$71,500	$43,000	$68,800	$0	$0	$414,294	$440,094				
TOTAL	$6,494,400	$637,101	$188,300	$293,700	$456,300	$206,000	$257,600	$1,325,101	$1,539,301	$2.03	$14.92	$1.48	$12.96
7 UPPER PRIVILEGE CREEK DAM W/PUMPING FROM MEDINA RIVER													
UPPER PRIVILEGE CREEK DAM AND RESERVOIR	$0	$0	$0	$30,000	$30,000	$168,000	$235,200	$198,000	$265,200				
PUMPING WORKS - MEDINA RIVER TO RESERVOIR	$1,283,400	$125,902	$90,300	$17,800	$30,000	$0	$0	$234,002	$246,202				
PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$626,500	$61,460	$17,300	$7,400	$12,900	$0	$0	$86,160	$91,660				
TREATMENT PLANT	$1,200,000	$117,720	$0	$195,500	$312,800	$0	$0	$313,220	$430,520				
STORAGE AND DISTRIBUTION SYSTEM	$3,056,000	$299,794	$71,500	$43,000	$68,800	$0	$0	$414,294	$440,094				
TOTAL	$6,165,900	$604,875	$179,100	$293,700	$454,500	$168,000	$235,200	$1,245,675	$1,473,675	$1.91	$14.03	$1.41	$12.40
8 LOWER PRIVILEGE CREEK DAM W/PUMPING FROM MEDINA RIVER													
LOWER PRIVILEGE CREEK DAM AND RESERVOIR	$0	$0	$0	$30,000	$30,000	$184,800	$252,000	$214,800	$282,000				
PUMPING WORKS - MEDINA RIVER TO RESERVOIR	$731,400	$71,750	$48,600	$27,100	$33,500	$0	$0	$147,450	$153,850				
PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$196,000	$19,228	$28,700	$3,300	$5,000	$0	$0	$51,228	$52,928				
TREATMENT PLANT	$1,200,000	$117,720	$12,000	$195,500	$312,800	$0	$0	$325,220	$442,520				
STORAGE AND DISTRIBUTION SYSTEM	$3,056,000	$299,794	$71,500	$43,000	$68,800	$0	$0	$414,294	$440,094				
TOTAL	$5,183,400	$508,492	$160,800	$298,900	$450,100	$184,800	$252,000	$1,152,992	$1,371,392	$1.77	$12.98	$1.32	$11.54

9 MIDDLE VERDE CREEK DAM - NUECES RIVER BASIN													
MIDDLE VERDE CREEK DAM AND RESERVOIR	$0	$0	$0	$30,000	$30,000	$0	$0	$30,000	$30,000				
PUMPING WORKS - RESERVOIR TO TREATMENT PLANT	$2,732,400	$268,048	$122,600	$30,300	$54,100	$0	$0	$420,948	$444,748				
TREATMENT PLANT	$1,200,000	$117,720	$0	$195,500	$312,800	$0	$0	$313,220	$430,520				
STORAGE AND DISTRIBUTION SYSTEM	$3,056,000	$299,794	$71,500	$43,000	$68,800	$0	$0	$414,294	$440,094				
TOTAL	$6,988,400	$685,562	$194,100	$298,800	$465,700	$0	$0	$1,178,462	$1,345,362	$1.81	$13.27	$1.29	$11.32
10 PURCHASE TREATED WATER FROM CITY OF BOERNE													
PURCHASE OF TREATED WATER	$0	$0	$0	$0	$0	$1,108,000	$1,772,800	$1,108,000	$1,772,800				
PUMPING WORKS-TREATED WATER-BOERNE TO BANDERA CO.	$3,094,000	$303,521	$145,100	$33,700	$60,600	$0	$0	$482,321	$509,221				
STORAGE AND DISTRIBUTION SYSTEM	$3,056,000	$299,794	$71,500	$43,000	$68,800	$0	$0	$414,294	$440,094				
TOTAL	$6,150,000	$603,315	$216,600	$76,700	$129,400	$1,108,000	$1,772,800	$2,004,615	$2,722,115	$3.08	$22.57	$2.61	$22.91

NOTES:

1. COST OF PROJECT COMPONENTS INCLUDES: 15% CONTINGENCIES; RIGHT-OF-WAY COSTS; AND 20% FOR PERMITTING, ENGINEERING, LEGAL, AND FINANCING.
2. ANNUAL COST FOR CONSTRUCTION AND POWER USING DEBT SERVICE FACTOR OF 7.5% FOR 20 YEARS.
3. AVERAGE ANNUAL POWER COST CALCULATED USING CONSTANT GRADIENT OVER 20 YEARS. ENERGY COST EQUAL TO $0.07 PER KWH.
4. ANNUAL O&M COST EQUAL TO 1% OF PROJECT CONSTRUCTION COST FOR PUMPING WORKS, PIPELINES, AND DISTRIBUTION SYSTEM.
5. ANNUAL O&M COST FOR WATER TREATMENT PLANTS EQUAL TO $0.30/1000 GALLONS.
6. ANNUAL O&M COST FOR DAMS SET AT $30,000.
7. COST OF WATER EQUAL TO $56 PER ACRE-FOOT FROM BMA WCID NO. 1 ON "PAY-FOR-USE" BASIS.
8. COST OF WATER EQUAL TO $53 PER ACRE-FOOT FROM GBRA ON "TAKE-OR-PAY" BASIS.
9. COST OF TREATED WATER FROM CITY OF BOERNE EQUAL TO $1.70/1000 GALLONS ($554 PER ACRE-FOOT).
10. COST PER 1000 GALLONS IN 2020 CALCULATED BASED ON AVERAGE ANNUAL DEMAND OF 2000 ACRE-FEET PER YEAR.
11. COST PER 1000 GALLONS IN 2040 CALCULATED BASED ON AVERAGE ANNUAL DEMAND OF 3200 ACRE-FEET PER YEAR.
12. MONTHLY COST PER CONNECTION IN 2020 ASSUMES 7,400 CONNECTIONS SERVED.
13. MONTHLY COST PER CONNECTION IN 2040 ASSUMES 9,900 CONNECTIONS SERVED.
14. ALL COSTS IN 1991 DOLLARS.