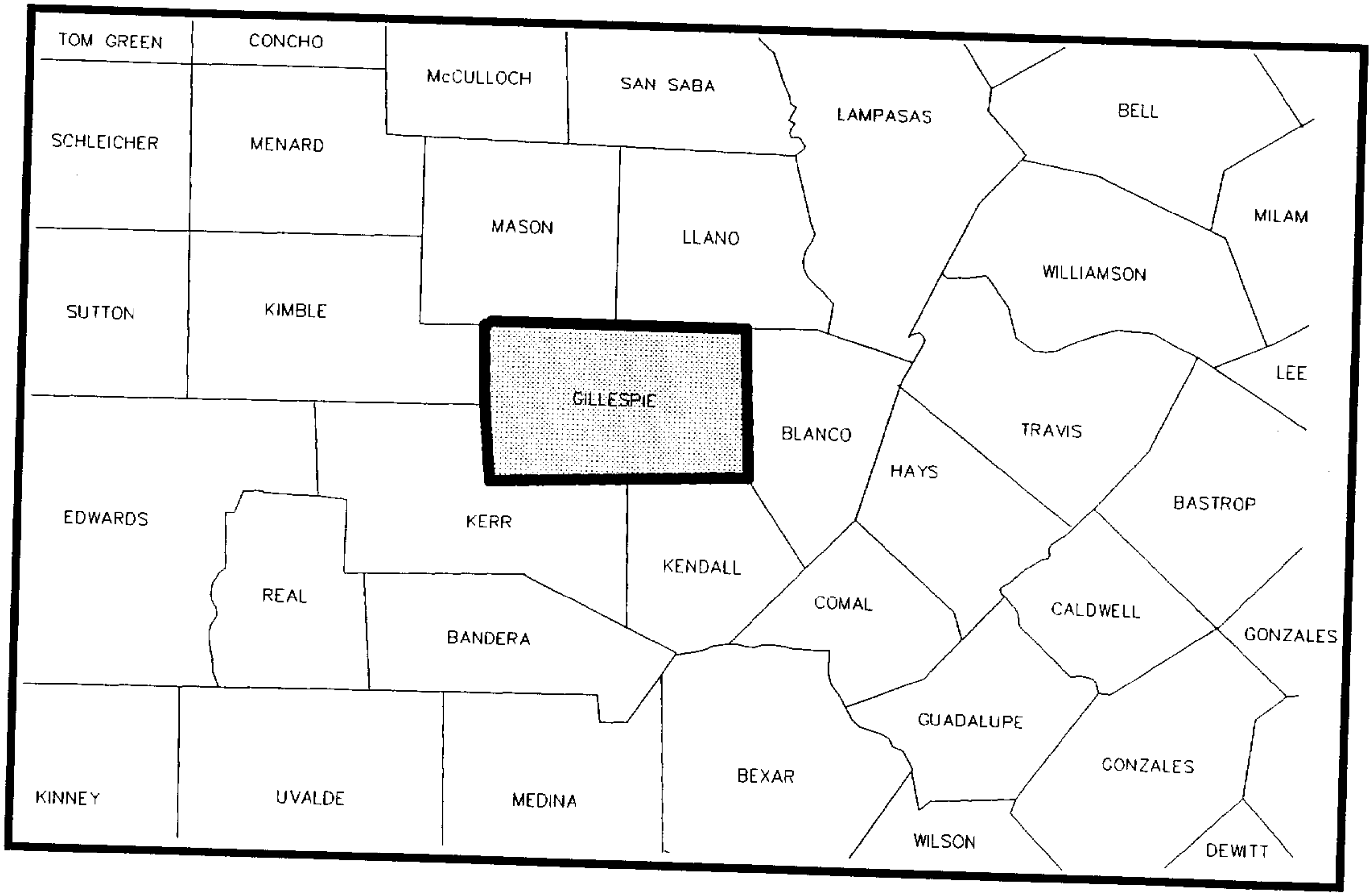
GILLESPIE COUNTY

REGIONAL WATER MANAGEMENT PLAN



PREPARED BY

HILL COUNTRY UNDERGROUND WATER CONSERVATION DISTRICT

in association with

BLACKWELL, LACKEY & ASSOCIATES INC.
McGINNIS LOCHRIDGE & KILGORE LLP
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REGIONAL PLANNING
& PROJECTS

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EXECUTIVE SUMMARY

INTRODUCTION

Gillespie County has been designated as a critical area by the Texas Water Development Board and is expected to experience ground-water supply shortages and diminished water quality well into the 21st century. As a result, the Hill Country Underground Water Conservation District has been organized to plan and implement water resource management procedures.

The overall objective of this effort is to develop a long-range plan to meet the water supply needs of Gillespie County and the City of Fredericksburg for the duration of the term of the Plan (year 2030).

PLAN OBJECTIVES

The specific Objectives of the Plan include:

1. Establish county-wide population and water demand projections for the City of Fredericksburg and Gillespie County;
2. Describe the quantity and quality of water resources that are available to meet future demands within the study area, and to quantify any limits to development of these resources;
3. Evaluate **conjunctive management** and use of ground water and surface water resources within Gillespie County and the City of Fredericksburg, and provide a basis for management strategies that may be used to fulfill the regional water demands; and
4. Formulate the basic elements of alternative plans that may be used to reconcile water demands with the resources available.

WATER DEMANDS

Approximately forty percent of the population of Gillespie County is located in the City of Fredericksburg. The remaining population resides in rural communities which derive their livelihood from livestock and feeding operations. The 1990 population in Gillespie County is 17,204 which includes a populace of 6,934 residing in the City of Fredericksburg. The population growth in the rural areas of the county is expected to increase by about 75 to 80 percent in the year 2030 with a corresponding increase of about 55 percent within the City of Fredericksburg.

Municipal water supply in Gillespie County is currently provided by ten public water systems. Ninety-five percent of the County's municipal demand that is being met by community water systems is supplied by the City of Fredericksburg with approximately two thirds of this demand being supplied for residential use. This pattern of municipal water demand is expected to remain the same throughout the county to the year 2030.

Conservation practices for municipal demands can decrease the current average per capita use of water from 223 gallons per day to a high use demand of 189 gallons per day in the year 2030 for the City of Fredericksburg. Similar projections for non-Fredericksburg municipal uses show a change from 135 gallons per day to 130 gallons per day. Projected population increases and per capita estimates of municipal water to the year 2030 convert to an increase in total water demand of about 640 acre feet for the City of Fredericksburg and about 950 acre feet per year for rural municipal water use.

Water demand projections for non municipal uses considered needs for manufacturing, irrigation, mining and livestock activities. Manufacturing activities were projected to occur solely within the City of Fredericksburg. Comparing historical water demands, as of 1989, for each of these activities with projected demands in the year 2030 indicate increased total water demand of 766 acre feet per year for manufacturing, decreased irrigation demands of 685 acre feet per year, decreased mining demands of up to 15 acre feet per year and increased livestock water demands of 517 acre feet per year.

Surface water in Gillespie County is widely used for irrigation and livestock purposes. Virtually all of the water rights are already permitted for these uses from flow in the Pedernales River and its tributaries. There are no large reservoirs in Gillespie County. Several preliminary studies by federal agencies have proposed reservoir sites, however there is inadequate water available to provide a dependable water supply after permitted uses are removed. Surface water rights may become available in the future that could help to prevent depletion of the ground-water supplies through watershed storage or aquifer recharge practices.

WATER RESOURCE MANAGEMENT OPTIONS

Water resource management options for Gillespie County would include :

1. Water Conservation
2. Water Reuse - Reclamation of Wastewater Effluent for Irrigation
3. Enhanced Recharge of the Ground Water

Water reuse & conservation projects such as reclaiming waste water effluent for irrigation of public lands or to bring new irrigated land into production. Enhanced recharge to the ground water is another option where water is ponded over land surfaces that have rapid infiltration processes. Upstream watershed dams could also be utilized to store excess rainfall and then released at rates which would maximize infiltration. Residential conservation measures would include more efficient lawn watering, toilet dams and tap water restrictors.

WATER SUPPLY ALTERNATIVES

The comparison of supply and demand provides a basis for the formulation of three basic alternatives that have optional implementation strategies. These alternatives can be defined as:

Alternative 1	Continue present policies or no action.
Alternative 2	Treat and Import water from the Lower Colorado River Authority with an interbasin transfer agreement.
Alternative 3	Purchase Additional Water Rights and Develop Surface Water Storage
Alternative 4	Range and Brush Management

ALTERNATIVE 1 - CONTINUE PRESENT POLICIES OR NO ACTION

The City of Fredericksburg will continue to pump from the Ellenburger Aquifer and will store water in storage tanks as they do today. With the development of a good conservation program coupled with a good water reuse program/system, the City of Fredericksburg should be able to meet the demands of the future.

Within Gillespie County, the high yielding Ellenburger and Hickory aquifers could be developed more efficiently than the low to moderate yielding Edwards and Hensell aquifers. The Ellenburger could be developed into a high yielding aquifer (thousands of gallons per minute) in the areas in the southeast portion of the County near Jenschke Lane. The Hickory could be developed into a moderately yielding aquifer (hundreds of gallons per minute) west of the City of Fredericksburg.

ALTERNATIVE 2 - TREAT AND IMPORT WATER FROM THE LOWER COLORADO RIVER AUTHORITY WITH AN INTERBASIN TRANSFER AGREEMENT

The basic tenet of this alternative is that a water treatment plant and transmission line from LCRA to the City of Fredericksburg can be developed and constructed to supply the city with an additional water supply.

The assumptions for this alternative are:

1. The city would utilize waters from LCRA that would equal 50% of their demand.
2. LCRA would treat the water at Marble Falls and deliver treated water to the City of Fredericksburg.
3. A transmission main would be constructed in the Highway Right of Way of US Highways 281 and 290 to deliver the water to the City.
4. Ground water not utilized by the City would be available for non city use.

COSTS

ITEM #	DESCRIPTION	QUANTITY	COSTS
1	Marble Falls Treatment Plant	2 MGD	3,250,000
2	16" Transmission Main	275,000 LF	13,200,000
3	Booster Pump/Storage Facilities	3 MGD	4,000,000
	Total Capital Costs		20,450,000

ALTERNATIVE 3 - PURCHASE ADDITIONAL WATER RIGHTS AND DEVELOP SURFACE WATER STORAGE

This alternative will require the City of Fredericksburg to purchase additional water rights and develop a surface water impoundment.

Based upon the records available from the Texas Natural Resource Conservation Commission there are some 80 existing water rights authorizing the annual diversion of up to approximately 2,260.91 acre-feet per year.

The District conducted a survey of the 80 identified surface water rights in Gillespie County to determine their interest, if any, in the possible sale or donation for use in developing the County's future municipal water supply. Thirty seven (37) surface water rights holders responded to the survey, of those thirty seven (37), seven (7) indicated an interest in selling their rights, which had a combined total of 416.87 acre-feet. Three (3) of the seven(7) who expressed interest in selling their water rights which total 44.81 acre-feet, also indicated that they would consider donating them under certain conditions.

The City of Fredericksburg can legally serve customers within its corporate boundaries and within its ETJ, and can acquire water rights outside of its boundaries to do so. However, the City would not be able to develop a water supply to serve the entire County.

The most practical solution is the development of a County-wide water supply, capable of conjunctively managing available surface and groundwater supplies on both a wholesale and resale basis.

An entity such as the District, which is knowledgeable about water matters would be best suited for this purpose. However, the District's enabling legislation, as presently enacted, does not allow the District to develop and sell the proposed water supply.
The City of Fredericksburg would require a firm yield of 2,240 acre-feet per year to supply a 2 MGD water treatment plant, and a storage capacity of 6,720 acre-feet (3 X Firm Yield). Costs for the reservoir would be as follows:

COSTS

ITEM #	DESCRIPTION	QUANTITY	COSTS
1	Fredericksburg Treatment Plant	2 MGD	3,250,000
2	Surface Water Impoundment Structure	6,720 Acre Feet	21,700,000
3	Booster Pump/Storage Facilities	3 MGD	4,000,000
	Total Capital Costs		**28,950,000**

ALTERNATIVE 4 - RANGE AND BRUSH MANAGEMENT

The project focuses on the clearing of non-productive high water consuming vegetation, particularly cedar trees. The increase run-off may be available to be used for recharge of groundwater formations and/or to firm-up available surface water rights.

While the total number of acre-feet of water potentially available for sale and/or donation is not significant, the entity ultimately identified to implement the county-wide strategy to develop the County's future water supply should investigate the acquisition of these rights.

SECTION 1

INTRODUCTION

The Gillespie County Regional Water Management Plan (the "Plan") is a planning effort led by the Hill Country Underground Water Conservation District (HCUWCD) in conjunction with Gillespie County and the City of Fredericksburg.

Funding for the development of this plan has been provided by each participant and the Texas Water Development Board. Each participant has also appointed a representative to the Technical Advisory Committee to provide local input and periodic review of the planning effort. This report provides the results of this study and satisfies the requirement of the TWDB contract requirements of this Plan.

OBJECTIVES

The overall objective of this effort is to develop a long-range plan to meet the water supply needs of Gillespie County and the City of Fredericksburg (See Figure 1) for the duration of the term of the Plan (50 years).

The specific Objectives of the Plan include:

1. Establish county-wide population and water demand projections for the City of Fredericksburg and Gillespie County;

2. Describe the quantity and quality of water resources that are available to meet future demands within the study area, and to quantify any limits to development of these resources;

3. Evaluate **conjunctive management** and use of ground water and surface water resources within Gillespie County and the City of Fredericksburg, and provide a basis for management strategies that may be used to fulfill the regional water demands; and

4. Formulate the basic elements of alternative plans that may be used to reconcile water demands with the resources available.

PHYSICAL DESCRIPTION OF THE STUDY AREA

The geographical area for the planning study is Gillespie County (Figure 1), which is located in the Hill Country of south-central Texas approximately 80 miles west of Austin on U.S. Highway 290. Gillespie County covers approximately 1,061 square miles. The principle physiographic feature is the Pedernales River.

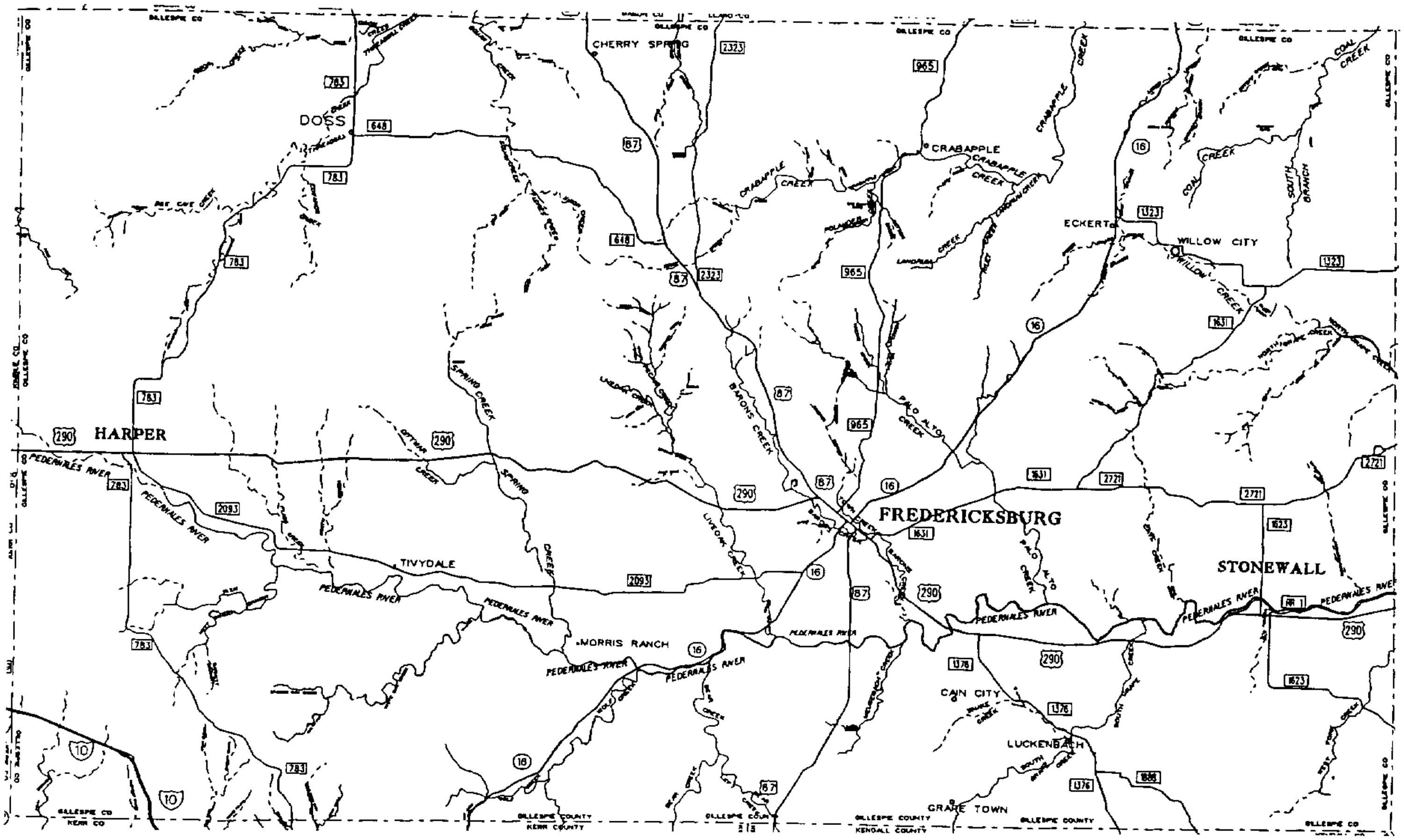


FIGURE 1

HILL COUNTRY UNDERGROUND WATER DISTRICT

Climate

According to the Climactic Atlas of Texas, the climate of the region is characterized as subtropical, subhumid with temperatures averaging between 32 and 96 degrees. Mean annual temperature is 64-66 degrees. The average gross lake surface evaporation rate for the area is 67 inches which is more than twice the average annual precipitation rate of 28 inches. Prevailing winds are out of the south southeast. The most damaging storms are flash floods which often occur in the low lying areas and cause extensive erosion. Because of the rugged terrain and shallow soils in the area, the destructive power of surface runoff tends to be great.

Wildlife and Natural Areas

Because of generally smaller populations and lack of extensive agricultural capacity, the Hill Country contains some relatively undisturbed and important areas of native woodlands. In addition, the numerous incised canyons serve as important natural habitats. Many endangered species make their home in this region. Among them are the Bald Eagle, the Arctic Peregrine Falcon, and the Texas Horned Lizard.

Surface and Groundwater

The Edwards-Trinity Aquifer lies in part in Gillespie County. Its principal use is for domestic, livestock and irrigation. The Ellenberger, San Saba and Hickory aquifers are also important supplies of water to the area.

The Colorado River Basin drains most of Gillespie County. In the region, the major streams rise in the hilly regions and generally move in a SE direction toward the Gulf of Mexico. The rapid movement of water through the region means a higher risk of erosion.

Ground-water in the area is generally available from four strata:

1. Hickory Sandstone
2. Ellenburger Limestone
3. Hensell Sand
4. Edwards Limestone

Topography

The Hill Country, which covers most of the area, has rough terrain with elevations ranging from slightly less than 1,000 to 2,500 feet mean sea level (MSL). Soils are shallow and underlain by limestone. The rough terrain of the Hill Country contains numerous, deeply incised canyons and ravines formed by rapidly flowing surface runoff. However, most of the hilltops are fairly flat to gently rounded with similar elevations, being remnants of the Edward's Plateau.

The top portion of Gillespie County lies in the Llano Basin which, like the Hill Country is characterized by rugged terrain and considerable relief. Some areas of this erosional basin may be as much as 1,000 feet below the high limestone rims, and elevations may reach 2,000 feet MSL.

Geology and Soils

Most of Gillespie County lies in the Hill Country. The northern part of the county is in the area of the Llano Basin. Soils in this area consisted of interlayered clay, clayey sand, and silty sand which is typical of the Hensell Sand strata. Below the Hensell are Paleozoic rocks and Precambrian granite and gneiss. The San Marcos Arch, a subsurface structural high, runs southeastward from the Llano Basin. The San Marcos River flows almost down the crest of the San Marcos Arch.

Alfisols, common in the prairie and plains areas, are also found in northern Gillespie County. The alfisol profile typically exhibits a light-colored upper horizon not darkened by humus and ranging from shallow to moderate depth, and a lower horizon of deep relatively impermeable clay. Alfisols are generally desirable for sludge application and landfill siting.

DEMOGRAPHIC DESCRIPTION

Table 1-1 depicts general demographic data for Gillespie County. Gillespie County has a population of 17,204 that is spread out over the county. Fredericksburg, the only large city has a population of 6,934. The average per capita income in the County is $17,757.

Population

Table 1-1 illustrates demographic data in Gillespie County:

TABLE 1-1

GENERAL DEMOGRAPHIC DATA

County	1990 Population	Area (sq mi)	Pop Density (cap/sq mi)	Per Capita Income
GILLESPIE COUNTY	17,204	1,061	16	$17,757

Gillespie County has shown a population increase in the ten years between 1980 and 1990. Gillespie County's population has increased 27% since 1980.

ECONOMIC DESCRIPTION

The area's total income totals approximately $514 million annually. Personal income grew by 96.7% between 1980 - 1989, well above the 75.5% statewide average. Average per capita personal income in 1990 was $17,757, which ranks the county as 64th in the state. Gillespie County has an employment growth rate of 23 percent.

Manufacturing

There is relatively no manufacturing in Gillespie County.

Airports

Though there are no commercially operated airlines that land in the County, one commercial airport services the area - County Airport.

Agriculture

A large percentage of the area's income comes from agricultural business. In Gillespie County most of the population's income is from cattle and other livestock. Hay, grain sorghum, oats and wheat are also profitable. Gillespie boasts being the largest peach growing county in Texas.

Tourism

Tourism is another major component of the County's economy. The County depends on profits from hunting and fishing licenses as well as profits from visitors to the many camps and parks located throughout the area. Fredericksburg has many local events such as Oktoberfest, night in old Fredericksburg, and the County Fair which draw many people from outside of the County.

CURRENT WATER PLANNING AND REGULATORY STATUS

In 1990 the former Texas Water Commission (now the Texas Natural Resource Conservation Commission) and the Texas Water Development Board released a report (Cross and Bluntzer, 1990) that proposed Critical Area Designation for all or portions of eight Hill Country counties (Figure 2). Included in this 5,500 square mile area is all of Gillespie County. Critical Areas are areas that are experiencing or will experience in the next 20 years ground water shortages, land subsidence, or ground water contamination. Based on potential ground water shortages due to lowering water tables and low recovery potential from the aquifers, the Hill Country Counties have been designated as a critical area (§ 31 TAC Sect #.294.24).

The Critical Area designation gives the Commission the authority to hold a hearing to determine if an underground water conservation district (UWCD) should be formed in the critical area. If an UWCD is formed it has full regulatory authority over ground water use and development in the critical area. Some of the regulatory powers of an UWCD include, but are not limited to:

1. Eminent Domain Power
2. Water Well Permitting
3. Restricting Well Spacing
4. Restricting Ground Water Use
5. Enforcing Well Abandonment Procedures

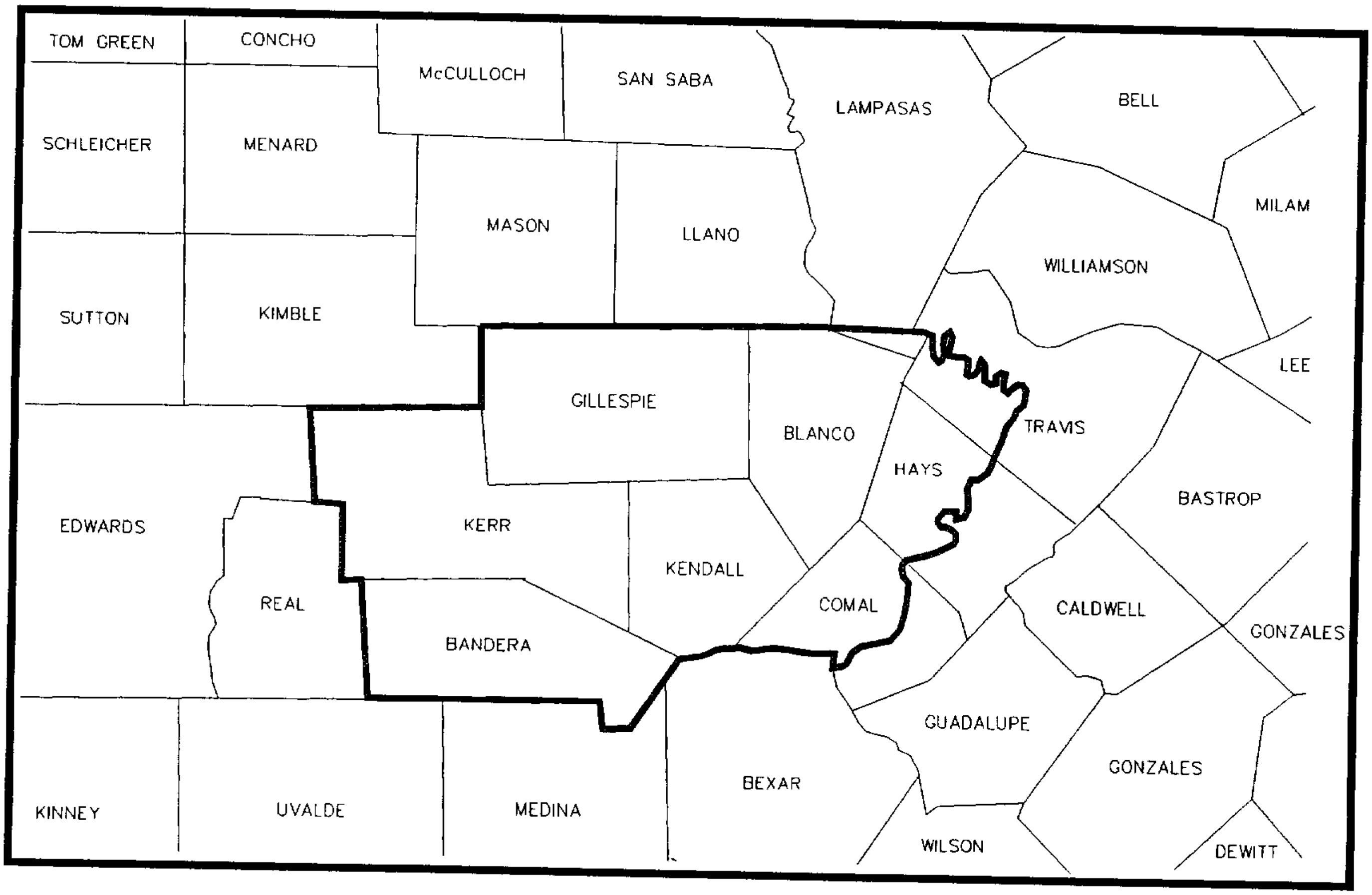


FIGURE 2
CRITICAL AREA DESIGNATION

While the designation of an area as a "Critical Area" by the Commission creates the possibility for imposing an underground water conservation district over the entire Critical Area, the demonstration of local initiative to respond to the potential ground-water shortages provides a means to retain local control over the issues and avoid creation of a multi-county district. At the time Gillespie County was included in the Hill Country Critical Area, the Hill Country Underground Water District was in existence. The Hill Country UWD had been created by the Legislature in 1987 with the regulatory authorities and duties of a Chapter 52 underground water district. The District's boundaries, which are coterminous with Gillespie County, provide the District the opportunity to develop ground-water resource management and enhancement programs, including the adoption of rules and regulations, to protect and enhance available ground-water resources. Accordingly, the District affords local opportunity for Gillespie County to retain its autonomy with regard to the management of ground-water issues, notwithstanding the County's inclusion in the Hill Country Critical Area.

Since its creation, the District has aggressively acted to promote water conservation, prevent pollution and enhance available ground-water resources. As a part of those programs, the District has adopted rules and regulations to protect limited ground-water resources, and has entered into various programs, including the "Regional Water Management Plan," with other qualified political subdivisions, e.g., Gillespie County and the City of Fredericksburg, to promote and enhance the conjunctive management of available ground water and surface water resources. Two other underground water management districts exist in the "Critical Area" in Bandera and Kerr county.

SECTION 2

WATER DEMANDS

One of the main purposes of any Regional Water Plan is to determine the demand for water over the length of the Planning Study. In doing so, population and water use projections have been developed for two alternative growth scenarios representing the high and low series water demand forecasts. These growth-related alternative water demand forecasts are then assessed for without- and with-conservation scenarios.

In general, the methods developed by the Texas Water Development Board for projecting population and water demands are used in this study, and modified based on additional water use data and local input. Demand forecasting has been prepared and analyzed for the following categories of water use:

1. **Municipal Water Demand** includes quantities of fresh water used in homes, offices, public buildings, restaurants, and stores for drinking, food preparation, bathing, toilet flushing, clothes laundering, lawn watering, car washing, air conditioning, swimming pools, fire protection, street washing, and other sanitation and aesthetic uses. It does not include water supplied by private wells for similar uses.

2. **Irrigation Water Demand** is the water required to meet consumptive use requirements of agricultural crops cultivated in the study area.

3. **Mining Water Demand** is the water used in sand and gravel washing operations and in the recovery of oil and gas.

4. **Livestock Water Demand** is the water required for drinking and sanitation associated with various livestock operations including: beef cattle, dairies, swine, sheep, goats, and poultry.

5. **Manufacturing Water Demand** is the water used in the normal operation of an industry for cooling water, process/product makeup water, sanitation, and landscaping.

6. **Steam Electric Demand** is the water needed to replace steam or induced evaporation generated through the operation of boilers, cooling the generation equipment and for general plant uses.

Per Capita Demands

Per capita demands, or the average volume of water used in gallons per person per day is multiplied by the population to arrive at **water demand**. For the purpose of the Regional Water Management Plan, historical demands are evaluated in relation to:

☐ Accepted Norms
☐ Water Conservation Goals
☐ Economic Impacts

Municipal Demands

Municipal water use requirements are based on projected population and per capita or individual, domestic water use. Data reported by suppliers of municipal and commercial water can provide the necessary information to compute historical per capita water use for the planning area. Per capita water use for the high series forecast should consider the highest recorded per capita water use for each supplier and should reflect demands during periods of below average rainfall conditions, while the low series forecast would reflect per capita water use representative of average rainfall conditions.

Irrigation Demands

Irrigated agricultural water requirements depend on the acreage that is currently in irrigated production, the current water usage per acre, water costs, and the availability of water supplies. Projections of irrigation water needs should reflect quantities of water associated with typical Texas irrigated farming operations, including regional water supplies and cropping patterns.

Mining Demands

Mining water requirements are based on water use coefficients. These coefficients are representative of each type of mining operation in the region, historical national and state trends in mineral production, and reflects substitutions of mineral fuels for energy production.

Livestock Demands

Livestock water use rates for the different classes of livestock are developed using animal nutrition data to determine daily water requirements and livestock census information. Water use rates and forecast of livestock production should provide the basis for estimating future livestock watering needs.

Manufacturing Demands

Manufacturing water use is estimated using national and state wide growth outlooks developed for each industrial category in the state, historical water use, known facility expansions or construction, the industry base of the county, and potential savings through recirculation and approved water use technology. Based on the different sets of potential growth patterns, high and low series of future manufacturing water use should be developed for each industry in the County.

Steam-Electric Demands

Steam-electric power generation future water needs are based upon forecasts of power demands, fuel sources used for generation, cooling technology, and plans for expanding power generating capacity identified by the industry. The high and low series should be based upon high and low series projected population and industrial growth reflected in future residential, industrial, and other power demands.

POPULATION PROJECTIONS

BACKGROUND

The Texas Water Development Board and Texas A&M *University* periodically develop population projections for the counties and cities across the state. The projection methodology and baseline assumptions vary among the different agencies. For purposes of this study, four different sets of population methods were analyzed:

1. TWDB - Low Series - This methodology is based on TWDB Programs that estimate population based on a low assumed growth rate.
2. TWDB - High Series - This methodology is based on TWDB Programs that estimate population based on a high assumed growth rate.
3. Texas A&M University Population Model - Low Series - Model developed by TAMU that assumes a low (worst case scenario) growth rate.
4. Texas A&M University Population Model - High Series - Model developed by TAMU that assumes a high (best case scenario) growth rate.

Note that the TWDB High Series and the TAMU Series are very close in estimating population through the year 2010. Beyond 2010, the TAMU model projects higher rates of growth. In developing water demands for Gillespie County and the City of Fredericksburg, the TWDB High Series population projections are used up through the year 2010. Beyond 2010, the TAMU High Series projections are used. See Table 2-1 for the resulting population estimates.

TABLE 2-1
GILLESPIE COUNTY POPULATION PROJECTIONS

Year	TWDB High Series	TAMU High Series	Adjusted Projections
2000	21,590	20,579	21,590
2010	23,598	23,461	23,598
2020	24,556	26,912	26,912
2030	25,881	29,026	29,026

Note : 1990 population was 17204

CITY OF FREDERICKSBURG

The TWDB develops population projections for cities in Texas, along with its county population projections. The projections for Fredericksburg are shown in Table 2-2. The TWDB population projections have been adjusted beyond the year 2010 in order to correlate the Fredericksburg population projections with the TAMU projections for Gillespie County.

TABLE 2-2

CITY OF FREDERICKSBURG POPULATION PROJECTIONS

Year	TWDB Projections	Adjusted Projections
1990	6,934	
2000	8,286	8,286
2010	8,905	8,905
2020	9,203	10,086
2030	9,608	10,775

PER CAPITA DEMANDS

Per capita demands or the average volume of water used in gallons per person per day is multiplied by population to determine total water demand. In developing water demand projections for the City of Fredericksburg, TWDB used an average per capita demand of 191 gallons per day and a high per capita demand of 219 gallons per day. Actual numbers are shown on Table 2-4. A record of water used in the City of Fredericksburg during recent years is shown in Table 2-3.

TABLE 2-3

CITY OF FREDERICKSBURG GROUNDWATER PUMPAGE

Year	Total Gallons Pumped	Acre-Feet Pumped
1987	684,639,400	2,101
1988	749,172,000	2,299
1989	835,226,000	2,563
1990	782,974,200	2,403
1991	717,335,400	2,202
Avg.	753,869,400	2,314

Municipal water is defined as what is supplied by community, public water systems. Although there are a total of ten public water supply systems in Gillespie County, the City of Fredericksburg supplies roughly 95% of the municipal water in the County. The majority of the smaller systems supply 50 to 200 customers each.

Table 2-4 shows a breakdown of municipal water uses in the City of Fredericksburg during 1991-1992. The per capita estimate is based on a service population of 7500.

TABLE 2-4

CITY OF FREDERICKSBURG
1991-92 MUNICIPAL WATER USE

Water Use	1991 Gallons Used	1992 Gallons Used
Residential	397,402,932	421,436,808
Government Facilities	53,772,168	46,323,324
Medical Institutions	28,869,636	25,923,000
Motels	18,820,332	22,341,144
Restaurants	18,475,524	24,702,828
Schools	16,971,132	15,286,332
Food Processing	70,334,676	67,313,484
Water Dependent Commercial	7,180,452	6,593,988
Misc. Commercial	38,428,140	42,816,300
Churches	5,661,192	5,458,332
TOTALS	**655,916,184**	**678,195,540**
Gallons per Person per Day	**214**	**223**

The TWDB has developed water demand projections for the City of Fredericksburg. These are based on historical records that exclude customers outside of the City. However, in planning for future water needs the City will need to include consideration of customers in areas adjacent to the City limits. Through most of the 1980's, the City's estimate of people served by its water supply system was 7500. The actual 1990 census population was 6934. For planning purposes, it will be assumed that the number of people outside of the City that have water connections will be approximately 10% of the City population.

Estimates of reduction in demand due to conservation practices were based on various research data and demand models. Table 2-5 shows the demands developed by TWDB and the 110% demands that would result from outside customers.

TABLE 2-5

CITY OF FREDERICKSBURG

PROJECTED WATER SYSTEM DEMANDS FOR MUNICIPAL USES

Year	Population	Average Use	High Use	Avg. Use w/ Conservation	High Use w/ Conservation
City Pop. Only					
2000	8,286	1,773	2,033	1,689	1,940
2010	8,905	1,905	2,184	1,736	1,995
2020	10,086	2,158	2,474	1,875	2,157
2030	10,775	2,305	2,643	1,979	2,281
City Pop. + 10%					
2000	9,115	1,950	2,236	1,858	2,134
2010	9,796	2,096	2,402	1,910	2,195
2020	11,095	2,374	2,721	2,063	2,373
2030	11,853	2,536	2,907	2,177	2,509

The TWDB also maintains records of water usage in the other public water supply systems in Gillespie County. The average per capita water use for these systems ranges from 68 gallons per day up to 135 gallons per day. The numbers are significantly lower than the City of Fredericksburg numbers due to the concentration of commercial and institutional establishments in the City. The City of Fredericksburg's residential per capita use is estimated at 145 to 155 gallons per day.

Table 2-6 shows a projection of municipal water demands for areas of Gillespie County outside of the City of Fredericksburg through the year 2030 based on the per capita demands used by TWDB. Populations have been adjusted on the assumption that a portion of county residents would be serviced by the City of Fredericksburg's water supply system.

TABLE 2-6
GILLESPIE COUNTY - OUTSIDE FREDERICKSBURG SYSTEM MUNICIPAL WATER DEMAND PROJECTIONS
(in acre-feet)

Year	Population	High Use	Average Use	High Use w/ Conservation	Avg. Use w/ Conservation
2000	12,475	2,166	1,747	2,055	1,648
2010	13,803	2,397	1,933	2,148	1,714
2020	15,817	2,746	2,215	2,336	1,875
2030	17,174	2,982	2,405	2,496	1,977

Note: High Use is 155 gallons per person per day.
Average Use is 125 gallons per person per day.

MANUFACTURING DEMANDS

Manufacturing in Gillespie County consists mostly of food processing industries. The largest water user in the County is Sunday House Foods. Food processing is a water-intensive industry. Manufacturing water demands in the County decreased from 1980 to 1990. Historical records also indicate that some surface water is used in supplying manufacturing demands.

TABLE 2-7

MANUFACTURING HISTORICAL DEMANDS
in acre-feet

Year	Groundwater Use	Surface Water Use	Total Water Use
1977	252	46	298
1980	505	80	585
1984	137	78	215
1985	156	117	273
1986	190	103	293
1987	223	99	322
1988	241	150	391
1989	333	51	384

The TWDB projections assume that manufacturing demands will increase by 6-8% per decade for the foreseeable future. For planning purposes, all manufacturing water is assumed to be supplied by the City of Fredericksburg system.

TABLE 2-8

MANUFACTURING DEMAND PROJECTIONS

Year	Demand in Acre-Feet
2000	540
2010	677
2020	904
2030	1,150

IRRIGATION DEMANDS

Historical records indicate a fluctuating demand for irrigation water during the 1980's and also significant variations in the use of surface water vs. groundwater. However, it is clear that the County relies more heavily on groundwater as an irrigation source than on surface water.

TABLE 2-9

HISTORICAL RECORDS OF IRRIGATION USE (in ac-ft)

Year	Groundwater Use	Surface Water Use	Total Water Use
1977	750	750	1,500
1980	800	880	1,680
1984	1,887	153	2,040
1985	1,711	148	1,859
1986	1,425	75	1,500
1987	465	35	500
1988	125	375	500
1989	1,954	231	2,185

TWDB projects that irrigation demands will level off and remain constant at roughly 1500 acre-feet per year (high series projections). Note that this represents a decrease for half of the years of available record listed in Table 2-9.

TABLE 2-10

IRRIGATION DEMANDS

Year	Demand (ac-ft/yr)
2000	1,500
2010	1,500
2020	1,500
2030	1,500

MINING DEMANDS

There is very little mining activity in Gillespie County. County records indicate annual water use for mining ranged from 0 to 17 ac-ft during the 1980's. All mining water was supplied from groundwater sources. TWDB projects a decrease in mining demands in coming years.

TABLE 2-11

MINING DEMANDS

Year	Demand (ac-ft/yr)
2000	12
2010	9
2020	5
2030	2

LIVESTOCK DEMANDS

Water demand for livestock use in Gillespie County has been relatively constant in the last ten to twenty years according to county records. Livestock water use is estimated by tabulating the numbers of livestock and multiplying by daily use rates obtained from animal nutrition data. In Gillespie County, roughly half of livestock water demands are met from groundwater sources and half from surface water sources.

TABLE 2-12

HISTORICAL RECORDS FOR LIVESTOCK WATER USE in acre-feet

Year	Groundwater Use	Surface Water Use	Total Water Use
1977	690	527	1,217
1980	664	497	1,161
1984	446	446	892
1985	456	456	912
1986	534	534	1,068
1987	498	498	996
1988	526	526	1,052
1989	509	509	1,018

The TWDB has projected an annual demand of 1,535 ac-ft/yr for livestock use for both its high and low series projections. Demands are projected to be constant through the year 2030.

TABLE 2-13

LIVESTOCK DEMANDS

Year	Demand (ac-ft/yr)
2000	1,535
2010	1,535
2020	1,535
2030	1,535

TOTAL DEMANDS

Total demands for the City of Fredericksburg and Gillespie County are shown in Table 2-14 below.

TABLE 2-14

PROJECTED TOTAL WATER USE IN GILLESPIE COUNTY
(Acre Feet/Year)

	Without Conservation				With Conservation			
	2000	**2010**	**2020**	**2030**	**2000**	**2010**	**2020**	**2030**
City of Fredericksburg								
Municipal	2,236	2,402	2,721	2,907	2,134	2,195	2,373	2,509
Manufacturing	540	677	904	1,150	540	677	904	1,150
Totals	2,776	3,079	3,625	4,057	2,674	2,872	3,277	3,659
Outside Fredericksburg								
Municipal	2,166	2,397	2,746	2,982	2,055	2,148	2,336	2,496
Irrigation	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Mining	12	9	5	2	12	9	5	2
Livestock	1,535	1,535	1,535	1,535	1,535	1,535	1,535	1,535
Totals	5,213	5,441	5,786	6,019	5,102	5,192	5,376	5,533
Gillespie County								
Totals	**7,989**	**8,520**	**9,411**	**10,076**	**7,776**	**8,064**	**8,653**	**9,192**

SEASONAL DEMAND FLUCTUATIONS

For any type of water use, the demand will vary from month to month. Typically, the highest demands are during the hot and often dry summer months when homeowners water their lawns and farmers irrigate their fields and require water for livestock. Swimming pools and air conditioning also add to the summer water demands. The monthly water demands in Fredericksburg also vary according to the number of tourists that visit during certain times of the year. Table 2-15 lists monthly pumpages for the City of Fredericksburg system from 1987 to 1991. Seasonal variations in water demand may be particularly significant when surface water sources are considered.

TABLE 2-15

CITY OF FREDERICKSBURG MONTHLY PUMPAGES

Month	1987	1988	1989	1990	1991	Avg
Jan	110.3	116.2	145.7	168.7	162.7	140.7
Feb	114.8	139.9	108.6	140.0	119.4	124.5
Mar	120.0	151.9	146.6	145.1	135.3	139.8
Apr	157.2	204.9	175.0	151.9	200.6	177.9
May	186.7	204.8	183.5	174.2	178.3	185.5
Jun	145.5	222.8	239.9	375.2	214.9	239.7
Jul	238.2	213.0	335.7	258.9	230.1	255.2
Aug	291.6	222.0	351.8	238.7	294.6	279.7
Sept	220.5	285.5	299.0	240.7	156.0	240.3
Oct	219.1	226.2	267.4	219.3	227.9	232.0
Nov	166.8	168.4	176.6	154.0	146.6	162.5
Dec	130.4	143.7	133.4	136.2	135.2	135.8
Totals	**2,101.2**	**2,299.3**	**2,563.4**	**2,403.0**	**2,201.6**	**2,313.7**

SECTION 3

SURFACE WATER RESOURCES

INTRODUCTION

The purpose of this section is to review existing surface water supplies available to serve the water supply needs of Gillespie County, review any additional surface water supplies that may be available from the Pedernales River and any limitations that may be imposed on the supply, with consideration of instream flow requirements and water quality.

EXISTING SURFACE WATER USE

The natural flows of the surface water streams of the State of Texas are subject to use under an appropriative rights system managed by the Texas Natural Resource Conservation Commission. A permit must be obtained from the Commission in order to divert or store surface water. A priority of use (municipal, agricultural, industrial) and a priority in time (first in time, first in right) has developed. The surface water rights in each river basin have been adjudicated and are reviewed periodically by the Commission. This process confirms and protects existing water rights or in instances where water rights have not been utilized to their fullest extent, may result in their cancellation, either in whole or in part to make water available to new users. This utilizes the resource to the greatest benefit without imposing upon the existing rights of other users.

Surface water in Gillespie County is widely used as irrigation and livestock water and virtually all of the water rights are permitted for these uses only. The exceptions are a 50 ac-ft permit for washing gravel and a 200 ac-ft permit held by the City of Fredericksburg for its reservoir on Live Oak Creek which is utilized for recreational purposes. One water rights holder has a 30 ac-ft permit for mining uses, but there is no record that this water right has been utilized. The Texas Parks and Wildlife Department has a water right for a 73 ac-ft impoundment for recreational use.

Table 3-1 summarizes the existing water rights on the Pedernales River watershed, based upon the records available from the Texas Natural Resource Conservation Commission. The holder with the largest single water right is the LBJ Company in combination with the U.S. Department of Interior and Tully R. Currie. They are listed as holders of permit number 1466 totaling 1260 ac-ft. The LBJ Company and the U.S. Department of Interior each hold additional rights as well.

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1405	RJ Sechrist, Route 2, Box 184, Fredericksburg, TX 78624	73.1 ac. ft.	Irrigation	1959, 1965 and August 31, 1964	Dam and Reservoir on White Oak Creek and Pedernales River	29 ac. ft. (1985)	0	8.5 ac. ft.	none
1406	RJ and Dorothy Sechrist, Route 2, Box 184, Fredericksburg, TX 78624	8 ac. ft.	Irrigation	September, 1957	Pedernales River	7 ac. ft. (1982)	0	1.7 ac. ft.	1985
1407	Estalla Grona, Route 2, Fredericksburg, TX 78624	60 ac. ft.	Irrigation	1940	Dam and Reservoir on the Pedernales River				1992-82
1408	Mrs. Herbert Reeh, HC 64,Box 26 Fredericksburg, TX 78624	8.25 ac. ft.	Irrigation	1955	Four reservoirs on Spring Creek and an unnamed tributary of Spring Creek	0	0	0	1991-90;
1409	Keyser Bierschwale, Harper Route, Fredericksburg, TX 78624	12.5	Irrigation	1958	Dam and reservoir on Spring Creek	0	0	0	1992-85
1410	Jay D. Rutledge, III, et al, Route 2, Box 196 Fredericksburg, TX 78624	25.34 ac. ft.	Irrigation	1970	Spring Creek	8.57 ac. ft. (1984)	0	.91 ac. ft.	none
1411	Paul D. and Beth Meek, P. O. Box 2159, Dallas, TX 75221		Irrigation	1951	Pedernales River				
1412	C H Bonn & Sons HC 12, Box 150 Fredericksburg, TX 78624	118 ac. ft.	Irrigation	March, 1955	Pedernales River	6.5 (1986-82)	0 (1992-87)	3.25	none
1413	Edwin & Werner Henke, HC 12, Box 96, Fredericksburg, TX 78624	20.6 ac. ft.	Irrigation	September, 1954	Dam and reservoir on Wolf Creek	0	0	0	none
1414	Ernest W. Kott HC 12, Box 94 Fredericksburg, TX 78624	12 ac. ft.	Irrigation	1955	Wolf Creek	0	0	0	none

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1415	Steve & Hilmer Juenke, HC 12, Box 90A, Fredericksburg, TX 78624	12.5 ac. ft.	Irrigation	July 1, 1974	Dam and reservoir on tributary to Wolf Creek	1+ ac. ft. (1984)	0		none
1416	C H Bonn & Sons Kerr Route Fredericksburg, TX 78624	21.75 ac. ft.	Irrigation	April, 1955	Wolf Creek	6.4 ac. ft. (1984)	.5 ac. ft. (1992)	2.51	none
1417	Roy Richard Henke, HC 12, Box 110, Fredericksburg, TX 78624	112.86 ac. ft.	Irrigation	May, 1938	Five reservoirs on Wolf Creek	90 ac. ft. (1983)	0	27.72 ac. ft.	none
	Larry Irvin, et ux, HC 12, Box 88B, Fredericksburg, TX 78624	120 ac. ft.	Irrigation			245 ac. ft. (1986-85)	4.86 ac. ft. (1988)	132.9 ac. ft.	1992-90; 1984-82
	Allen Roy Henke, et al, c/o Roy Richard Henke, HC 12, Box 110, Fredericksburg, TX 78624	7.14 ac. ft.	Irrigation			31 ac. ft. (1992)	0	0	1991-82
		240 ac. ft.							
1418	Nathan Kott, et al, HC 12, Box 130, Fredericksburg, TX 78624	44 ac. ft.	Irrigation	1955	Wolf Creek	0	0	0	none
1419	George L. Heimann, Route 3, Box 295, Fredericksburg, TX 78624	3 ac. ft.	Irrigation	April, 1960	Existing dam and reservoir on Bear Creek	0	0	0	1990; 1986
1420	Stanley and Lillian Wissemann Kerr Route, Box 52-I, Fredericksburg, TX 78624	20 ac. ft.	Irrigation	August 15, 1980	Bear Creek	1 ac. ft. (1982)	0		1992; 1990; 1988

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1421	Rex McElroy Route 2, Box 205A, Fredericksburg, TX 78624	98 ac. ft.	Irrigation	1935	Two reservoirs on Nasser Creek (Masse Creek)	18.95 ac. ft. (1983)	0	7.4 ac. ft.	1992-90; 1988
1422	Grady and Diane George, 609 E. Main St., Fredericksburg, TX 78624 (see 11/13/94 ltr. to George re: change in ownership)	50.2 ac. ft.	Washing Gravel	1959	Pedernales River	7.14 ac. ft. (1982)	0	0	1992-86; 1984-83
1423	Ben C. Hagel HC 12, Box 52 Fredericksburg, TX 78624	80 ac. ft	Irrigation	April 15, 1967	Dam and Reservoir on the Pedernales River and an off-channel reservoir				none
1424	Greg Kowalski, et al, 1220 E. Commerce, San Antonio, TX 78205	20 ac. ft.	Irrigation	June, 1964	Pedernales River and Live Oak Creek	9 ac. ft. (1991-82)	0 (1992)	8.18 ac. ft.	none
1425	Ray E. & Annette Gilbert, 104 Ridgewood Dr., Fredericksburg, TX 78624	2 ac. ft.	Irrigation	1963	Live Oak Creek				1992-82
1426	F.W. Burgess Rt. 2, Box 123 Fredericksburg, TX 78624	17 ac. ft.	Irrigation	April 1963	Live Oak Creek				1992-1982

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1427	City of Fredericksburg Public Works and Utilities Mr. Jerry Bain, Director, P.O. Box 111, Fredericksberg, TX 78624	100 ac. ft (old certificate) 100 ac. ft. (cert. amendment) Total not to exceed 100 ac. ft.	Recreational Recreational	April 1, 1968 June 24, 1992	Existing dam and reservoir on Live Oak Creek Additional existing dam and reservoir on Live Oak Creek	0	0	0	1990
1428	Van C. Brown HC 12, Box 49-B Fredericksburg, TX 78624	21 ac. ft.	Irrigation	1952	Live Oak Creek	32 ac. ft (1985)	0 (1992-1988; 1983)	16.27 ac. ft.	none
1429	Conrad Ernst P.O. Box 252 Fredericksberg, TX 78624	6 ac. ft.	Irrigation	1951	Live Oak Creek	.5 (1985)	0 (1984-82)	.125 ac. ft.	1992-1986
1430	Milton C. Boos HC 12, Box 43 Fredericksburg, TX 78624	25 ac. ft.	Irrigation	1950	Pedernales River	0	0	0	1992
1431	Lillian M. Wissemann Kerr Route, Box 52-I, Fredericksburg, TX 78624	11 ac. ft.	Irrigation	April 15, 1967	Pedernales River	0	0	0	1992; 1990; 1988
1432	The TWC is currently investigating who owns this water right.	47.5	Irrigation	1947	Three dams and reservoirs on an unnamed tributary to Barons Creek	28.9 ac. ft. (1984)	0	6.7 ac. ft.	1991; 1987

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1433	Theodore J. Stehling, HC 10, Box 19A, Fredericksburg, TX 78624 Carolyn Gross c/o Theodore J. Stehling, HC 10, Box 19A, Fredericksburg, TX 78624	25 ac. ft. 5 ac. ft. Total 30 ac. ft	Irrigation Irrigation	January 11, 1949	Dam and reservoir on Barons Creek	40.4 ac. ft. (1984)	0 (1992-91; 1987-86)	12.68 ac. ft.	none
1434	Dr. J. Hardin Perry, Cherry Creek Blvd. Fredericksburg, TX 78624	6 ac. ft.	Irrigation	1963	Barons Creek	7 ac. ft. (1988)	3.5 ac. ft. (1988)	4.95 ac. ft.	1992
1435	The Estate of Clemens Immel c/o Viola K. Immel, Rt. 1, Box 75 Fredericksburg, TX 78624	4 ac. ft.	Irrigation	1957	Barons Creek	0	0	0	none
1436	Dale Vestal P. O. Box 583 Fredericksburg, TX 78624	12 ac. ft.	Irrigation	May, 1965	Barons Creek	7 ac. ft. (1982)	0 (1992-83)	.63 ac. ft.	none
1437	Dr. Dor W. Brown, et al, 109 S. Adams St. Fredericksburg, TX 78624	30 ac. ft.	Irrigation	April, 1964	Pedernales River	0	0	0	1992-90; 1987-86; 1984-82

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1438	Alex R. Frantzen c/o Lester C. Frantzen, P. O. Box 513 Fredericksburg, TX 78624	6.361 ac. ft.	Irrigation	1952	Pedernales River	0	0	0	1991-89; 1986-84
	Lester C. Frantzen, P. O. Box 513, Fredericksburg, TX 78624	23.246 ac. ft.							
	Albert G. Dwarshus, Jr., 712 Main St., Suite 1820, Houston, TX 77002					8.0 ac. ft. (1989)	0	4 ac. ft.	1991-90; 1988-82
	Laura Herbort Frantzen, 501 E. Oltorf, #101, Austin, TX 78704	.576 ac. ft.							1992-82
		9.817 ac. ft.							
		Total 40 ac. ft.				0	0	0	1989-82
1439	Hilmer Weinheimer Route 1, Box 224 Fredericksburg, TX 78624	221 ac. ft.	Irrigation	May, 1948	Pedernales River	140 ac. ft. (1982)			1992-83
1440	Issam Texas Land & Cattle Co., N.V., Route 4, Box 280, Fredericksburg, TX 78624	121 ac. ft.	Irrigation	1943	Two reservoirs on Upper Palo Alto Creek and an unnamed tributary to Palo Alto Creek	0	0	0	1990-91; 1986; 1984-82

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1441	Issam Texas Land & Cattle Co., N.V., c/o Jerry R. Mayfield, Route 4, Box 280 Fredericksburg, TX 78624	34 ac. ft.	Irrigation	1943	Dam and reservoir on Upper Palo Alto Creek	0	0	0	1990-89; 1986; 1984-82
1442	Liston Maner Route 1, Box 374 Fredericksburg, TX 78624	12 ac. ft.	Irrigation	1940	Three tributaries on Meyer Creek and unnamed tributaries to Meyer Creek				1992-1982
1443	Eugene Patteson Llano Route, Box 72, Fredericksburg, TX 78624	13.175 ac. ft.	Irrigation	1966	Palo Alto Creek	0	0	0	1992; 1990; 1988-86; 1983-82
	Janice C. Patteson, 809 Quinlan, Kerrville, TX 78028	.252 ac. ft.	Irrigation			0	0	0	1992-83
	Stephen G. Reeh, et ux, Rt. 1, Box 372, Fredericksburg, TX 78624	1.573 ac. ft.							
		Total 15 ac. ft.	Irrigation			0	0	0	none
1444	K & S Supply Corp., P. O. Box 130288, Houston, TX	100 ac. ft.	Irrigation	1915	Dam and reservoir on an unnamed tributary of Palo Alto Creek	53 ac. ft. (1991-85)	44 ac. ft. (1983)	51.24 ac. ft.	1992
1445	Edna Mohr & Sons - Wayne and Curtis Mohr 105 S. Olive Fredericksburg, TX 78624	30 ac. ft.	Mining	1951	Existing Dam and Reservoir on Palo Alto Creek	0	0	0	1992; 1990; 1988-82
1446	Martin & Elvira Beyer, Route 1, Box 102, Fredericksburg, TX 78624	45 ac. ft.	Irrigation	December 31, 1964	Pedernales River	3.48 (1990)	2.42 (1991)	0.8	1992

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1447	Keller Equipment Co., Allen Keller, Pres., P. O. Box 393, Fredericksburg, TX 78624	31 ac. ft.	Irrigation	August, 1964	Pedernales River	0	0	0	1992
1448	Mrs. Victor Klinksiek, Route 3, Box 342, Fredericksburg, TX 78624	22 ac. ft.	Irrigation	1923	Grape Creek	0	0	0	1990
1449	Daniel Hohenberger, P. O. Box 357, Johnson City, TX 78636	26 ac. ft.	Irrigation	1966	South Grape Creek and Hells Dale				1992-82
1450	Clayton Klinksiek, et. al., Box 982, Fredericksburg, TX 78624	35 ac. ft	Irrigation	1943	3 reservoirs on South Grape Creek and an unnamed tributary to South Grape Creek	10 ac. ft. (1988)	1.79 ac. ft. (1983)	4.80 ac. ft.	none
1451	V. N. Schultz, Inc. c/o V. N. Schultz, President, HC 13, Box 24 Fredericksburg, TX 78624	25 ac. ft.	Irrigation	1952	Existing Dam and Reservoir on Hunters Creek	20 ac. ft.	0	4.4 ac. ft.	1991-92
1452	Warren A. Petsch HC 13, Box 30 Fredericksburg, TX 78624	37 ac. ft.	Irrigation	1952	Three reservoirs on an unnamed tributary of Hunter's Creek	27 ac. ft. (1984; 1982)	0 (1992-91; 1989-87)	12 ac. ft.	none
1453	Willie A. Wehmeyer, Jr. HC 13, Box 1 Fredericksburg, TX 78624	41 ac. ft.	Irrigation	1964	Lower South Grape Creek	0	0	0	none
1454	Willie A. Wehmeyer, Jr. HC 13, Box 1 Fredericksburg, Tx 78624	67.5 ac. ft.	Irrigation	1962	Lower South Grape Creek	0	0	0	1982
1455	Felix W. Beckmann Rt. 1, Box 199 Fredericksburg, TX 78624	8 ac. ft.	Irrigation	1967	Pedernales River	0	0	0	none

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1456	Elgin O. Behrends Route 1, Box 196 Fredericksburg, TX 78624	10.5 ac. ft.	Irrigation	1967	Pedernales River	0	0	0	1991
1457	Bernard Staudt Estate 1317 Warrington Dr., Austin, TX 78753	14 ac. ft.	Irrigation	1965	Pedernales River	15 ac. ft. (1989)	0 (1992; 1987-82)	3.63 ac. ft.	none
1458	Hilmer Nebgen P.O. Box 993 Stonewall, TX 78671	1.7 ac. ft.	Irrigation	August 1, 1966	Pedernales River	4.44 (1984)	.33 ac. ft. (1983)	1.35 ac. ft.	none
1459	Ruben Ruebsahm P.O. Box 235 Stonewall, TX 78671	25.5 ac. ft.	Irrigation	1953	Pedernales River	0	0	0	none
1460	Simon J. Burg Box 987 Stonewall, TX 78671	10 ac. ft.	Irrigation	1948	Pedernales River	2 ac. ft. (1986)	0 (1992-90)	.81 ac. ft	none

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1461	The LBJ Company P.O. Box 1209 Austin, TX 78769	3.26 ac. ft	Irrigation	1966	Pedernales River	0	0	0	1991-90; 1988-86
	Tully R. Currie No. 6 Granbury Place San Antonio, TX 78218	499.83 ac. ft.	Irrigation			516 ac. ft. (1989)	150 ac. ft. (1991)	414 ac. ft	1988-82 (see below)
						9 ac. ft. (1987-85)	0 (1983-82)	5.35 ac. ft.	K&S Supply Corp (1988-82)
	J. Mike Howard, et. ux. (Martha Howard) Rt. 4, Box 667 McKinney, TX 75069	13.81 ac. ft.	Irrigation			0	0	0	1992-91; 1982
	Byron C. Hulett, et. ux. (Elizabeth C. Hulett) P.O. Box 265 Stonewall, TX 78671	13.10 ac. ft.	Irrigation			0	0	0	1992-86;1983-82
		Total 530 ac. ft.							
1462	Texas Parks and Wildlife Dept. - LBJ Park Operations 4200 Smith School Rd. Austin, TX 78744	Impound - 73 ac. ft.	Recreation	May 8, 1972	Dam and reservoir on Pedernales River	11.05 (1982)	0 (1992; 1990-85; 1983)	1.98 ac. ft.	1991

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1463	Ernest Hodges Estate and William B. Hodges HC 1, Box 470 Stonewall, TX 78671	39 ac. ft.	Irrigation	1950	Off-channel reservoir from Pedernales River	12 ac. ft. (1987; 1985)	0 (1992-88; 1986; 1983-82)	3.09 ac. ft.	none
1464	The LBJ Company P.O. Box 1209 Austin, TX 78769	86 ac. ft.	Irrigation	January 8, 1952	Dam and reservoir on the Pedernales River	16 ac. ft. (1982)	0 (1989; 1985; 1984; 1983)	3.2 ac. ft.	1992-90; 1988-86
1465	U.S. Dept. of Interior, c/o Superintendent LBJ National Historic Site P.O. Box 329 Johnson City,TX 78636	114 ac. ft.	Irrigation	January 8, 1952	Dam and Reservoir on the Pedernales River	192 ac. ft. (1986)	0 (1992-91)	55.83 ac. ft.	none

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1466	The LBJ Company 8309 N IH-35 Suite 200 Austin, TX 78753	1243.96 ac. ft.	Irrigation	1952	Pedernales River	0	0	0	1991-90;1988-86
	US Dept. of Interior, c/o Superintendent LBJ National Historic Site P.O. Box 329 Johnson City, TX 78636		Irrigation			0	0	0	none
	Tully R. Currie No. 6 Granbury Place San Antonio, TX 78218	16.04 ac. ft. Total 1260 ac. ft.	Irrigation			6 ac. ft. (1988-85) (Based on	0 (1989, 1984-82) K&S	13 ac. ft. Supply	1992-90 Corp Reports)
1467	Austin Invest-ments Company 8309 N. IH35, Suite 200 Austin, Texas 78753	220 ac. ft.	Irrigation	1953	Dam and Reservoir on Pedernales River	0	0	0	
	U. S. Dept. of Interior c/o Superintendent LBJ National Historic Site, P. O. Box 329, Johnson City, TX 78636					1.75 ac. ft. (1982)			1991-90; 1988-86

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1468	Barton C. English, et al (Mary O'Boyle, II) Redstone Ranch, P. O. Box 860, Stonewall, TX 78671-0860	500 ac. ft.	Irrigation	Spring, 1963	Off-channel reservoir of Pedernales River	500 ac. ft. (1989)			1992-90; 1988
1469	The State of Texas c/o Texas Parks and Wildlife Dept. Design & Construction Division, 4200 Smith School Rd. Austin, TX 78744	160 ac. ft.	Irrigation	March, 1964	Pedernales River	0	0	0	1991-90
1470	Werner Schumann c/o Harvey Schumann, P. O. Box 191, Hye, Texas 78635 Texas Parks & Wildlife Dept. LBJ Park Operations 4200 Smith School Road, Austin, TX 78744	50 ac. ft.	Irrigation	1967	Pedernales River	0 0	0 0	0 0	1991-90; 1986-82
1471	J. O. Tanner, HC 01, Box 400, Albert, TX 78671-9710	56 ac. ft.	Irrigation	1944	Two dams and reservoirs on Williamson Creek	0	0	0	1982-92
1472	Addie Lindig Route 2, Box 210 Johnson City, TX 78626	7 ac. ft.	Irrigation	1933	Reservoir on Rocky Creek	(convert gallons to ac. ft.)	0 (1992-85; 1983)		none
1473	John W. O'Boyle, Jr., P. O. Box 13, Fredericksburg, TX 78624	276 ac. ft.	Irrigation	1964	Pedernales River, Waller Branch and an unnamed tributary to Waller Branch	0	0	0	1988; 1985-82
1474	Kermit Eckhardt Route 1, Box 133 Fredericksburg, TX 78624	26 ac. ft.	Irrigation	1900	Dam and Reservoir on an unnamed tributary of North Grape Creek	0	0	0	1992-82

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
1475	Charles Ottmers 110 East Centre St. Fredericksburg, TX 78624	3 ac. ft.	Irrigation	1942	Two dams and reservoirs on Spring Creek	5 (1992-89; 1988-86; 1984-83	0 (1982)	3.72 ac. ft.	none
1476	Jonnie W. Otmers Route 1, Box 160, Fredericksburg, TX 78624	3 ac. ft.	Irrigation	1966	2 dams and reservoirs on Schmidts Creek				1992-1982
1477	Keller Equipment Company c/o Allen Keller, Pres. P.O. Box 393 Fredericksburg, TX 78624	4.25 ac. ft.	Irrigation	December 31, 1964	Dam and reservoir on Spring Creek and Towhead Creek	0	0	0	1992
1478	James J. Mooney Johnson City, TX 78636	9 ac. ft.	Irrigation	August 16, 1965	Flat Creek	0	0	0	1992-85
1479	City of Johnson City, TX 78636	220 ac. ft. 345 ac. ft.	Municipal Recreational (Non-consumptive)	November 29, 1966	Dam and reservoir on Pedernales River				1990
1480	W. T. Yett, c/o Roddy M. Smith, P. O. Box 565, Blanco, TX 78606	Impoundment of 30 ac. ft	Recreational Purposes	April 17, 1967	Dam and Reservoir on Miller Creek	0	0	0	1992-91; 1989-82
1481	Texas Parks & Wildlife Dept. - Pedernales Falls 4200 Smith School Rd., Austin, TX 78744	30 ac. ft.	Municipal	April 24, 1972	Pedernales River	18.4031 ac. ft. (1986)	12.0011 ac. ft. (1985)	14.562 ac. ft.	1991-90; 1983
1482	Nancy Warren Frasher, P. O. Box 5898, Austin, TX 78763	34 ac. ft.	Irrigation	Sept. 7, 1962	Pedernales River				1992-89; 1986-82
2640	R. G. and Blanche Fussell P. O. Box 565, Katy TX 77492-0565	10 ac. ft.	Irrigation	March 31, 1966	Dam across Hairston Creek	0	0	0	1992-91; 1989-82

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
2641	G. S. Allen P. O. Box 547 Burnet, TX 78611	253 ac. ft.	Irrigation	Frbruary 28, 1958	Colorado River (Lake Travis)	15.69 ac. ft. (1992)	0		1991-89; 1982
2642	D. M. Doyle The Doyle Ranch Route 4, Box 126 Marble Falls, TX 78654	89 ac. ft.	Irrigation	December 31, 1961	Colorado River (Lake Travis)	0	0	0	1982
2643	Costillo C. Lewis HC 2, Box 12-J, Marble Falls, TX 78654	80 ac. ft.	Irrigation	April 30, 1967	Colorado River (Lake Travis)	80 ac. ft. (1987-83)	0	40 ac. ft.	1982
2644	Salem Ranch, a partnership P.O. Box 24788, Winston-Salem, NC 27114-4788	27.67 ac. ft.	Irrigation	December 31, 1954	Post Oak Creek, tributary of Cow Creek, and tributary of the Colorado River	0	0	0	1991-90; 1982
2645	LagoVista, Inc. P. O. Box 4500 Lago Vista, TX 78645	9 ac. ft.	Irrigation	January 28, 1974	Existing Dam and Reservoir on Unnamed tributaries of the Colorado River	6.4 ac. ft. (1983)	2.10 ac. ft. (1992)	5.24 ac. ft.	1982
2646	James L. Anderson, 714 E. 32nd St., Austin, TX 78705	.07 ac. ft.	Irrigation	April 30, 1964	Bid Sandy Creek, tributary of the Colorado River	0	0	0	1990; 1988; 1982
2647	Texas Conference Association of Seventh Day Adventists 23421 Nameless Rd., Attn: Youth Dept./Nameless Valley, Leander, TX 78641	5.7 ac. ft.	Irrigation	April 30, 1964	Big Sandy Creek, tributary of the Colorado River	0	0	0	1992; 1983-82

TABLE 3-1 EXISTING WATER RIGHTS

Permit/ Cert. No.	Water Rights Holder	Permitted Amount by use	Permitted Use	Priority Date	Source of Diversion (River/ Reservoir, etc)	Highest Annual Usage 1982-1992	Lowest Annual Usage 1982-1992	Average Annual Usage 1982-1992	Years for which Surface Water Reports Unavailable
2648	Walter L. and Reta Mae Moore 3800 Woodbrook Circle Austin, TX 78759	.23 ac. ft.	Irrigation	April 30, 1964	Big Sandy Creek, tributary of the Colorado River	0	0	0	1982
2649	James L. Anderson, 714 E. 32nd St., Austin, TX 78705	10 ac. ft.	Irrigation	July 31, 1963	Big Sandy Creek	0	0	0	1990; 1988; 1982
2650	Marvin T. & Peggy Jean Talbott, 1712 Cathedral, Plano, TX 75023	1 ac. ft.	Irrigation	July 31, 1963	Big Sandy Creek	.03 (1989)	0 (1992-90; 1988-83)	0.003	1982
2651	Henry Bradley Martin, Jr. HCO 4, Box 880 Marble Falls, TX 78654	14.33 ac. ft.	Irrigation	December 31, 1954	Dam across Post Oak Creek	0	0	0	1982

EXISTING SURFACE WATER FEATURES

The primary surface water feature in Gillespie County is the Pedernales River. The river and its tributary creeks are subject to severe flooding. However, many of the creeks and even the river itself may be dry at certain times of the year or during periods of drought. Because groundwater supplies historically have been readily available in Gillespie County, no comprehensive study of the Pedernales River as a water supply source has been undertaken prior to this time. The limited studies of potential reservoir sites have been aimed at flood control projects.

TWDB performed a study in the 1960's entitled Eastern Hill Country Resource Conservation and Development Project of Texas. The study covered Gillespie and Blanco Counties and included a summary of then existing reservoir studies for the Pedernales watershed. The Soil Conservation Service was reported to have studied a total of 41 potential floodwater retarding structure sites in Blanco and Gillespie Counties. In 1959, the Commissioners Court of Gillespie County engaged a private engineering firm to study the feasibility of multi-purpose reservoirs. The firm examined twenty sites and recommended six of the sites for further study.

The USGS has maintained a gaging station on the Pedernales near Fredericksburg since 1980. Table 3-2 lists the monthly flows at the gaging station through 1991. Note that the Pedernales is subject to severe floods and also very dry periods.

TABLE 3-2

MONTHLY FLOWS FOR PEDERNALES AT FREDERICKSBURG

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Totals
1980	1,510	1,295	1,230	1,348	3,870	609	142	161	2,020	1,080	926	1,170	15,361
1981	1,140	1,110	5,360	5,630	2,730	26,930	4,310	1,700	2,900	9,560	2,360	1,950	65,680
1982	1,600	1,570	1,850	1,380	3,260	1,190	398	230	184	0	437	573	12,672
1983	698	1,720	3,780	1,240	2,350	2,910	569	245	136	309	490	454	14,901
1984	761	478	601	354	181	138	55	16	18	11,470	1,310	8,530	23,912
1985	4,500	6,480	4,340	3,130	2,320	2,090	570	14	234	25,070	3,180	2,790	54,718
1986	1,630	1,740	1,190	1,380	5,650	7,400	1,160	329	1,280	5,420	3,750	8,530	39,459
1987	5,150	3,620	4,330	3,190	14,400	37,800	11,730	2,960	2,520	1,780	2,550	2,860	92,890
1988	2,130	1,380	1,400	1,220	7,190	3,780	10,550	3,510	820	684	617	865	34,146
1989	2,030	2,060	1,860	1,820	3,670	4,290	601	200	603	351	427	442	18,354
1990	540	930	1,310	2,290	16,200	663	1,340	1,380	879	952	1,060	1,210	28,754
1991	1,880	1,820	1,370	1,350	1,810	1,480	448	271	1,030	609	1,080	61,070	74,218
Avgs	**1,964**	**2,017**	**2,385**	**2,028**	**5,303**	**7,440**	**2,656**	**918**	**1,052**	**4,774**	**1,516**	**7,537**	**39,589**

TABLE 3-3

RECORDS OF SURFACE WATER USE IN GILLESPIE COUNTY

Year	Manufacturing	Irrigation	Livestock	Total
1977	46	750	527	1323
1980	80	880	497	1457
1984	78	153	446	677
1985	117	148	456	721
1986	103	75	534	712
1987	99	35	498	632
1988	150	375	526	1051
1989	51	231	509	791

POTENTIAL SURFACE WATER FEATURES

There are no large existing reservoirs in Gillespie County such as would be required for either an on-channel or off-channelwater supply source for the City of Fredericksburg and/or a County water supply system. As previously discussed, a number of reservoir sites have been considered within the County as potential flood control facilities. Several of the potential water impoundment sites are located near the City of Fredericksburg. None of the previous studies included a firm yield analysis for water supply purposes for a reservoir within Gillespie County.

However, the Corps of Engineers did study a site on the Pedernales River closer to Johnson City. Their study indicated a potential yield of 19,000 ac-ft annually. The continued validity of that analysis would be subject to the availability of water rights to develop the project.

Based on gage data shown in Table 3-2 for the Pedernales at Fredericksburg, the following table represents an initial consideration of the performance of a potential reservoir in the vicinity of Fredericksburg with an assumed storage volume of 300 ac-ft. Water demands are based on maximum projected 2030 water needs. Note that the analysis is based on the driest year in only a twelve-year period of record, which did not include the drought of record. Also, evaporation losses are ignored in this analysis and these losses would be especially high during periods of drought unless an enclosed reservoir is utilized.

TABLE 3-4

SURFACE WATER SUPPLY ANALYSIS - 2030
CITY OF FREDERICKSBURG

Month	Monthly Usage Distribution	2030 Monthly Demands	1982 USGS Gage Record	Gage Less Demand	End of Month Reservoir Storage	Water Shortage
Jan	5.3%	213	1,600	1,387	300	0
Feb	5.5%	222	1,570	1,348	300	0
Mar	5.7%	232	1,850	1,618	300	0
Apr	7.5%	303	1,380	1,077	300	0
May	8.9%	361	3,260	2,899	300	0
Jun	6.9%	281	1,190	909	300	0
Jul	11.3%	460	398	(62)	238	0
Aug	13.9%	563	230	(333)	0	95
Sept	10.5%	426	184	(242)	0	242
Oct	10.4%	423	0	(423)	0	423
Nov	7.9%	322	437	115	115	0
Dec	6.2%	252	573	321	300	0
Totals	**100.0%**	**4,057**	**12,672**	**8,615**		**760**

The results of this cursory analysis indicate that surface water would not be suitable as a primary water source for Gillespie County and/or the City of Fredericksburg since there is not enough water to provide a dependable water supply. Surface water could only partially serve the County's water demands and it would be necessary to rely on groundwater during even minor droughts.

However, the proper conjunctive management of available surface and ground water supplies could develop water resources sufficient to meet projected demands. Using surface water as a supplemental supply source when it is available may help to prevent depletion of the groundwater supplies so that adequate amounts of groundwater will be available during periods of drought.

SURFACE WATER SUPPLY ALTERNATIVES

Currently, the City of Fredericksburg has water rights for 100 ac-ft/year for recreational use only. Using surface water as a municipal source will require obtaining additional water rights and/or purchasing water from a holder of existing rights. Options available for the acquisition of additional water rights include purchase, donation, subordination and/or condemnation. Specific options for acquiring additional water rights are still being investigated.

Two large water rights holders may be willing to sell water to the City of Fredericksburg pursuant to water supply contracts. The LBJ Company, as previously mentioned, holds rights to large quantities of water in the Pedernales basin and does not currently utilize all of the water. Also, the LCRA holds water rights within the Colorado River Basin and recently passed legislation allows them to sell water outside of their ten-county service area, but within the lower river basin. LCRA holds water rights that are senior to the LBJ Company rights.

Engineering options for utilizing surface water include an on-channel reservoir, an off-channel reservoir, ASR and enhanced recharge. ASR and enhanced recharge are methods for storing surface water as groundwater for later utilization and will be discussed under groundwater supply alternatives. Development of either an on-channel or off-channel reservoir would require environmental impact studies, land acquisition and extensive permitting. The preferred option would be utilizing above ground tanks for off-channel storage

SECTION 4

GROUND WATER RESOURCES

INTRODUCTION

This section of the report summarizes and evaluates the ground water resources available within Gillespie County, Texas.

This information is used to determine future ground water availability within Gillespie County and in the formulation of the future water resource management planning.

METHODOLOGY

This section of the study was prepared using published data and reports from the Texas Water Development Board (TWDB), the Kerr County Regional Water Plan Report, the City of Fredericksburg and the Hill Country Underground Water Conservation District (HCUWCD).

The contour maps presented in this section were derived from the HCUWCD's computerized data base mapping system. This data base has been developed since 1990. Over 4000 wells from Gillespie County make up the data base, which allows easy access to any individual aquifer's data concerning water availability and quality.

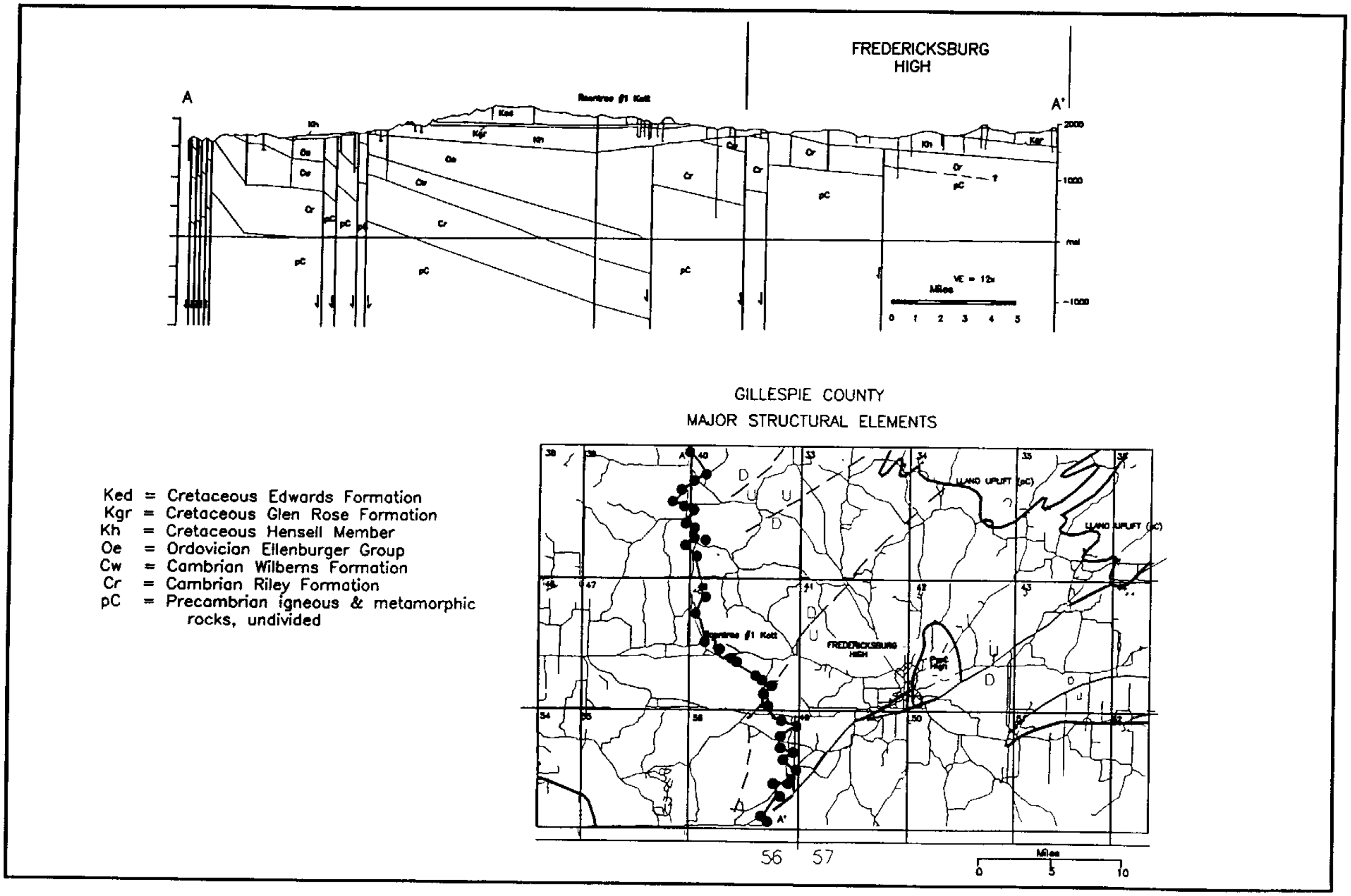
OVERVIEW OF THE REGIONAL HYDROGEOLOGY

Gillespie County is on the southern flank of the geologic structure called the Llano Uplift, which is comprised of very old igneous and metamorphic rocks of Precambrian age (> 1.0 Billion years). Younger rocks of Paleozoic and Cretaceous age overly this basement rock complex in Gillespie County. After the Paleozoic sediments were deposited but before Cretaceous deposition, the area was faulted, uplifted and subsequently exposed to erosion. This tectonic episode was associated with the Pennsylvanian Ouachita Uplift which formed the Ouachita Mountains of Oklahoma and Arkansas and the Marathon Uplift of West Texas. After the tectonic event occurred, a long period of time elapsed (> 100 million years) before Early Cretaceous seas transgressed the area and deposited Trinity sediments. As a result of the faulting and subsequent erosion that occurred after the Ouachita Uplift, the geology below the Cretaceous age rocks is very complex within Gillespie County. This has resulted in a complicated hydrogeological picture for Gillespie County with stratigraphic units from Cretaceous through Precambrian presently serving as aquifers. Table 4-1 list all the geological units and their water bearing properties found in Gillespie County. This table was taken from Report 339 Evaluation of the Ground-Water Resources of the Paleozoic and Cretaceous Aquifers in the Hill Country of Central Texas, August 1992, Bluntzer. To illustrate better the complex nature of the subsurface geology within Gillespie Co., the HCUWCD compiled a N-S cross section through the county utilizing well log data (Figure 4-1). Also on Figure 4-1 is an areal map of Gillespie County and shows some of the major structural elements which influence the distribution of the Paleozoic rocks and aquifers.

Table 4-1 Geological and Hydrological Units and Their Water-Bearing Properties

Geological Units: Era	Geological Units: System	Geological Units: Group	Geological Units: Formation	Geological Units: Member or Unit	Hydrological Units	Approximate Range in Thickness (feet)	Character of Rocks	Water-Bearing Properties
Cenozoic	Quaternary	Pleistocene 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 ‡ Edwards-Trinity (Plateau) Aquifer (in area adjacent to northwestern portion of study area.)	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.	* 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. ‡ Yields small to moderate quantities of fresh water to wells and small to very large quantities of fresh water to numerous springs.
				Fort Terrett Member	* 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".	* 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.	* Yields very small to small quantities 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 consistent Corbula bed (fossiliferous limestone) dividing Glen Rose Formation into upper and lower units.	* 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		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		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)		0-350 (pinches-out northward and northwestward)	Sandstone, siltstone, claystone, shale, dolomite, limestone and basal conglomerate.	
Paleozoic	OF: Undifferentiated Precambrian(?), Cambrian, Ordovician, Silurian, Devonian, Mississippian and Pennsylvanian rocks of the Ouachita Facies (OF) in the Ouachita Structural Belt.	Paleozoic Foreland Facies Units (PFF)			OF: Ouachita Facies rocks in the northern portion of the Ouachita Structural Belt serve as the downdip underlying confining beds beneath the Lower Trinity Aquifer PFF	OF: Range of thickness of Ouachita Facies rocks is estimated to be 0 to 10,000 feet (pinch-out northwestward due to thrust faulting). PFF	OF: Ouachita Facies rocks consist of weakly metamorphosed dark shale and gray sandstone, unmetamorphosed to weakly metamorphosed chert, limestone, dolomite, shale, siltstone and sandstone; extremely sheared, folded and metamorphosed dark shales and sandstones; and metamorphosed and sheared rocks consisting of phyllite, slate, quartzite, marble and schist PFF	OF: Ouachita Facies rocks are not known to yield fresh to slightly saline water, but may contain significant amounts of moderately saline to brine waters. PFF
	Pennsylvanian	Strawn Group	Not Differentiated	Not Differentiated	Confining Beds	0-1600	Limestone, shale and fine-grained sandstone	Not known to yield significant amounts of water to wells and springs
		Bend Group	Smithwick Formation	Not Differentiated		300-500	Claystone, siltstone and sandstone	
			Marble Falls Formation	Upper Unit	Marble Falls Aquifer	95 - 480	Mostly very fine grained cherty, thinly to thickly bedded, fossiliferous, brownish to olive gray limestone.	Yields very small to moderate quantities of fresh to slightly saline water to wells in northeastern Blanco County and perhaps east-central Gillespie County. Well yields may be significantly increased by acidizing
				Lower Unit			Mostly massive high calcium, very fine grained gray limestone reef with interspersed shale in lower 10 feet	
	Mississippian and Devonian	Consists from youngest to oldest of Barnett Formation (Mississippian), Chappel Limestone (Mississippian), Houy Formation (Devonian), and Stribling Formation (Devonian)			Usually Confining Beds Where Present	0 - 50	Thin, scattered remanant deposits consisting of dark shale, petroliferous limestone, crinoidal limestone, chert breccia, fractured chert, and microgranular limestone with bedded chert.	Not known to yield significant amounts of water to wells and springs.
	Ordovician	Ellenburger Group	Honeycut Formation	Not Differentiated	Ellenburger-San Saba Aquifer	0 - 850 (truncated by erosion southward)	Thinly to thickly bedded, light-gray, aphanitic limestone and thinly to thickly bedded, fine-grained to microgranular, gray dolomite. Both limestone and dolomite have fossiliferous chert	Yields very small to very large quantities of fresh to slightly saline water to wells in the Pedernales River Valley in Gillespie and Blanco Counties. Yield of a well is very dependent on the amount and size of fracture openings and caverns encountered by the well bore. Where such openings are encountered, wells may be capable of yielding over a 1,000 gallons per minute. Where such openings are not encountered wells may yield less than 5 gallons per minute. Where limestone (calcium carbonate) is encountered well yields may be significantly increased by acidizing. Yields small to very large quantities of fresh water to springs in northwestern Gillespie County and northern Blanco County
			Gorman Formation	Not Differentiated		280 - 500 (partially truncated by erosion southward)	Predominantly aphanitic light gray limestone in upper part and predominantly micro-granular to fine-grained, pink, gray and yellowish-gray dolomite in lower part. Has prominent bed containing fossiliferous chert nodules near middle of formation	
			Tanyard Formation	Staendebach Member		475 - 730 (thins westward)	Thickly to thinly bedded, aphanitic, very light gray, cherty limestone and thickly to thinly bedded, fine to medium grained gray to brownish gray, cherty dolomite. Chert is fossiliferous	
				Threadgill Member			Predominantly medium to coarse grained, light gray dolomite which may locally and laterally grade to massive, light gray limestone. Lower part may be Cambrian in age	
	Cambrian	Moore Hollow Group	Wilberns Formation	San Saba Member		250 - 680 (thins northward)	Fine to very fine grained, yellowish to brownish to medium gray, thickly to thinly bedded, slightly cherty dolomite. Upper part may be Ordovician in age.	
				Point Peak Member	Confining Beds	0 - 270 (pinches out southeastward)	Predominantly laminated siltstone with some limestone and shale	Not known to yield significant amounts of water to wells and springs.
				Morgan Creek Member		50-190 (thins southeastward)	Thickly to thinly bedded, granular, glauconitic, pink to reddish-brown to gray to greenish and brownish gray, fossiliferous limestone	
				Welge Member	Mid-Cambrian Aquifer	5-32 (thins south eastward)	Thickly bedded, nonglauconitic to slightly glauconitic, medium grained, brownish yellow sandstone	Yields very small to moderate quantities of fresh water to wells in northern two-thirds of Gillespie County and northwestern quarter of Blanco County. Well yields may be significantly increased by acidizing. May yield small quantities of fresh water to some springs in northern Gillespie and northern Blanco counties
			Riley Formation	Lion Mountain Member		25-85 (thins southeastward)	Quartzose greensand, glauconitic quartz sandstone, impure fossiliferous limestone, crossbeds of trilobite coquinite and minor amounts of shale and siltstone	
				Cap Mountain Member	Confining Beds	380-550 (thins north-westward)	From top down, limestone, siltstone, and silty limestone and mottled limestone grading to calcareous, well cemented sandstone at base. Limestone is thickly bedded, glauconitic, partly oolitic and various shades of gray and brown.	Not known to yield significant amounts of water to wells and springs
				Hickory Member	Hickory Aquifer	150-400 (may be absent over some subsurface Precambrian highs and thins south-eastward)	Top part is thinly bedded, mostly well cemented, silty, argillaceous, micaceous, fine to medium grained red, brown and gray, quartz sandstone. Lower part is more thickly bedded, well to slightly cemented, fine to coarse grained, poorly sorted, red brown, yellow, gray and white, cross-bedded, quartz sandstone with local occurrence of quartz and feldspar pebble conglomerate at base.	Yields small to very large quantities of fresh to slightly saline water to wells and springs in northern half of Gillespie County and northwestern quarter of Blanco County. Wells may be capable of yielding over 500 gallons per minute where sandstone is fractured and slightly cemented, and where saturated thickness of 300 to 400 feet is encountered
Precambrian		Llanite (porphyry) Six Mile Granite Oatman Creek Granite Pegmatite and quartz veins Town Mountain Granite			Usually Confining Beds	Unknown	Granitic intrusive igneous rocks composed of quartz, feldspar, biotite and other associated minerals.	Where rocks are not fractured, these rocks are not known to yield significant amounts of water to wells and springs. Where rocks are fractured, these rocks may yield very small to moderate amounts of fresh water to wells and springs
		Metarhyolite dikes Red Mountain Gneiss Big Branch Gneiss					Metamorphosed sedimentary and igneous rocks	

FIGURE 4-1
GEOLOGICAL CROSS SECTION AND MAJOR STRUCTURAL ELEMENTS ACROSS GILLESPIE COUNTY



Although many different stratigraphic units presently serve as aquifers within Gillespie County, four are the main producers of ground water. These are the Cretaceous Edwards Formation and Hensell Member, the Ordovician Ellenburger Group and the Cambrian Hickory Member. These four aquifers will be described in detail within this report. Other units which serve as aquifers on a limited extent are the Glen Rose along the southeastern boundary of the county, the Marble Falls Formation within the Cave Creek area, the San Saba Member within the Stonewall area, the Welge Member east of Cherry Springs, the Tivydale-Usener Road area and Double Horn Road area, and the Precambrian rocks of the Llano Uplift in the northeastern part of the County.

Gillespie County is approximately 1061 square miles with elevations ranging from a low of less than 1100 feet on the Llano Uplift in the north-eastern part of the County to more than 2200 feet on the Edwards Plateau in the western part of the County (National Geodetic Vertical Datum-NGVD). Surface drainage is to the east along the Pedernales River. Along the northern part of the County, drainage is to the northeast toward the Llano River. Generally, Edwards limestone forms the tops of the hills while the Hensell sand forms the valley floors within the County.

STRATIGRAPHY

POST CRETACEOUS

Within Gillespie County deposits of the Quaternary system are found generally exposed along abandoned channels of the streams and the Pedernales River. These deposits are made up of sand-gravel conglomerates; however, fine grain alluvial deposits are also present. The thickness of the Quaternary is generally less than 50' and is not important from a ground-water resource standpoint.

CRETACEOUS

Rock units of Cretaceous age in Gillespie County are as follows:

- Fredericksburg Group
  - Edwards Formation
- Trinity Group
  - Glen Rose Formation
  - Travis Peak Formation
    - Hensell Member
    - Cow Creek Member
    - Hammett Member
    - Sligo Member
    - Hosston Member

The Edwards Formation of the Fredericksburg Group is comprised of limestone and dolomite with interbeds of chert and shale. The Edwards outcrops across the western half of the County where it defines the eastern edge of the Edwards Plateau. In the river and stream valleys, the Edwards has been removed by erosion leaving older units exposed. The maximum thickness of the Edwards may exceed 350' in extreme western Gillespie County. On the Edwards Plateau of Gillespie County, the Edwards Formation is an important aquifer; however, yields are generally less than 15 gpm. This is based on the fact that in Gillespie County, the HCUWCD computerized data base has a total of 463 wells that produce water from the Edwards aquifer. Of these 463 wells, 319 wells or 69 % produce 15 gpm or less, with an average yield for all 463 wells of 13 gpm.

In geological sequence beneath the Edwards Formation are rock units from the Trinity Group. The first being the Glen Rose Formation. This unit outcrops in the southeastern part of Gillespie County and on the slopes in the eastern portions of the County. The formation is comprised of limestone and clay with some sand beds interspersed. Except in the southern part of the County, the unit is not an important water-bearing unit due to its high clay content. Where the Glen Rose produces water, it is often of poor quality (high TDS, sulfate).

The Travis Peak Formation is comprised of several members that serve as aquifers within Gillespie and adjoining counties. The youngest unit is the Hensell Member and is a very widespread unit across the County. It outcrops on the floor of most of the stream and river valleys. It covers most of the older underlying Paleozoic sediments due to the fact that the older Travis Peak members pinch out near the southern Gillespie County line. The Hensell Member produces moderate (20 gpm) amounts of good quality ground water throughout the county. In addition to it serving as a moderate to good aquifer, it also is a very good recharge unit to the older underlying rocks. The unit is predominately a sand, reddish in color, with associated pinkish white clay and caliche layers. The unit is generally sandier towards the bottom with a conglomerate often present at the base.

The Cow Creek Member of the Travis Peak Formation is a massive fossiliferous limestone which is present along the southern edge of the County in the subsurface. It is doubtful that it serves as an aquifer in Gillespie County. Beneath the Cow Creek is the Hammett Member (Pine Island Shale) and is also present in the subsurface only along the southern edge of Gillespie County.

The Hosston and Sligo Members of the Travis Peak Formation are also only present towards the southern edge of Gillespie County and pinch out towards the north. The Sligo is a sandy dolomitic limestone while the Hosston is a dolomitic sandstone and hence the two are difficult to distinguish. The units may serve as aquifers in some of the deeper wells (>500 feet) located in the southwestern part of Gillespie County.

PALEOZOIC

Pennsylvanian - Mississippian

The Pennsylvanian-Mississippian rocks in Gillespie County include the Marble Falls Formation and Barnet Formation. The Marble Falls is a massive, brownish to olive gray limestone. It is an aquifer on a very restricted basis in the Cave Creek area of the eastern part of Gillespie County. It is present along a trend running northeast to southwest along Klein-Ahrens Road. The unit produces low to moderate amounts of generally good quality ground water. The Barnet Formation underlies the Marble Falls and is a dark gray shale with no ground water producing potential.

Ordovician

The Ordovician rocks within Gillespie County are from the Ellenburger Group which is subdivided into the following:

- Ellenburger Group
    - Honeycut Formation

- Gorman Formation
- Tanyard Formation
  - Staendebach Member
  - Threadgill Member

Within Gillespie County the various formations of the Ellenburger Group are generally massive cherty dolomites with some areas containing limestone. The youngest formation is the Honeycut and is generally a limestone. It is often not present due to the erosion after the Ouachita Uplift which removed a large portion of the unit. The Gorman and Tanyard Formations are for the most part dolomites and are difficult to differentiate. Of the two, the Gorman is generally found to be an aquifer, due largely to its being younger than the Tanyard and nearer the surface. However, where the Gorman has been removed through erosion, the Tanyard can also serve as an aquifer. The Ellenburger Group is the most important water-bearing unit in Gillespie County. Very large capacity municipal wells are completed within the Ellenburger. The hydrological characteristics of this unit will be discussed in detail in the Major Aquifers section of the report.

Cambrian

The Cambrian age rock units are the Moore Hollow Group and comprise the following:

- Moore Hollow Group
  - Wilberns Formation
    - San Saba Member
    - Point Peak Member
    - Morgan Creek Member
    - Welge Member
  - Riley Formation
    - Lion Mountain Member
    - Cap Mountain Member
    - Hickory Member

Within the Wilberns Formation of the Moore Hollow Group, the Morgan Creek, Lion Mountain and Cap Mountain are predominately massive carbonates and generally produce little ground water. However, the Cap Mountain does produce ground water in the White Oak Creek Road area, the Blumenthal area, and in an area east of Willow City. The Point Peak member is comprised of massive limestone and silty shale and is considered a non water-bearing unit.

Within the Moore Hollow Group, the members which serve as aquifers are the San Saba, Welge and Hickory Members. The San Saba is a limestone and dolomite and produces water only in the Stonewall area in the eastern part of the county. The Welge is a sand and produces moderate to good amounts of ground water east of Cherry Springs, along Usener Road west of Fredericksburg, and in far eastern Gillespie County on Doublehorn Road. Both the San Saba and Welge are considered to be limited local aquifers within Gillespie County.

The Hickory Member of the Riley Formation is mostly a thick sand (200-300 ft) and is capable of producing large amounts of ground water throughout Gillespie County, and hence is considered a major aquifer. The City of Fredericksburg produces water for municipal purposes from three wells in this member. This aquifer will be characterized in detail in the following section.

PRECAMBRIAN

The Precambrian age rocks in Gillespie County consist of granites and metamorphic rocks (schist, gneiss) and are generally void of any ground water. Where the Precambrian produces ground water, the rocks are locally fractured.

WATER BEARING CHARACTERISTICS AND AQUIFER USE

This section rates the main four aquifers within Gillespie County according to their water yield potential and use.

The Ellenburger aquifer is the most productive aquifer within Gillespie County. The City of Fredericksburg gets 80-90% of its water from six wells completed within the Ellenburger. These wells in combination produce in excess of 2 million gallons per day. In high demand periods, these wells yield 4 million gallons per day. In addition to municipal use, the Ellenburger is used considerably for the irrigation of the peach and pecan orchards and vineyards within Gillespie County. Many Ellenburger wells are also used for stock and domestic needs.

The Hickory aquifer is the County's next strongest aquifer. Yields in the excess of 200 gpm are possible in the City's three municipal wells. However, significant drawdown is observed when these wells are pumped on a continuous basis. Presently, the City utilizes these three wells to supplement the Ellenburger wells during high demand periods. The Hickory aquifer provides water for many domestic and livestock wells within the County, but is only sparingly used for irrigation. Only one vineyard in the County, north of Eckert uses the Hickory to irrigate. The reason the Hickory is not used more for irrigation is that where the Hickory occurs, usually the overlying Hensell aquifer is utilized for irrigation and not the deeper Hickory aquifer.

The Hensell aquifer is very widespread across the County and very extensively used for irrigation, domestic and stock needs. It is generally capable of producing moderate (20-30 gpm) amounts of water, but does give better than 100 gpm in some wells. It recharges quickly due to its exposure and high sand content, and hence is an important recharge unit to the underlying Ellenburger and Hickory aquifers.

The Edwards aquifer is a fairly widespread unit where the edge of the Edwards Plateau extends across Gillespie County from the west. The aquifer yields low to moderate (10-20 gpm) amounts of water for stock and domestic needs in the more remote areas of Gillespie County. The town of Harper and several subdivisions in the western part of the County rely heavily on the Edwards aquifer. Although this unit is marginal to moderate as an aquifer it is a very important recharge unit to the underlying Hensell aquifer and the older units beneath the Hensell. Very little surface runoff occurs from the Edwards Plateau, with the bulk of rainfall that falls on the Edwards percolating into its fractured porous limestone-dolomite. The Edwards Plateau carbonates also serve as the source for the headwaters of the many streams and rivers which originate in the Hill Country.

Each of the above four aquifers will be discussed in more detail in the Major Aquifer portion of this study.

RECHARGE

Recharge to the aquifers within Gillespie County occurs from local precipitation and subsequent percolation. The total area of the County includes 675,200 acres upon which 2.7 feet (28 inches) of precipitation falls annually. This equates to 1,823,040 acre feet of rainfall per year. Based on stream flow measurements taken at various stream flow gage stations located around the Hill Country area, the TWDB has estimated the recharge from this precipitation to be from 4 to 6 percent. Based on these estimates, of the 1,823,040 acre feet of rainfall which falls on Gillespie County, recharge to the aquifers would range from 72,922 acre feet/year to 109,382 acre feet/year.

In an attempt to try and refine the amount of recharge available to the aquifers within Gillespie County, the HCUWCD studied in detail the stream flow measurements available from the Pedernales River gage located south of Fredericksburg on Highway 87. This site was established after the flood of 1978 with records available from October 1979 through present.

On Table 4-2, annual rainfall values in inches/year are presented along with an annual acre feet value. The inches per year is from a site located at Fredericksburg. The accompanying acre feet rainfall value is the amount of rainfall in acre feet that would have fallen on the drainage area above the gage on the Pedernales River. This catchment area above the gage is 236,160 acres. Also on Table 4-2 is the annual flow data in acre feet that passed the gage. This flow value is also expressed as a percent of the amount of rainfall that fell on the catchment area above the gage. This percentage represents ground water discharge and runoff from annual rainfall less any recharge loss to evapotranspiration.

These percent of flow to rainfall values range from 0.85 to 17.28 percent with an average of 7.2 percent. Since this value includes runoff, it is too high to be representative of recharge only, plus it does not take into account any water loss to evapotranspiration.

To try and eliminate the effect of runoff and evapotranspiration, the rainfall and hydrograph flow data were reworked using only the months from the winter quarter (January, February, March) when evapotranspiration was at a minimum. This is also a low precipitation time in the Hill Country when heavy rainfall events are generally low. However, the hydrographs were still scalped to remove any high runoff events that did occur during the twelve year record period. This data is presented on Table 4-3 in the same manner as on Table 4-2. The difference between the two is that only rainfall and flow measurement data from January through March are used, and the high flow measurements due to runoff were removed or scalped. By using the data from these months, when evapotranspiration was negligible and removing the effects of runoff, the resulting streamflow gaged data should closely represent rejected recharge. Over the 36 month period representing the three winter months for twelve years, the catchment area above the stream gage received 1,196,150 acre feet of rainfall. The total flow at the gage for this time period was 76,478 acre feet. The flow at the gage after removing the values due to storm runoff was 52,725 acre feet. This latter value represents 4.4 percent of the total amount of rainfall on the catchment area, above the gage and is probably a good percentage value to use across the county for recharge.

The total number of acres within Gillespie County is 675,200 acres and using the 4.4 percent of annual rainfall (1,823,040 acre feet) to represent recharge, a county wide value of 80,214 acre feet per year of effective recharge is available. This equates to 71.6 mgd of recharge to the aquifers.

TABLE 4-2

RAINFALL - SURFACE WATER FLOW - RECHARGE

Year	Rainfall Inches[1]	Acre Feet[2]	Total Discharge and Runoff in Acre-Feet at Fredericksburg Pedernales River[3]	% Flow to Rainfall
1980	25.80	507,744	16,024	3.16 %
1981	40.54	798,221	54,986	6.89 %
1982	25.55	503,021	25,532	5.08 %
1983	28.28	557,338	14,870	2.67 %
1984	22.90	451,066	3,854	0.85 %
1985	34.38	675,418	45,025	6.67 %
1986	38.67	760,435	52,799	6.94 %
1987	46.40	913,939	103,400	11.31 %
1988	29.84	588,038	37,690	6.41 %
1989	21.84	429,811	19,300	4.49 %
1990	28.24	554,976	26,572	4.79 %
1991	26.24	517,190	14,731	2.85 %
1992	52.09	1,024,934	177,149	17.28 %
Avg.	32.37	637,087	45,535	7.20 %

1. Rainfall Amounts taken from a station located in Fredericksburg.
2. Acre feet of rainfall based on 236,160 acres comprising drainage area above measuring point on the Pedernales River Gage Station.
3. USGS Pedernales River Gage Station located on US Highway 87 South

Total of 675,200 acres in Gillespie County X 2.7' Annual Rainfall = 1,823,040 Annual Rainfall in Acre Feet.

Total recharge in Gillespie County :

Percent of Annual Rainfall	Recharge (Acre Feet)
6%	109,281
5%	91,152
4%	72,922

TABLE 4-3

1980-1991 WINTER QUARTER RAINFALL SURFACE WATER FLOW - RECHARGE

1. Rainfall (inches) at Fredericksburg

	Jan	Feb	Mar	36 Month Totals
Min	0.35	0.22	0.14	
Max	4.62	3.17	5.2	
Total	18.53	21.96	20.28	60.77
Avg	1.54	1.83	1.69	

2. Rainfall (Acre Feet) in drainage area above gage on Pedernales at Hwy 87 S. of Frdbrg.

	Jan	Feb	Mar	36 Month Totals
Min	6,888	4,330	2,755	
Max	90,922	62,385	102,336	
Total	364,867	432,172	399,111	1,196,150
Avg	30,406	36,014	33,259	

3. Total Flow (Acre Feet) at Pedernales River Gage South of Fredericksburg

	Jan	Feb	Mar	36 Month Totals
Min	540	478	601	
Max	5,150	6,480	5,360	
Total	23,569	24,248	28,661	76,478
Avg	1,964	2,021	2,388	

4. Total Flow (Acre Feet) at Pedernales River Gage South of Fredericksburg with Scalping (removal of heavy rainfall runoff events)

	Jan	Feb	Mar	36 Month Totals
Min	540	478	601	
Max	2,125	2,499	2,724	
Total	15,836	16,743	20,146	52,725
Avg	1,320	1,395	1,679	

5. % Recharge (% Flow at gauge station in relation to rainfall in catchment area)

	Jan	Feb	Mar	36 Month Totals
Min	1.70 %	1.6 %	3.1 %	
Max	30.0 %	17.5 %	43.2 %	
Avg	10.6 %	2.1 %	10.9 %	6.4 %

6. % Recharge with Scalping

	Jan	Feb	Mar	36 Month Totals
Min	1.7 %	1.6 %	2.0 %	
Max	30.9 %	17.5 %	43.2 %	
Avg	8.0 %	5.6 %	9.4 %	4.4 %

EDWARDS AQUIFER

Distribution

Within Gillespie County an arm of the Edwards Plateau extends into the County from the west to the east. Of the 675,200 acres comprising Gillespie County, Edwards Limestone covers 380,800 acres. Figure 4-2 illustrates the extent of the Edwards Limestone present in Gillespie County. This figure also shows the locations of Edwards wells inventoried by the HCUWCD. The elevation of the unit ranges from a high of approximately 2200 feet (Figure 4-3) to a low of approximately 1900 feet (Figure 4-4). Thickness of the Edwards ranges from 0 feet along the Plateau edges to more than 300 feet in extreme western Gillespie County (Figure 4-5). The thickness of the west to east arm of the Plateau reaches a maximum of greater than 200 feet along the middle portion of the trend (Figure 4-5). Springs are present near the base of the Edwards along both the northern and southern sides of this extension of the Plateau. These springs form the headwaters for the many streams within the County, as well as the Pedernales River whose headwaters are located to the southeast of Harper. Much of the rainfall that falls on the Edwards limestone goes to springflow.

FIGURE 4-2
EDWARDS AQUIFER WELLS
GILLESPIE COUNTY

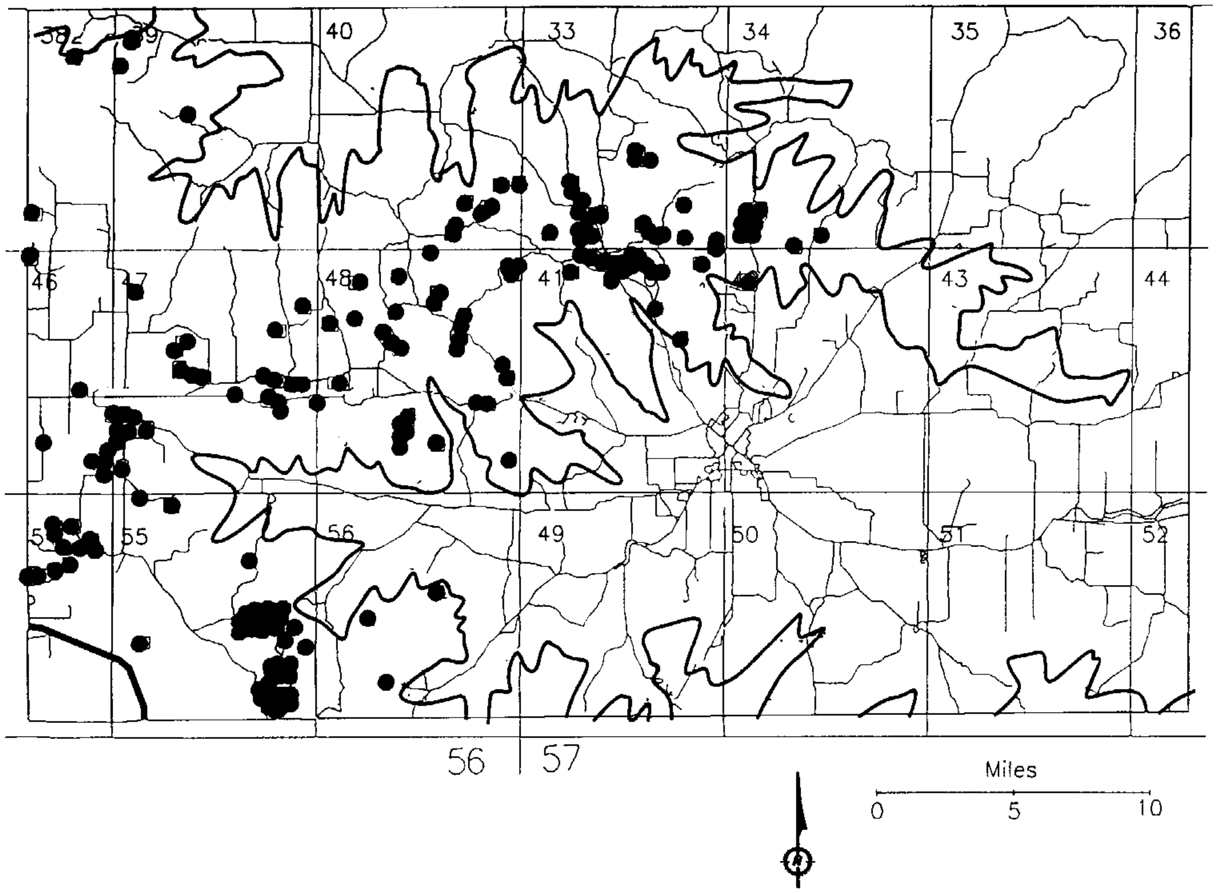


Figure 4-2
Page 4-12

FIGURE 4–3
TOP ELEVATIONS OF EDWARDS FORMATION IN GILLESPIE COUNTY
(FEET ABOVE SEA LEVEL)

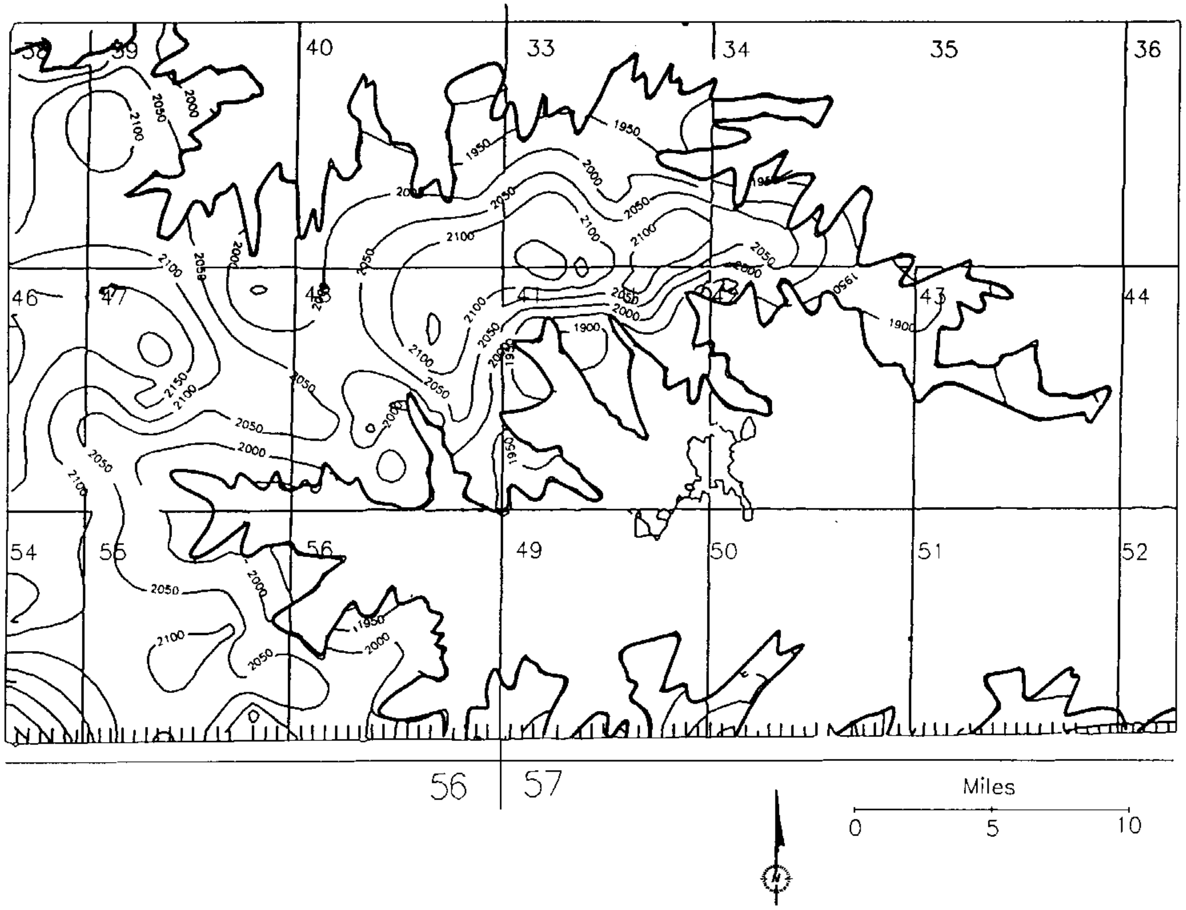


FIGURE 4-4
BASE ELEVATIONS OF EDWARDS FORMATION IN GILLESPIE COUNTY
(FEET ABOVE SEA LEVEL)

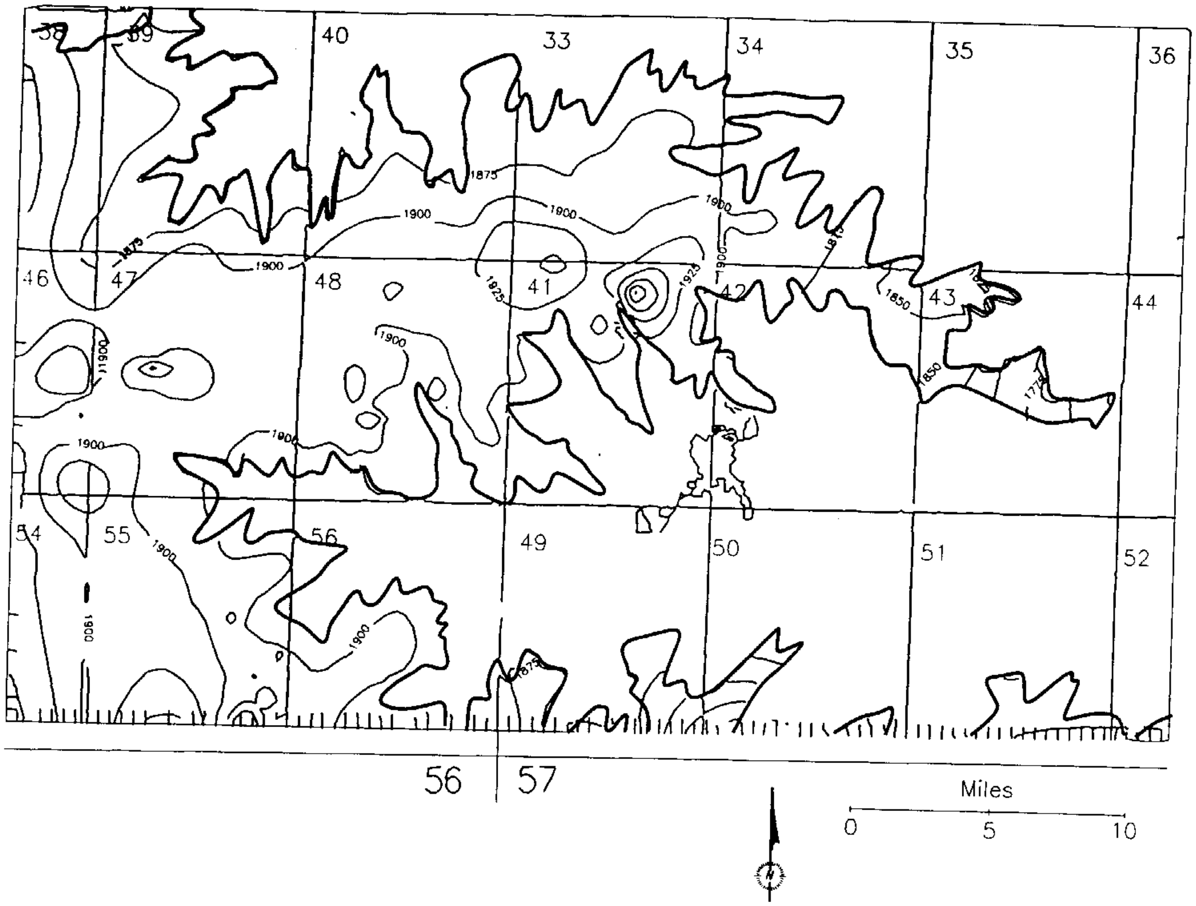
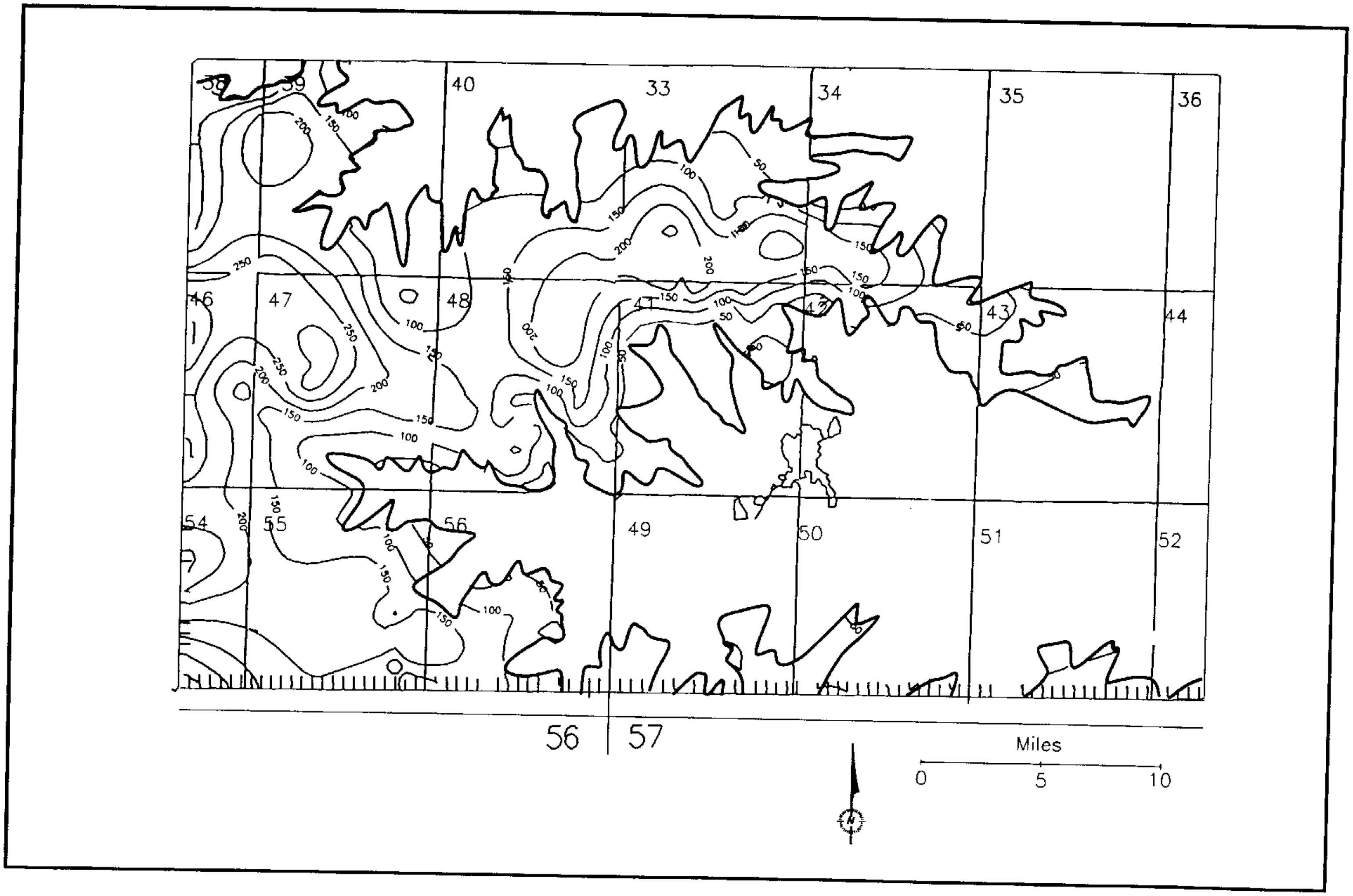


FIGURE 4–5
THICKNESS OF EDWARDS FORMATION (FT)
GILLESPIE COUNTY



Flow Directions and Water Levels

The Edwards aquifer is under unconfined conditions. Rainfall percolates through secondary porosity caused by solution weathering and fracturing of the carbonates, which in carbonates can have a wide range of values. Porosity within the Edwards varies from 3 percent to 26 percent. Based on the 28 inches average annual rainfall value and 4.4 percent available for recharge, the Edwards Aquifer receives approximately 45,000 acre feet of annual recharge.

The HCUWCD measures water levels twice a year from 71 wells across Gillespie County. Of these 71 wells, twelve are Edwards aquifer wells. Figure 4-6 is a contour map of the water levels (in feet above sea level) measured during the Spring of 1993. These levels closely correspond to the topography of the surface, which is common for unconfined aquifers. The levels also indicate that a ground water divide occurs along the center of the west-east Edwards Plateau extension across Gillespie County. In addition there is a ground water mound or high along the center of this west-east extension. A fairly steep hydraulic gradient extends away in all directions from the center part of the mound towards the headwater springs located along the edge of the Plateau. As a result ground-water movement is toward the north on the northern part of the extension and south along the southern part of the extension. From the main part of the Plateau in extreme western Gillespie County, the flow direction is generally to the east towards the Pedernales River Valley. The water levels from these twelve wells range from a low of 1961 feet (R-00134) to a high of 2054 feet (R-00313) which converts to a hydraulic gradient of 26 feet/mile between these two wells (Table 4-4). Steeper hydraulic gradients (31 feet/mile) exist between the center of the ground-water mound (R-00313) and the edge of the Edwards Plateau (R-00036) where spring flow occurs (Figure 4-6).

TABLE 4-4
EDWARDS WATER LEVELS (1990-1993)

#	Grid	Top Elev	Base Elev	WATER ELEVATION Low	High	Avg	Saturated Thickness	Unit Thickness	% Saturated
R-00047	KK-56397	2121	1871	1993	2006	2001	130	250	52 %
ER-00127	KK-56409	2099	1919	2007	2025	2016	97	180	53 %
ER-00392	KK-56474	2035	1885	1999	2002	2001	116	150	77 %
ER-00262	KK-56475	2140	1920e	1991	2011	2000	80e *	220	36 %
R-00146	KK-56476	2060	1900e	2003	2006	2005	105e	160	65 %
ER-00560	KK-56483	2199	1910e	2021	2045	2029	119e	289	41 %
R-00030	KK-56485	2084	1905e	1987	2001	1992	87e	179	48 %
R-00171	KK-56488	2030	1899	1972	1981	1978	79	131	60 %
R-00088	KK-56556	2080	1905	1982	1996	1992	88	175	50 %
R-00036	KK-57339	2061	1898	1971	1980	1976	78	163	47 %
R-00313	KK-57338	2195	1925e	2042	2054	2045	120e	270	44 %
R-00134	KK-57347	2085	1895e	1961	1967	1963	68e *	190	36 %
						Avg	97	196	49

Note: **e - Estimated**
*** - Possible Dewatering Due to Pumpage**
Elevations are in feet above sea level

The saturated thicknesses for the measured Edwards aquifer wells range from an estimated 68 feet to a maximum of 147 feet (Table 4-4). The wells with thin saturated thicknesses are generally towards the edge of the plateau; however, heavy pumpage from some of these wells may also be responsible for the lower thicknesses. The wells with high saturated thicknesses are located along the identified ground-water mound or towards the extreme western edge of the County where the Edwards Plateau thickens. The percent saturated thickness to total formation thickness generally ranges from 40 percent to 50 percent (Table 4-4).

Aquifer Characteristics

Within Gillespie County, the Edwards aquifer is used for domestic and livestock use. Well yields are usually low with the average being 13 gpm. Figure 4-7 is a contour map of yields from the Edwards. The majority of the area covered by Edwards limestone yields less than 15 gpm. However, there are areas on Figure 4-7 where yields are in excess of 30 gpm. These higher yielding areas are generally aligned up gradient of the strong springs that form the headwaters of the perennial streams which include Spring Creek, Live Oak Creek, Barons Creek, Palo Alto Creek, Crabapple Creek, and Threadgill Creek. Above the headwaters of the Pedernales River there is an elongated area trending from the southeast to northwest where many wells yield greater than 30 gpm. Apparently ground water flow within the Edwards is becoming concentrated in these areas above the springs. These areas within the Edwards limestone could be developed more extensively than the adjoining lower yielding areas. However that could affect flow to the down gradient spring discharge areas.

The Edwards aquifer like most carbonate aquifers, exhibit variable hydrological characteristics. The following list the representative hydraulic characteristics of this aquifer.

EDWARDS AQUIFER

Hydraulic Characteristics in Texas Hill Country

Specific Capacity	0.4 gpm/ft
Hydraulic Gradient	26-31 feet/mile; 29 feet/mile
Hydraulic Conductivity	4-877 gpd/ft^2
Transmissivity	1,900-386,000 gpd/ft
Storage Coefficient	0.0004-0.020
Porosity	3-26 percent
Annual Recharge	45,000 acre-feet

Water Quality

The water quality of the Edwards aquifer is characterized as very good but very hard due to the relative abundance of calcium, magnesium and bicarbonate. The other major cations and anions are usually very low and well under the maximum contaminant levels as promulgated by the Environmental Protection Agency.

The HCUWCD has been performing water testing of gross chemical constituents since 1990. One of the parameters tested for in this analysis is nitrates. Figure 4-8 is a map of nitrate concentrations of Edwards aquifer wells tested by the District. As the map shows, with the exception of one well south of Harper, all wells analyzed have nitrate values below the maximum contaminant level of 10 mg/l (NO_3 as N). The bulk of the wells are below 3 mg/l with a few areas having nitrate concentrations in excess of 6 mg/l. One of these is the Harper area where a number of old wells are in close proximity to septic systems. Consequently the background nitrate levels are somewhat elevated there. The wells that have elevated nitrate levels are generally the older wells which have little if any cement around the outside of the casing near the surface. Consequently near surface nitrate contamination can enter the well. In addition the Edwards limestone has solution cavities and fractures near the surface, which can easily allow pollution to enter the unit. Presently the HCUWCD requires that all wells drilled be sealed with cement from the surface down to a depth of 50 feet below the land surface. This will minimize the potential for new wells to become contaminated; however, the older Edwards wells in the County still pose a potential problem.

The nitrate data presented on figure 4-8 includes only the results obtained by the HCUWCD using its HACH equipment. In Texas Department of Water Resources Report 235, nitrate data obtained from Edwards aquifer wells in Gillespie County are presented. In that study, 89 wells from the Edwards aquifer were analyzed with 7 wells (6.7 percent) having nitrate values greater than 44.3 mg/l nitrate as nitrate. The Texas Department of Health (TDH) performed these analyses in the 1960's and early 1970's. The difference between the two data sets may be due to the age of the wells with the older wells analyzed by the TDH being poorly sealed and acting as conduits for contamination to enter the aquifer.

FIGURE 4–7
EDWARDS AQUIFER YIELD (GPM)
GILLESPIE COUNTY

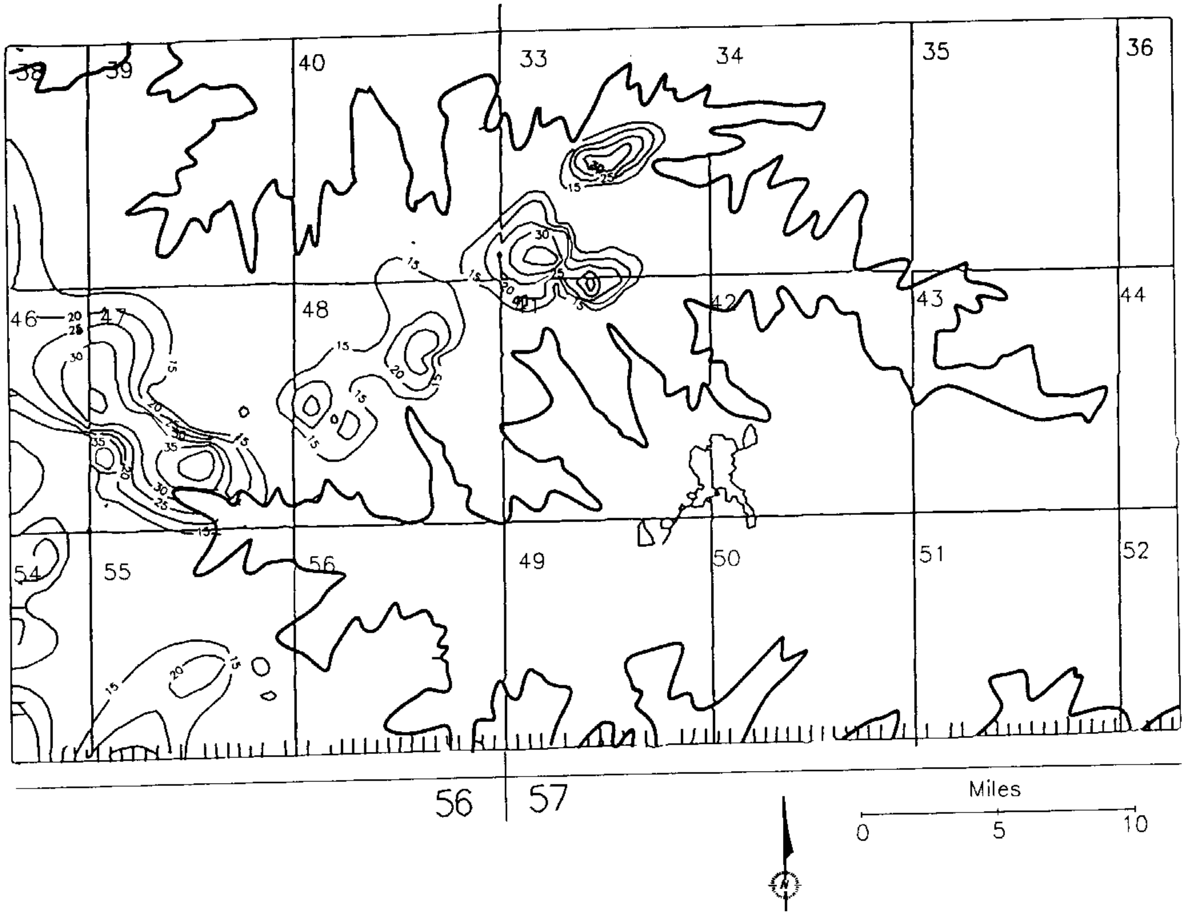
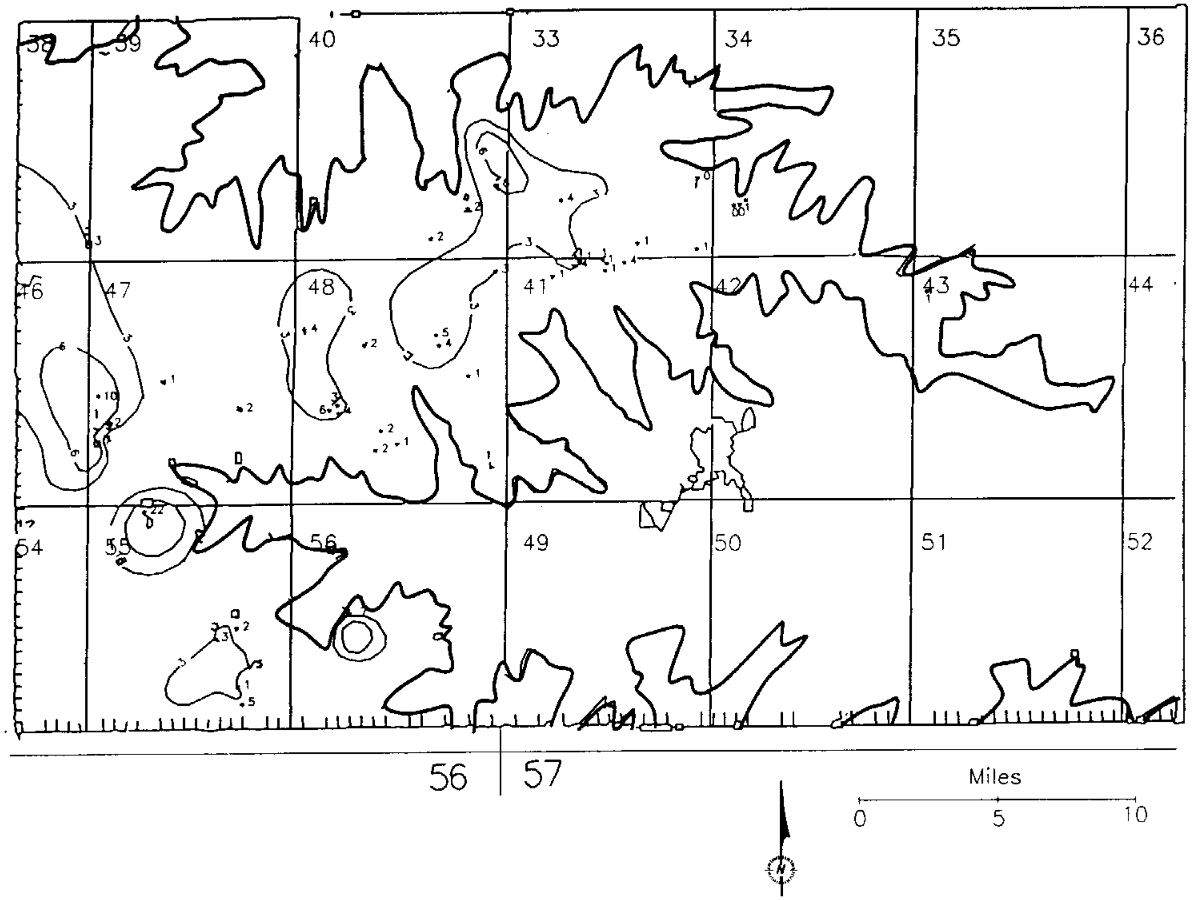


FIGURE 4-8
EDWARDS AQUIFER NITRATE LEVELS (MG/L)
GILLESPIE COUNTY



Using the 11 percent as a percentage to represent the amount contributed by the Edwards, future projection can be made for this aquifer.

Future Water projections for the Edwards Aquifer - Gillespie Co.

1990	2000	2010
794 ac.ft.	935 ac.ft.	1025 ac.ft.

If these projections are accurate, then it needs to be determined if the Edwards aquifer has sufficient water to meet these future demands and remain under its safe yield limit. The TWDB in Report 339 estimated annual sustained yields for the various aquifers within the counties included in Critical Area II. For Gillespie County, the estimated sustained yield for the Edwards aquifer was put at 1400 acre feet per year. The TWDB used hydrographs of historical water levels from observation wells in and near centers of pumpage and the historical records of annual pumpage to determine annual sustained yield for an approximate specific area.

Safe yield can also be estimated by calculating flow through an area by using the following Darcy equation:

SAFE YIELD DETERMINATION

Q = TiW	For Gillespie Co.
Q = flow volume (ft^3/day)	?
T = transmissivity (ft^3/day/ft)	254
i = hydraulic gradient (ft/ft)	0.0055
W = width (ft)	132,000

Sustained yield for the Edwards Aquifer in Gillespie Co.

Q = 254 ft^3/day X 0.0055 ft/ft X 132,000 ft
Q = 184,404 ft^3/day
Q = 1,379,342 gal/day
Q = 4.2 acre ft/day
Q = 1544 acre ft/year

The above computed value of 1544 acre ft/year is based on water flowing into Gillespie County at the County line from the west where the width of the County is approximately 25 miles. This is a very approximate value but does correlate reasonably well with the sustained yield assigned to the Edwards aquifer (1400 acre feet/year) in Gillespie County by the TWDB.

If we assume the 1500 acre feet/year is available from the Edwards, we can estimate how many years into the future the Edwards will meet projected demand. Utilizing the 11% of total water demand as presented in Report 339 to represent the amount contributed by the Edwards aquifer the following projections can be made.

TWDB REPORT 339

Year	County Wide Use (Acre Feet)	Edwards Water Use (Acre Feet)
1985	5124	557
1990	7222	794
2000	8509	935
2010	9316	1025

In this study projected County wide demand is made through to the year 2030. In 2030 demand is projected to be 10,076 ac.ft./year without conservation and 9192 acre feet/yr. with conservation. Eleven percent of the high demand (10,076 ac.ft.) is 1108 acre feet Consequently the Edwards aquifer within Gillespie County should be able to meet the projected demand of 1,108 acre feet in the year 2030 provided it is still contributing 11 percent of the total projected county wide demand of 10,076 acre feet. This would assume that future water usage from the Edwards aquifer would continue to be for rural domestic and stock purposes. If the percentage of Edwards aquifer water to the total County wide projected demand of 10,076 acre feet increases to 15 percent, then the 1500 acre feet per year sustainable yield will be reached in 2030. It should be noted that these estimates are based on years where average rainfalls occurred and possible drought conditions have not been taken into account.

HENSELL AQUIFER

Distribution

With the exception of the Llano Uplift area of the northeastern portion of the County and a few areas north of Doss and around the Stonewall area, the Hensell Member is present over the majority of Gillespie County (607,360 acres). It is present at the surface in the stream and river valleys where erosion has removed the overlying Glen Rose and Edwards units. Towards the western part of Gillespie County on the Edwards Plateau, the Hensell underlies the Edwards and Glen Rose. Figure 4-9 shows all wells within the County that have encountered Hensell. There is a heavy concentration of wells around the City of Fredericksburg. Here the Hensell is at the surface and illustrates the heavy development around the city, which is projected to continue.

The top of the Hensell is over 1900 feet above sea level in an area to the northwest of Fredericksburg. This is an area where Paleozoic rocks (Cap Mountain) are also at a topographic high (Figure 4-10). The top of the Hensell is at its lowest elevation in extreme southeast Gillespie County where it is less than 1400 feet above sea level. This is due to the fact that erosion has removed much of the unit. In both of these areas the base of the Hensell is also at its highest and lowest elevations. The base ranges from 1900 feet northwest of Fredericksburg to less than 1300 feet in southeast Gillespie County. (Figure 4-11).

The map of the base of the Hensell Member is also the top of the subcrop of the older units beneath the Hensell. This surface represents the surface which was exposed for several hundred million years after the Ouachita Uplift and prior to the Lower Cretaceous seas transgressing the area. Figure 4-11 shows the presence of the northerly trending high ridge comprised of Cap Mountain limestone and Hickory sand through the center of the County. Also on Figure 4-11 the map shows the presence of several valleys, in the southeastern portion of the County that drain to the south. These represent surface drainage over Paleozoic rocks prior to the Cretaceous sea transgression.

This drainage had an impact on the Paleozoic carbonate rocks which promoted cavity development in these valleys. Today, this has influenced the water producing capability of units such as the underlying Ellenburger rocks. This will be discussed in detail later in this report.

Figure 4-12 is a contour map of Hensell thickness. The unit varies from less than 50 feet in many portions of the County to more than 200 feet in the western part of Gillespie County. Average thickness usually ranges from 150 feet to 200 feet.

FIGURE 4-9
HENSELL AQUIFER WELLS
GILLESPIE COUNTY

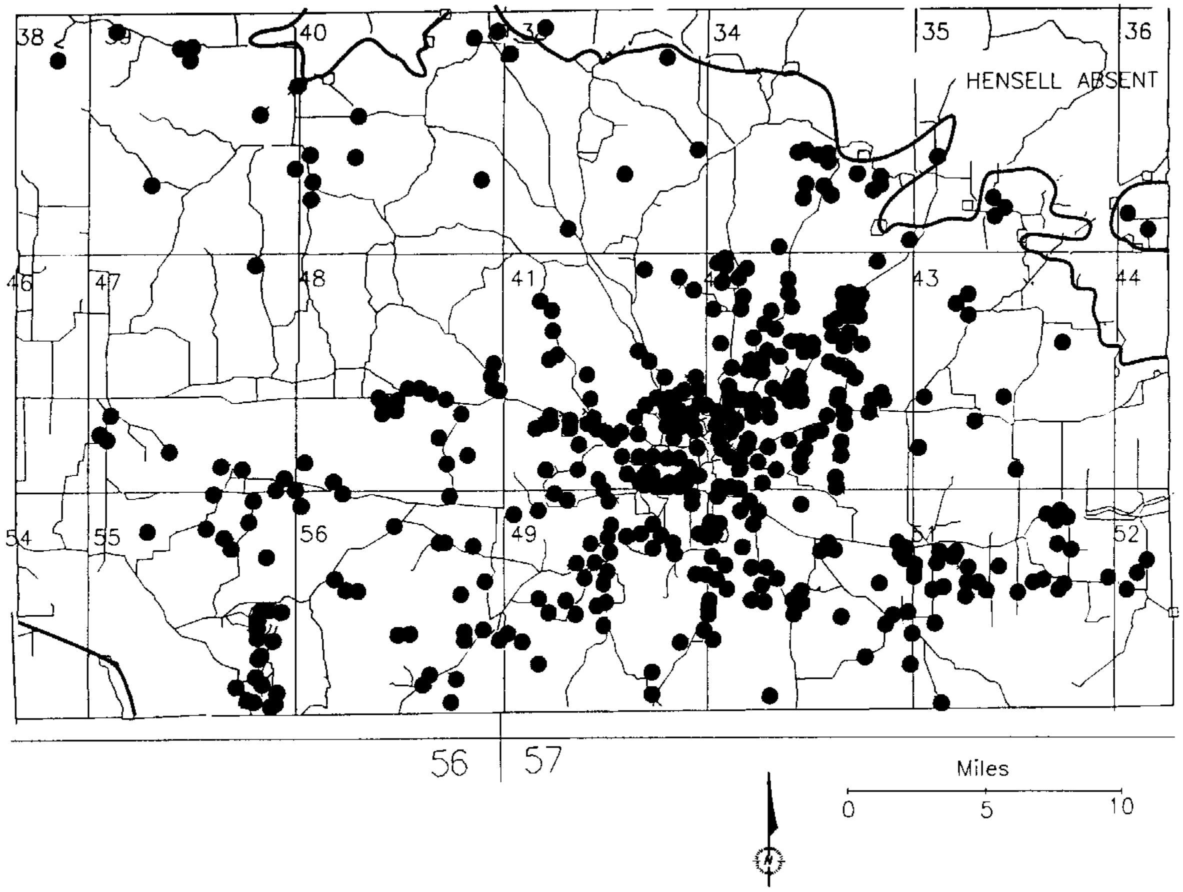


FIGURE 4-10
TOP ELEVATION OF HENSELL MEMBER IN GILLESPIE COUNTY
(FEET ABOVE SEA LEVEL)

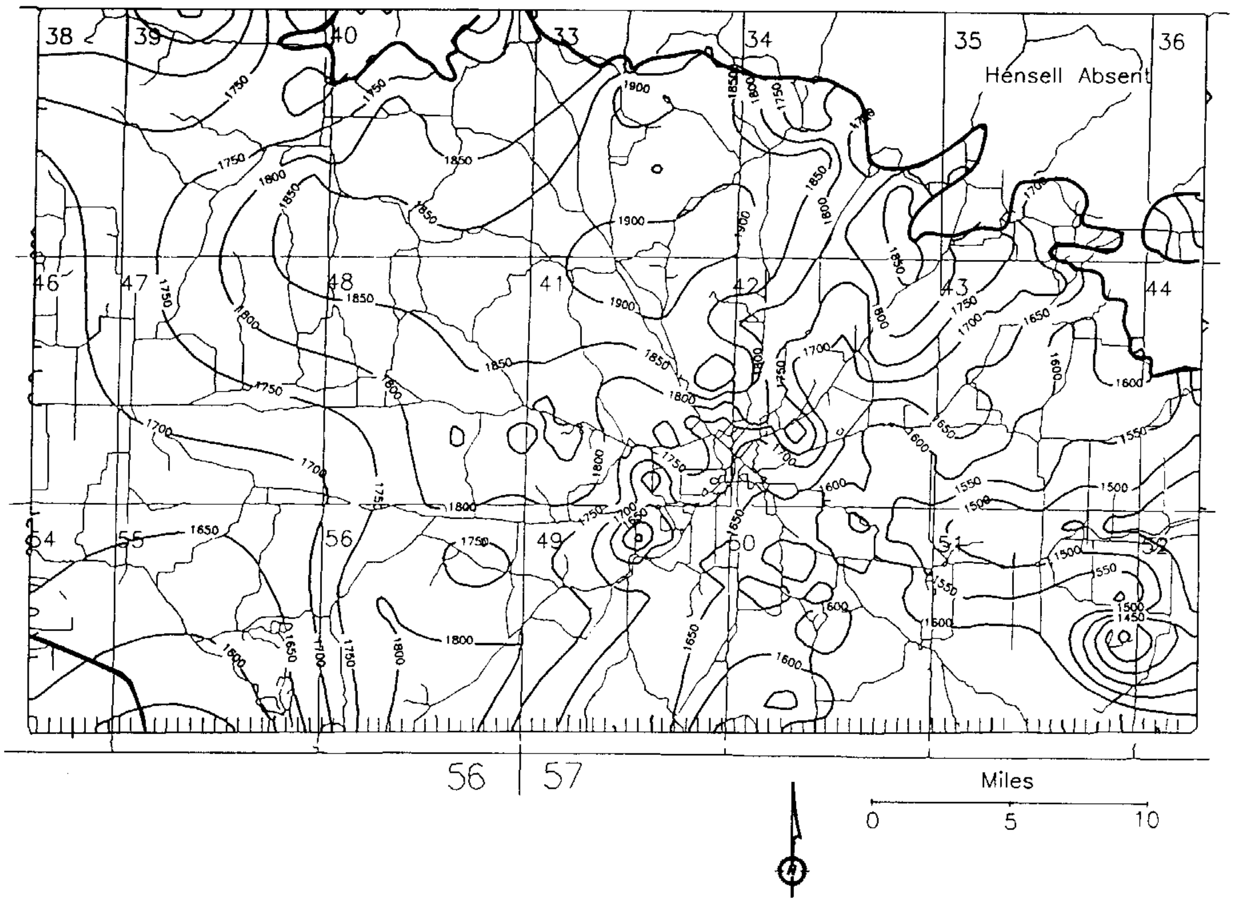


FIGURE 4-11
BASE ELEVATION OF HENSELL MEMBER IN GILLESPIE COUNTY
(FEET ABOVE SEA LEVEL)

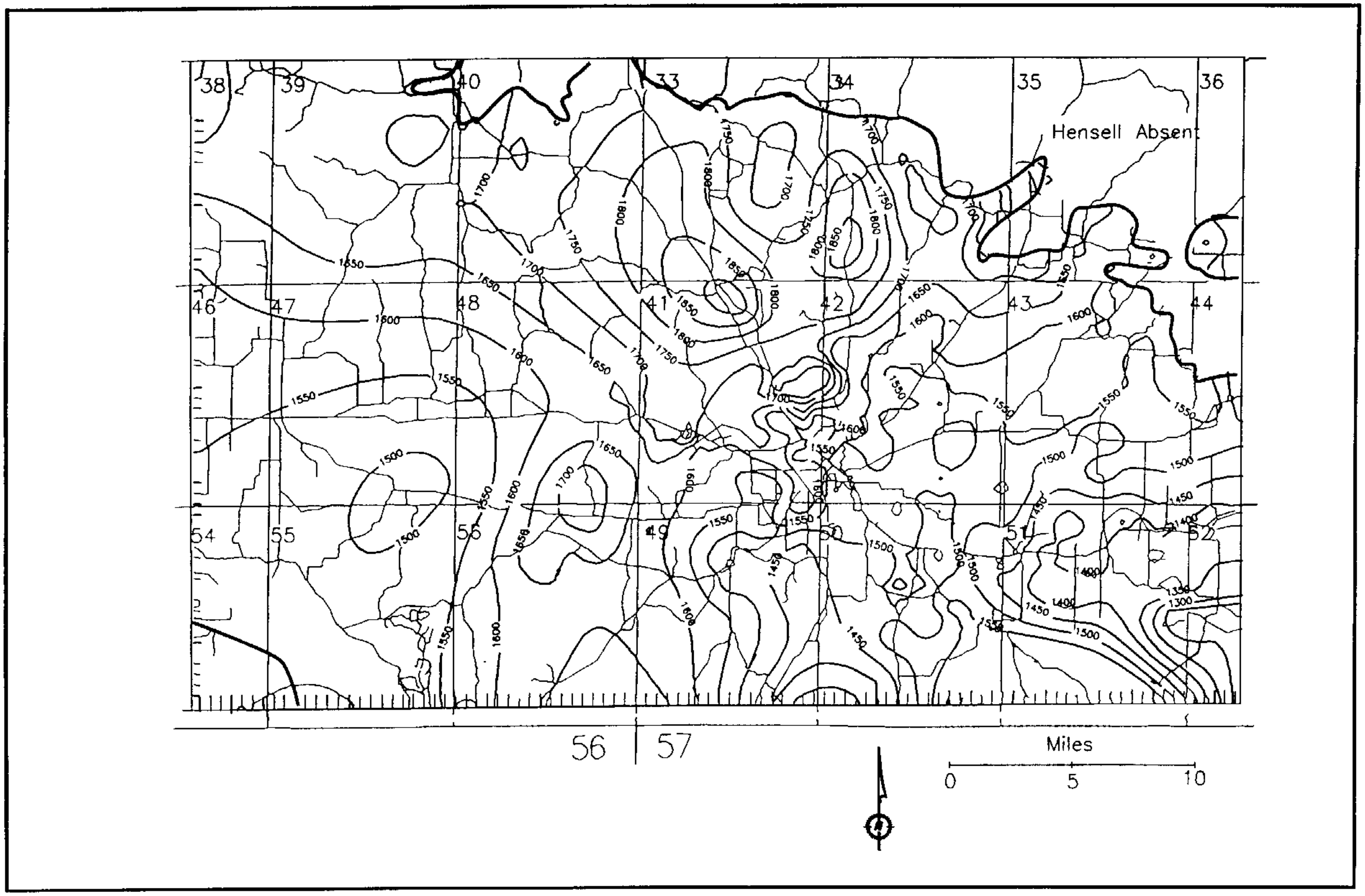
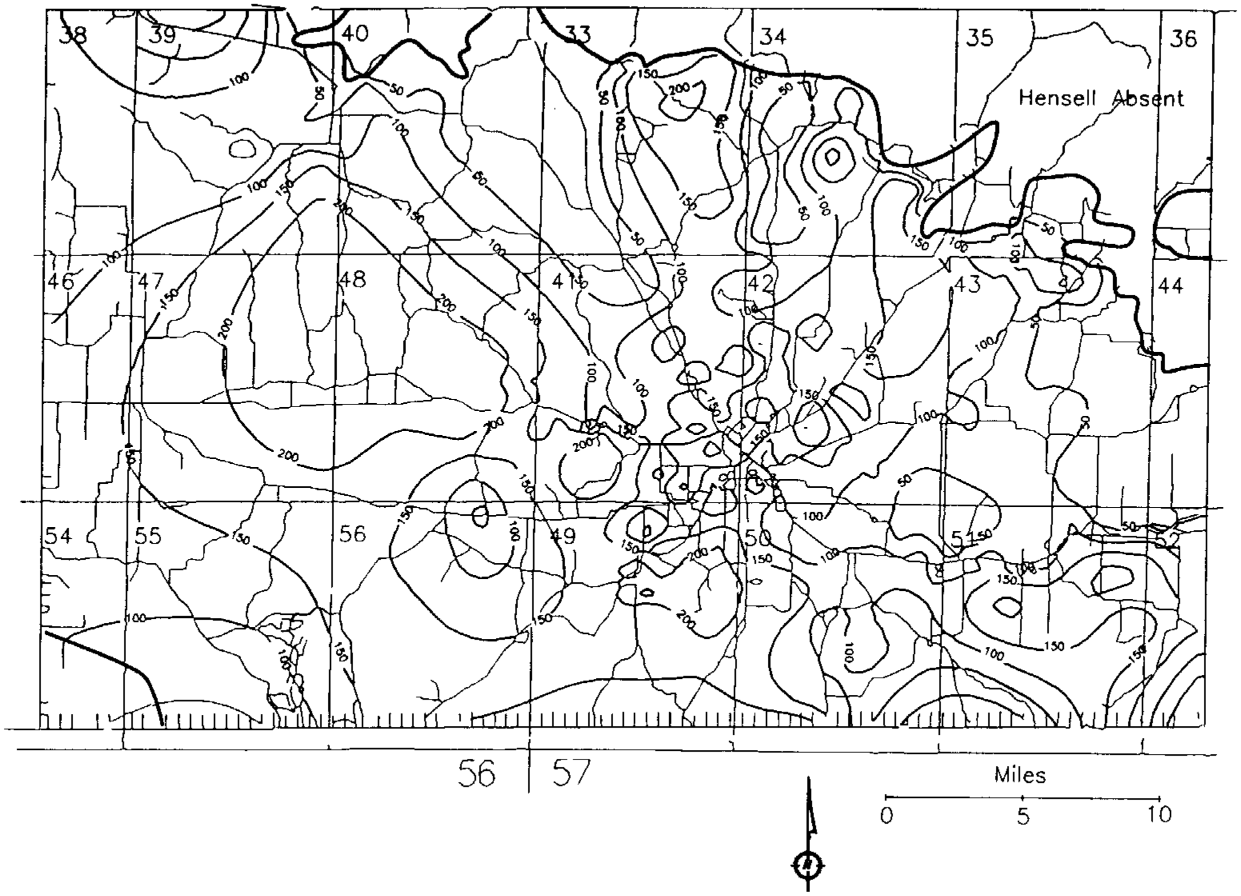


FIGURE 4-12
HENSELL MEMBER THICKNESS (FT)
GILLESPIE COUNTY



Water saturation thicknesses range from 35 feet to an estimated 182 feet with an average saturated thickness of 119 feet. This equates to approximately 64 percent saturated thickness of total aquifer thickness. Many of the saturated and total unit thicknesses given on Table 4-5 are estimated since the majority of the monitor wells do not completely penetrate the Hensell. However three of the wells do completely penetrate the unit with the following thicknesses:

#	Sat. thickness	Unit Thickness	% Sat
R-00059	35'	108'	32%
ER-02746	108'	131'	82%
R-00238	176'	263'	67%

Since the above thicknesses are close to the values estimated for the remaining monitor wells, it appears that the estimated values on Table 4-5 are valid.

An interesting observation is that the hydraulic gradients within the Edwards aquifer are higher than in the Hensell. This may reflect the large amount of water that leaves the Edwards through springflow.

FIGURE 4-13
HENSELL AQUIFER WATER LEVELS (APRIL 1993)
GILLESPIE COUNTY

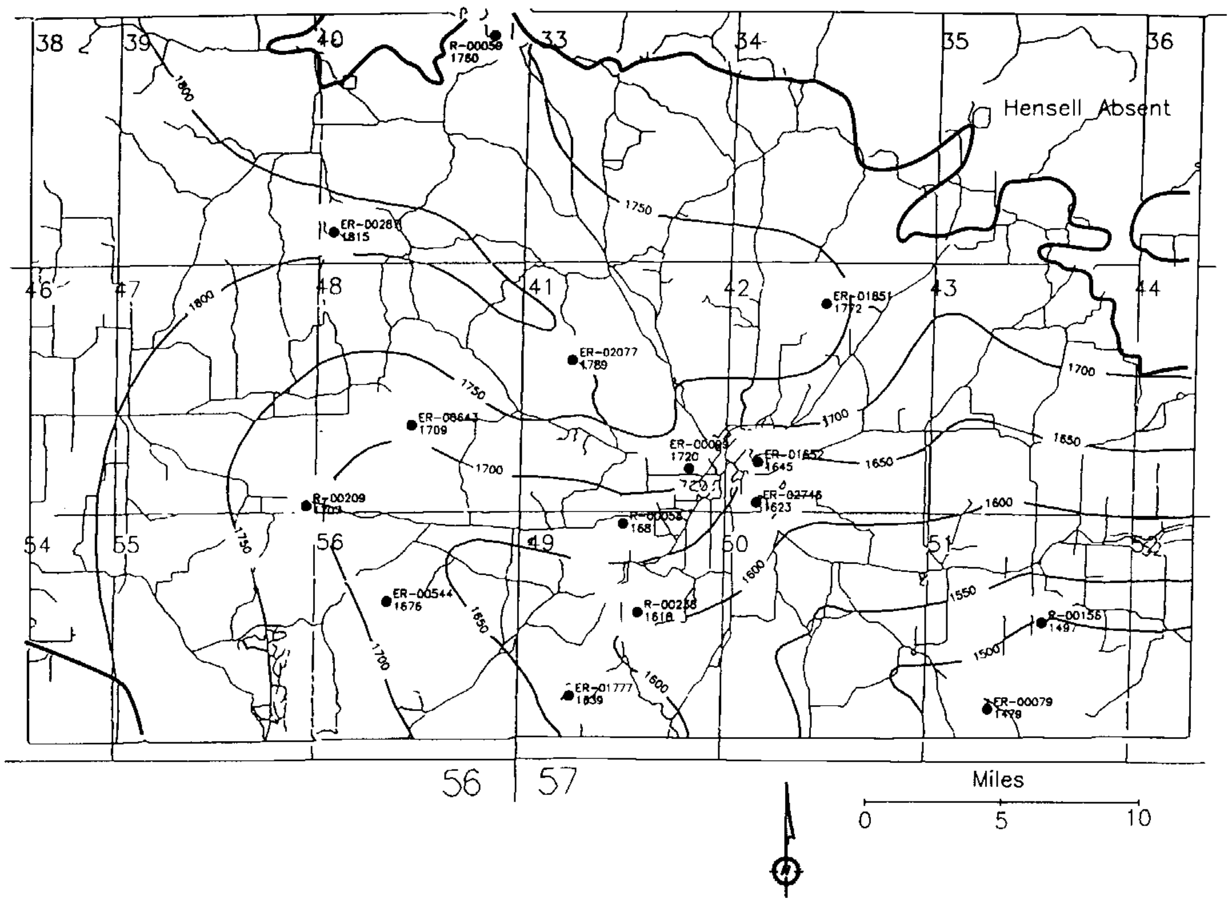


Figure 4-13
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FIGURE 4–14
HENSELL AQUIFER YIELD (GPM)
GILLESPIE COUNTY

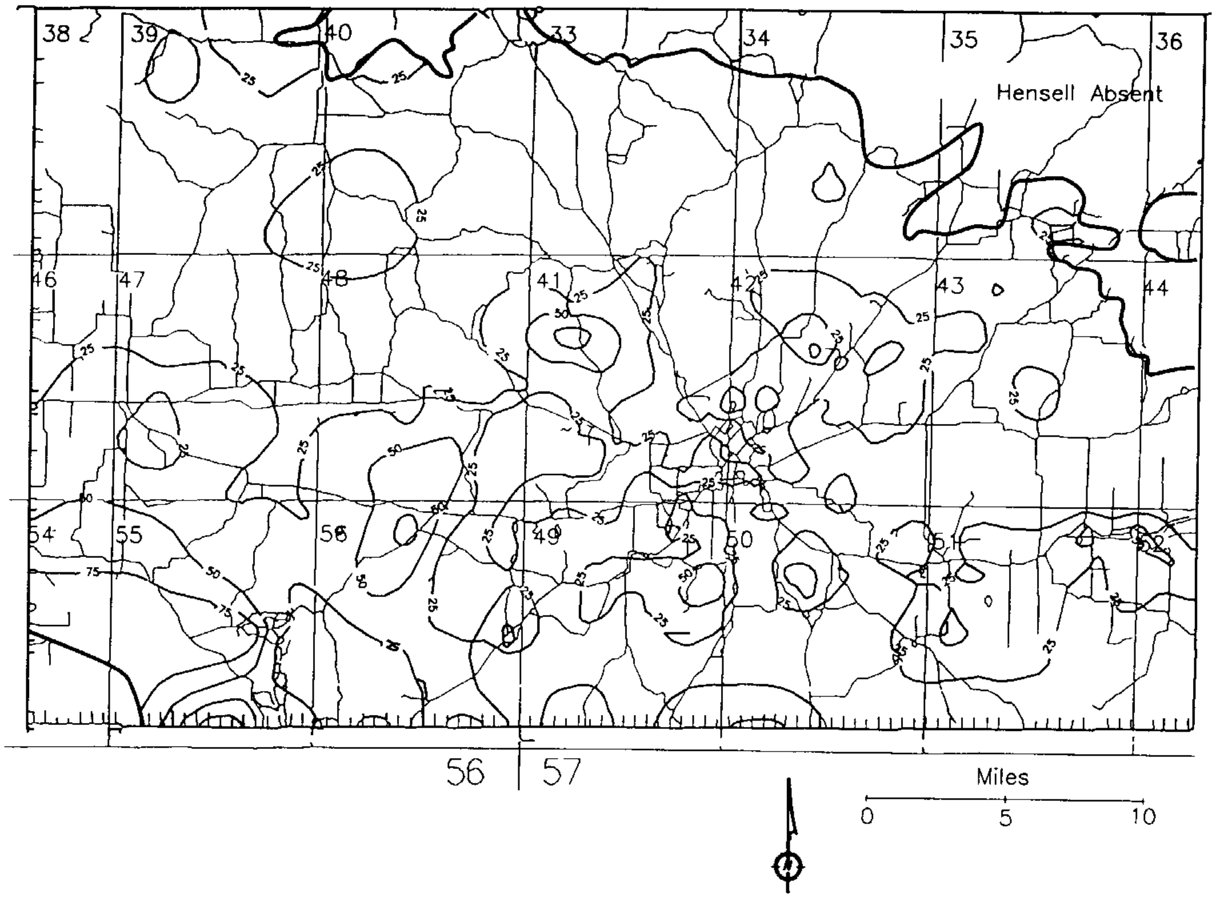

Figure 4–14
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Water Quality

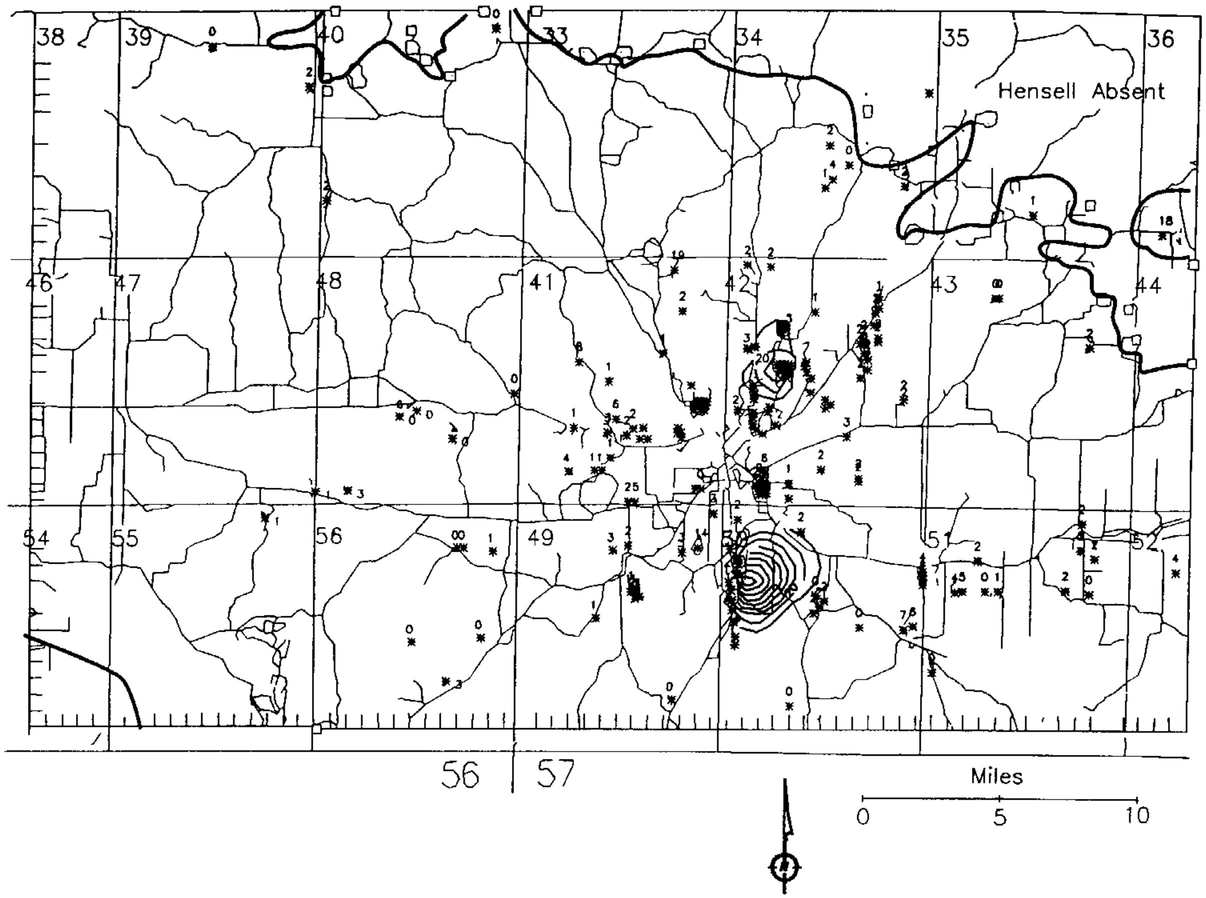
The water quality of the Hensell is very similar to that of the Edwards aquifer. It is generally very hard enriched in Ca, Mg and bicarbonate. It is usually low in chlorides, sulfates, nitrates, iron and fluoride. However, within Gillespie County there are some areas where the Hensell is high in nitrates, chlorides, sulfates and calcium/magnesium. In the areas where these constituents are high it is usually due to surface or near surface contaminants entering old deteriorated wells or wells with gravel pack extending up near the surface.

Figure 4-15 is a contour map of nitrate concentrations within the Hensell. The bulk of the wells analyzed have nitrate concentrations well below the upper level of 10 mg/l (NO_3 as N). In those areas where nitrates are in excess of 10 mg/l it is usually due to one well that is poorly constructed. An exception is the area north of Fredericksburg where 6 wells are high in nitrates. The wells are gravel packed up close to the surface and the area once was used to raise turkeys. In addition, livestock is currently being raised in the area. Those features in combination probably have caused the nitrate problem in this area.

In the areas where high chlorides, calcium and sulfates are present, it is usually due to the location of wells near surface bodies of water like stock tanks. The dissolved solids in the tanks become concentrated due to evaporation. If wells that are gravel packed near the surface are located near the tank, then the chloride enriched water will move down the outside of the casing through the gravel pack, contaminating the aquifer. The HCUWCD has adopted rules that require a minimum of 50 feet of cement from the surface around the annular space which will help minimize surface and near surface contaminants from entering the wells. In addition, many of the older wells have been reworked and resealed to prevent them from acting as conduits for this type of pollution.

The Hensell is the most susceptible aquifer within the County to contamination. It is often exposed at the surface in the more highly developed areas of the County where an abundance of septic systems and underground storage tanks are in place. The soils that have developed in this unit are also highly conducive to agriculture and livestock production, consequently fertilizers, pesticides and herbicides are regularly applied. All of these factors taken together make this aquifer susceptible to contamination. As a result the HCUWCD has and will continue to closely monitor water quality in the Hensell aquifer.

FIGURE 4-15
HENSELL AQUIFER NITRATE LEVELS (MG/L)
GILLESPIE COUNTY



Hill Country Underground Water Conservation District
Regional Water Plan
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The TWDB in Report 339 estimated annual sustained yield for the Trinity Group aquifer in Gillespie County (Hensell Member) to be 3400 acre feet per year. This was based mainly on the use of hydrographs of historical water levels from observation wells in and near center of pumpage (City of Kerrville) and applying this data for the whole Hill Country region. Another method of determining sustained yield is provided through the following calculation based on Darcy's Law:

Hensell Sand in Gillespie County

Q= Tiw; where:	
Q = flow volume (ft^3/day)	?
T = Transmissivity (ft^3/day/ft)	414
i = Hydraulic gradient (ft/ft)	0.0055
w = Width (ft) (Width across N-S of Gillespie County)	132,000

Sustained yield for the Hensell Aquifer in Gillespie County based on the above calculation is as follows:

Q = 414 X 0.0055 X 132,000
Q = 300,564 ft^3/day
Q = 2,248,214 gal/day
Q = 6.90 acre ft/day
Q = 2517 acre ft/year

The above calculation, taking the higher hydraulic conductivity and transmissivity value obtained from the Middle Trinity pump tests in Kerrville, is considerably less than the TWDB's estimate of 3,400 acre ft/yr. However, it should be pointed out that the above calculation is only a very rough estimate of sustained yields and is based on very broad and general assumptions for a very large regional area. As a result, the TWDB's estimate of 3400 acre feet per year is taken to be representative of the Hensell aquifer sustainable yield in Gillespie County.

In 1985, the demand from the Hensell aquifer within Gillespie County was estimated to be 1415 acre feet (TWDB Report 339). This accounted for 28 percent of the total amount of 5124 acre feet produced county wide in that year. In this report, projected county wide water demands for the year 2030 have been placed at 9,192 and 10,076 acre feet for with and without conservation. If the Hensell aquifer continues to provide 28 percent of the County total water demand, then the Hensell will need to be able to provide 2821 acre feet in the year 2030. This is only 580 acre feet less than the estimated annual sustained yield of 3400 acre feet/year.

It is conceivable that the 28 percent currently provided by the Hensell could increase since the areas adjacent to the City of Fredericksburg are projected to see the bulk of future development and growth. In the areas adjacent to the City, the Hensell is generally the dominant aquifer. Consequently, due to projected growth and demand placed on the Hensell and its susceptibility to contamination, the HCUWCD estimates that this aquifer will be in critical status within the next 20 years or even sooner if drought conditions such as those experienced in the 1950's reoccur. By the year 2030 or sooner, areas adjacent to the City, presently relying on water from the Hensell may need additional and alternate water supplies.

Distribution

The distribution of wells producing from the Ellenburger aquifer is presented on Figure 4-16. The unit is absent through the central part of the County and north of Stonewall and east of the Cave Creek area. The absence of the Ellenburger in these areas is due to the faulting that occurred after the Ouachita Orogeny when subsequent erosion removed the Ellenburger and many older rock units. A 150 million year period of erosion occurred between this tectonic event and the transgression of the Lower Cretaceous seas that deposited the Hensell over the area.

The Ellenburger is an aquifer in much of the southeastern portion of the County (Figure 4-16). It is also an aquifer around the Doss area in northwestern Gillespie County. In western and southwestern Gillespie County, the Ellenburger is present but it is deeply buried with little well control. Wells that have completely penetrated the Ellenburger are very few within the County. One oil test well drilled prior to 1950, located near the corner of Highway 290W and Doss Spring Creek Road in western Gillespie County encountered 1342 feet of Ellenburger from 504 feet to 1846 feet. Another well, recently drilled by the TWDB on City of Fredericksburg property where the city produces from the Ellenburger, encountered 754 feet of Ellenburger sediments from 126 feet to 880 feet, as determined from well cuttings by HCUWCD. As a result of the very thick nature of the Ellenburger, little to no data is available concerning its thickness and bottom elevation.

The elevation of the top of the Ellenburger is contoured on Figure 4-17, and varies from a high of 1800 feet in an area to the east of Doss in northwest Gillespie County, to a low of less than 1300 feet above sea level in extreme south eastern Gillespie County. The regional dip of the unit is to the south-southeast.

FIGURE 4-16
ELLENBURGER AQUIFER WELLS
GILLESPIE COUNTY

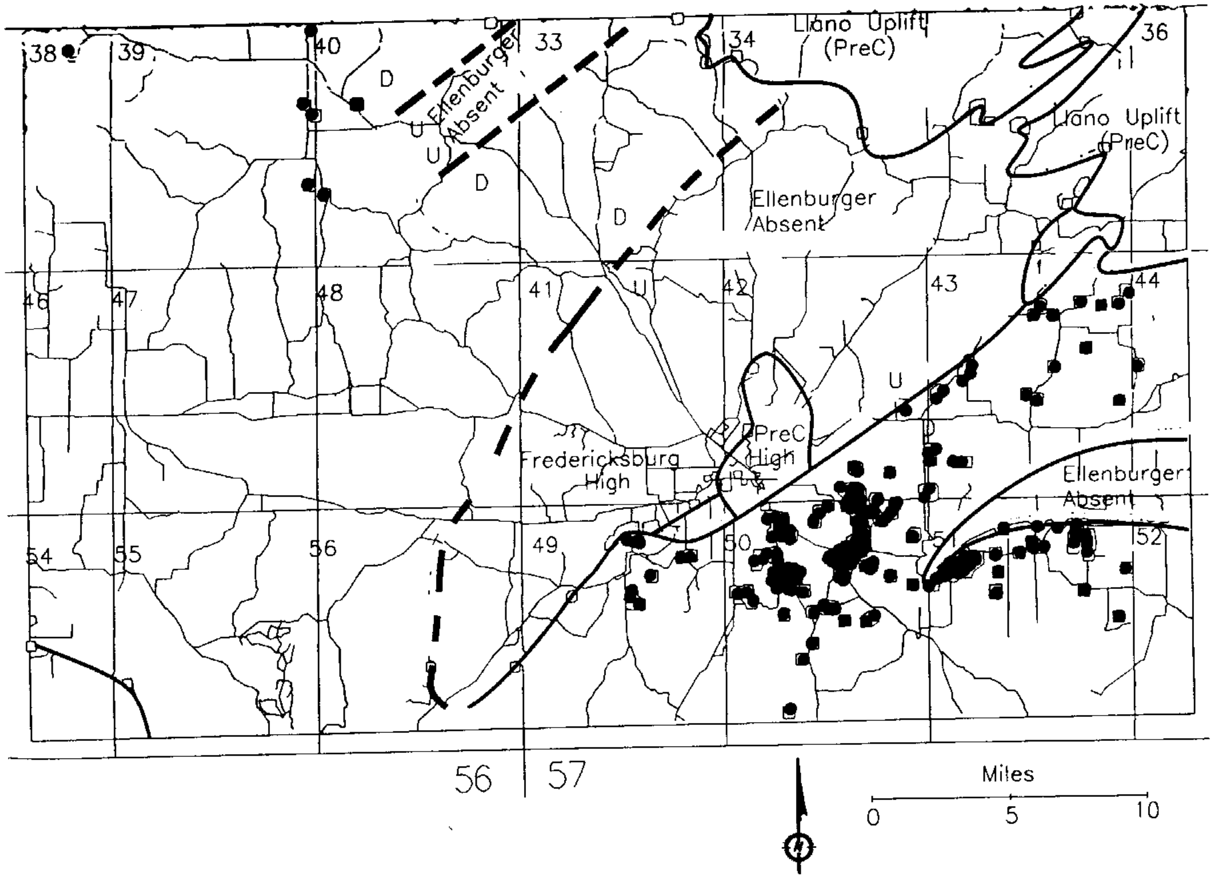
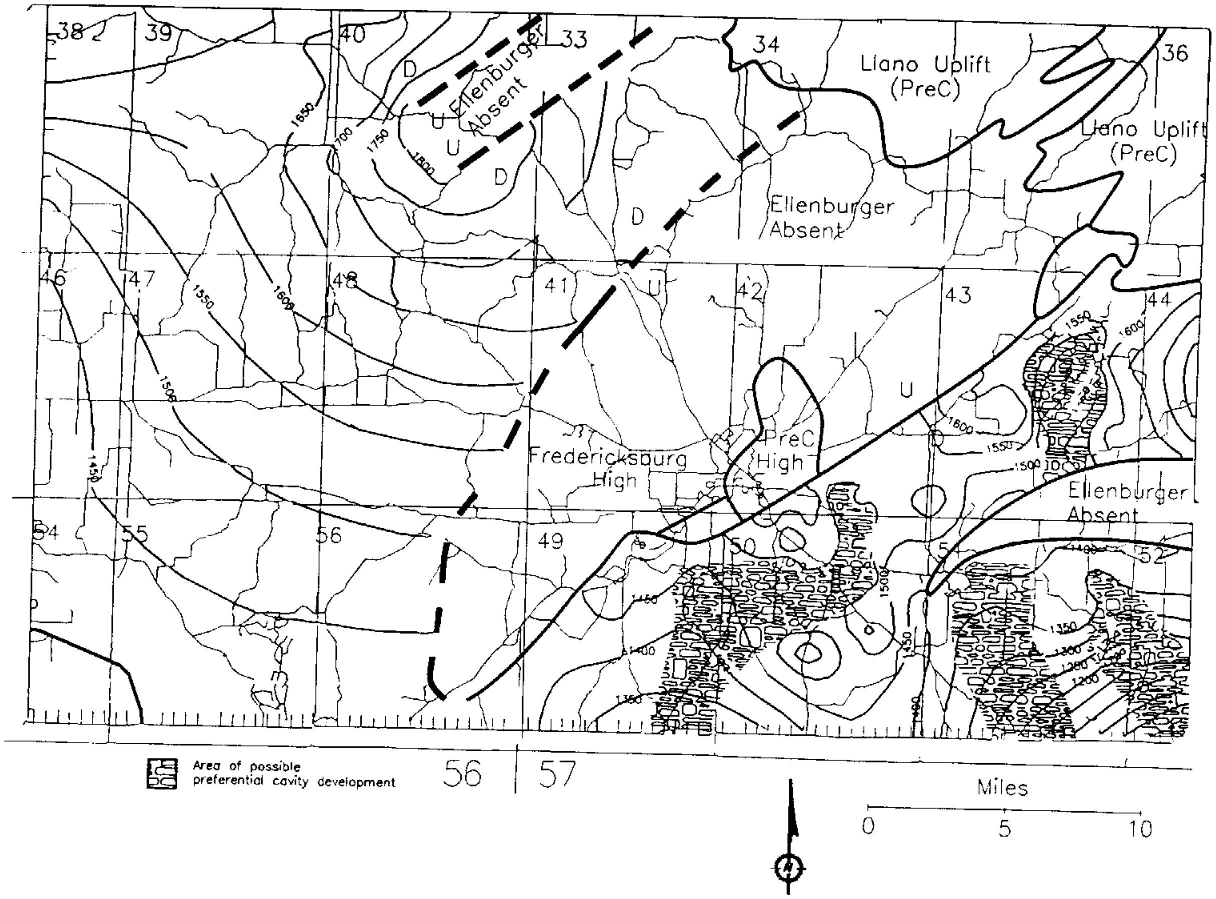


FIGURE 4-17
ELLENBURGER GROUP TOP IN GILLESPIE COUNTY
(FEET ABOVE SEA LEVEL)



In the southeastern part of the County where the bulk of the wells completed in the Ellenburger are located, the contoured map of the Ellenburger top (Figure 4-17) shows the presence of several topographic lows. The lows are apparently the result of drainage over this surface when it was exposed prior to the Lower Cretaceous sea transgression. This drainage appears to have resulted in the preferential development of cavities within the upper portion of the Ellenburger in these lower lying areas. This cavity development is responsible today for the high yielding wells (>900 gpm) found within this aquifer.

Flow Direction and Water Levels

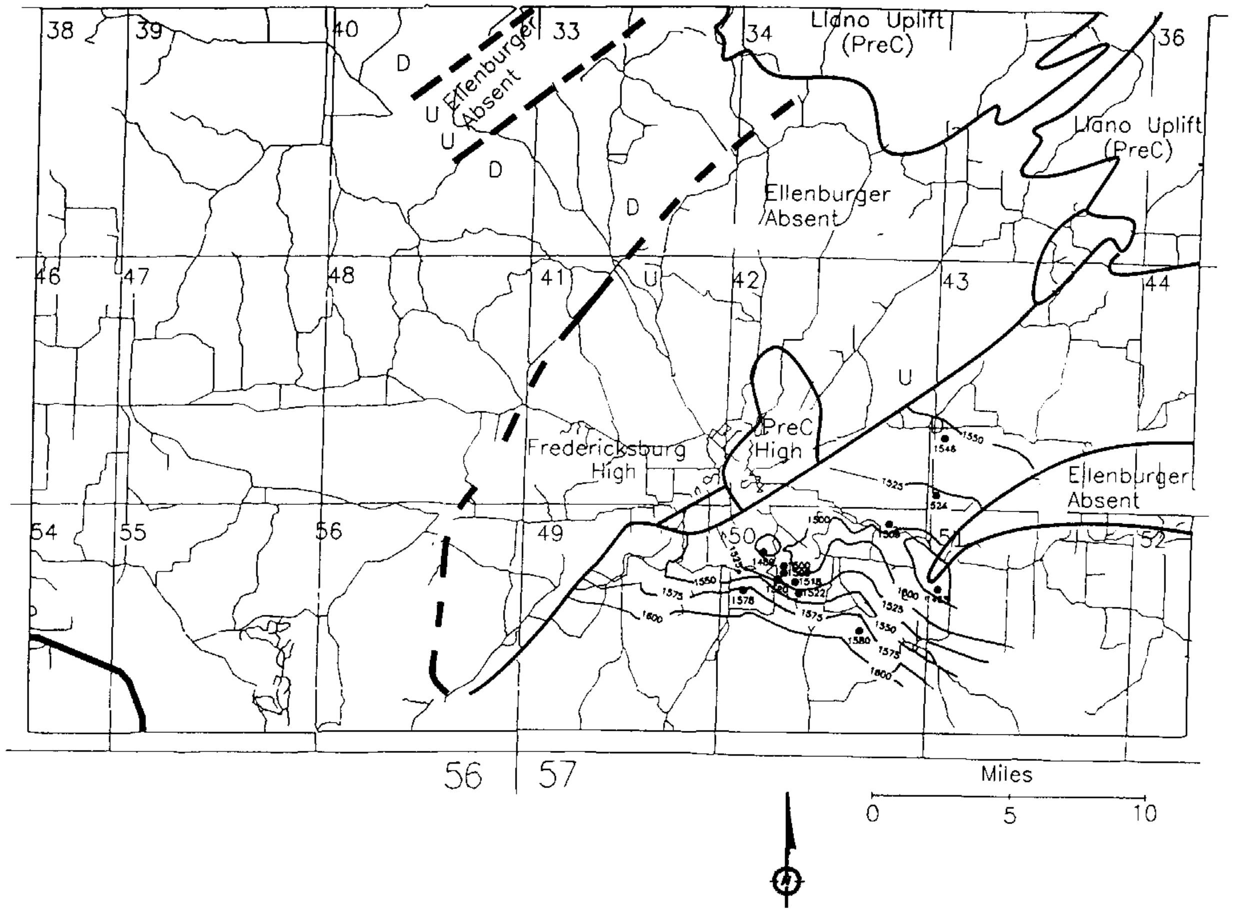
The Ellenburger aquifer is generally under confined conditions except in the heavily pumped areas where unconfined conditions exist. Except where it outcrops, the Ellenburger is generally covered by the Hensell which recharges the Ellenburger. The Ellenburger outcrops to the northeast of the Cave Creek area (57 43; Figure 4-17) and here the unit recharges itself and is unconfined.

In the southeastern portion of Gillespie County flow directions are towards the Pedernales River which serves as its natural discharge zone. Flow is also towards the heavily pumped areas around the municipal well field of the City of Fredericksburg, the irrigated areas and other community water systems that are present in the Pedernales River Valley between Fredericksburg and Stonewall. Figure 4-18 is a contour map of Ellenburger water levels taken during the Spring of 1993. The wells on the map include six Ellenburger wells from the HCUWCD monitor program (Table 4-6) and six City Ellenburger wells. Flow direction is from the topographic high areas north and south of the river valley to the lower elevations along the river itself. Gradients are steeper south of the river than they are to the north of the river. This is probably due to higher elevations being present south of the river then they are to the north. South of the river hydraulic gradients of 39 feet per mile are found which probably also reflects the steeper gradients associated with the heavy pumpage that occurs at the City well field. North of the river and away from the well field hydraulic gradients are only 11 feet per mile (Figure 4-18).

TABLE 4-6
ELLENBURGER WATER LEVELS (1990-1993)

#	Grid	Top Elev	Land Elev	Water Level Elevation		
				Low	High	Avg
R-00078	KK-57437	1555	1705	1542	1547	1544
R-00152	KK-57429	1564	1600	1507	1529	1515
R-00074	KK-57503	1550	1563	1506	1512.2	1508
ER-00826	KK-57504	1456	1684	1571	1578	1575
R-00135	KK-57506	1570	1780	1576	1581	1579
ER-01037	KK-57514	1440	1550	1459	1467	1464

FIGURE 4–18
ELLENBURGER AQUIFER WATER LEVELS (APRIL 1993)
GILLESPIE COUNTY



The HCUWCD since the summer of 1992, has been monitoring water levels at and near the City of Fredericksburg Ellenburger well field. Each summer water levels are taken from seven wells that form a line which runs north-south through the field. Figure 4-19 is an areal map of the well field with water levels contoured for July 1993. This shows the development of the cone of depression that forms around the municipal wells. Water levels were taken over a three day period by both City (E-Line and airlines) and District (tape) personnel. This map also shows the wells that make up the north-south cross section. Figure 4-20 is the north-south cross section along with water levels that were measured on three different days during 1992 and one day in July 1993. Those water levels are superimposed on the cross section. The beginning of 1992 was a very wet period when a great amount of recharge occurred. This is reflected on the 6/25/92 measurement where the pumping levels in the City's Boerner #5 well were above the Ellenburger contact making it a confined aquifer. Later in the summer pumping levels dropped below the Hensell-Ellenburger contact on 8/7/92, but recovered by December 1992. The levels measured on 7/23/93 are also plotted on the cross section. On that day, levels are lower than on any of the days in 1992. This reflects the addition in 1993 of the Weimers production well that is located on Figure 4-19.

FIGURE 4-19
CITY OF FREDERICKSBURG ELLENBURGER FIELD WATER LEVEL MEASUREMENTS (JULY 20-23, 1993)

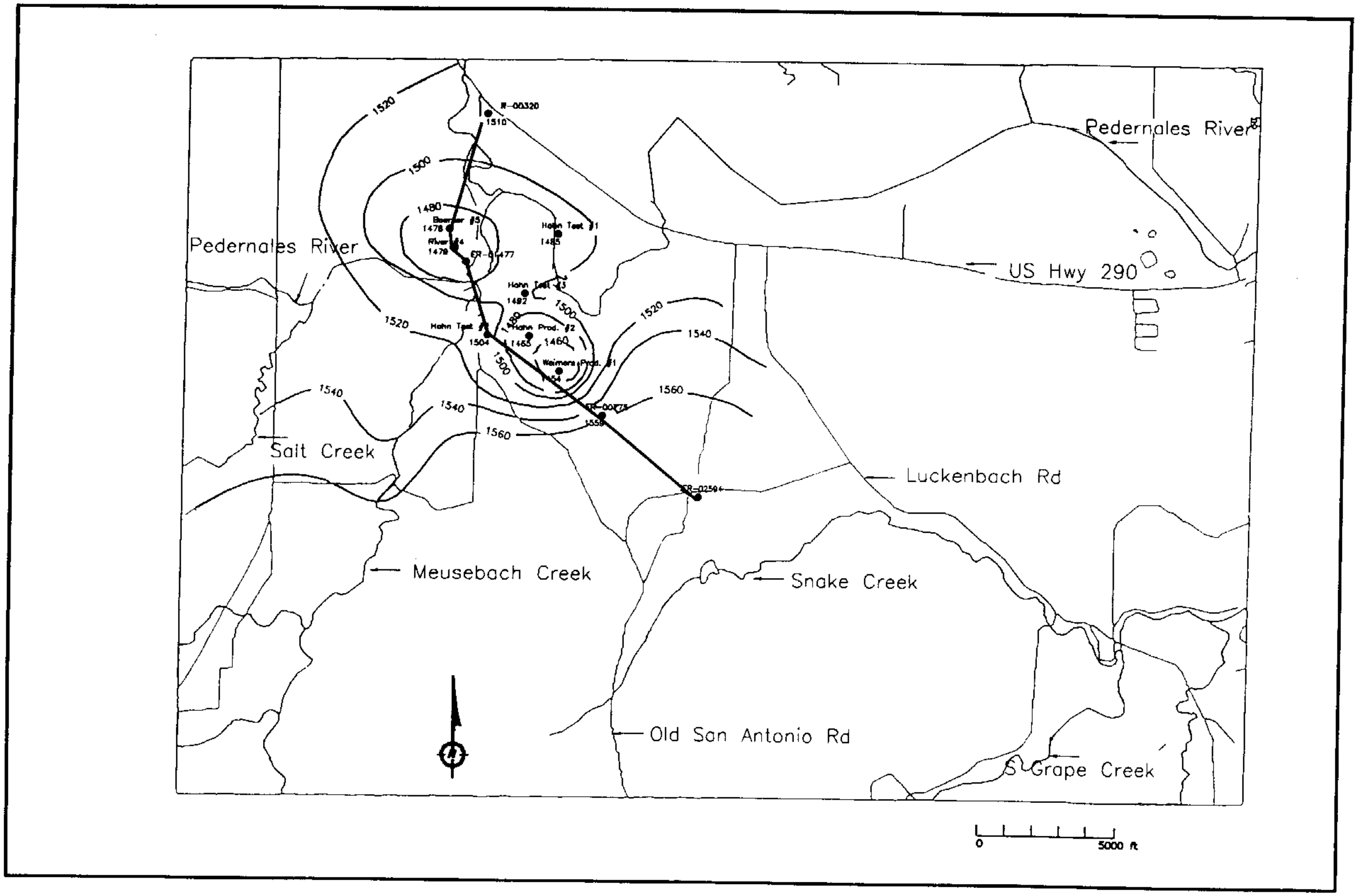
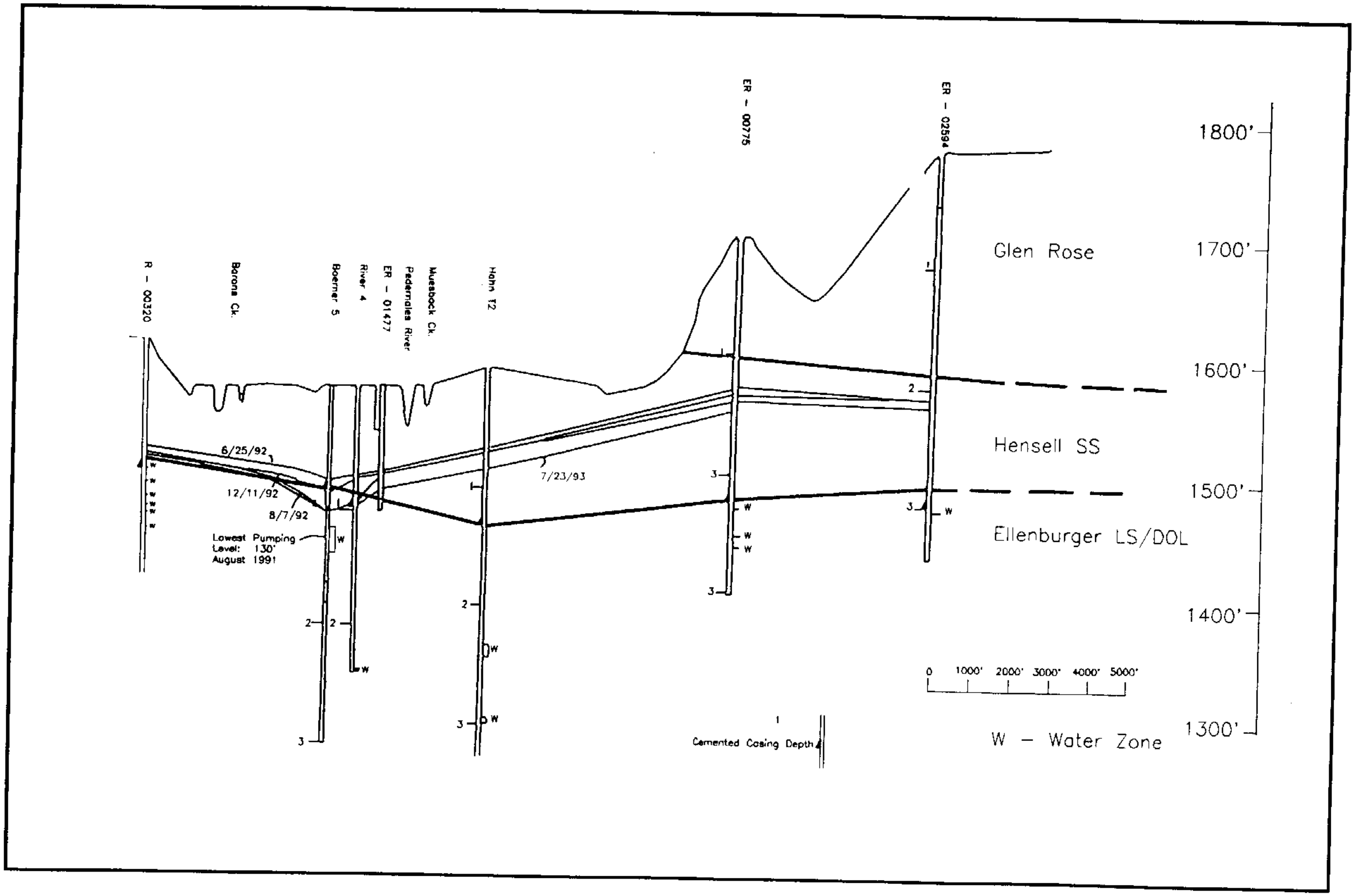


FIGURE 4-20
WATER LEVELS - CITY OF FREDERICKSBURG ELLENBURGER FIELD
1992 & 1993



Pumping levels did not drop to critical levels during 1992 due to the large amount of rainfall that occurred from the end of 1991 to the Spring of 1992. However, with the exception of 1992, since 1989 pumping levels within the Boerner #5 have dropped each summer to within the cavity zone between 120 feet - 140 feet. Water from the Ellenburger is derived from fractures and cavities which occurs in the upper 50 feet - 100 feet within the unit. These fractures and cavities are generally not present at depth within the Ellenburger. Consequently water from the Ellenburger is taken from relatively shallow depths. The City produces annually on the average of 1.8-2.0 million gallons per day from six wells within the Ellenburger field. The HCUWCD estimates that to keep pumping levels above the cavity zone in the Boerner #5 well, annual pumpage should be limited to an average of 1.6 - 1.8 million gallons per day. Table 4-7 tabulates the water produced from the Ellenburger well field from 1981 - 1993 along with the resulting water levels in the main well (Boerner #5) from that field. This shows the decline in water levels in relation to increased pumpage.

TABLE 4-7
CITY OF FREDERICKSBURG ELLENBURGER ANNUAL PUMPAGE & WATER LEVELS FROM BOERNER 5 PRODUCTION WELL

Total Ellenburger Annual Pumpage (5 Wells)		Time of Measurement		Water Level Feet Below Land Surface		Water Elevation, Feet Above Sea Level	
Annual (mg)	Avg/Day (mg)	Month	Year	Lowest	Highest	Lowest	Highest
		Aug	1980	99	97	1482	1484
480	1.3	Apr	1981		86		1495
537	1.5	Jul-Aug	1982	96	91	1485	1490
519	1.4	Jun-Jul	1983	94	93	1487	1488
636	1.7	Jun-Sep	1984	108	101	1473	1480
576	1.6	Apr-Oct	1985	108	86	1473	1495
591	1.6	Apr-Sep	1986	101	87	1480	1494
552	1.5	Jan-Sep	1987	91	42	1490	1539
678	1.9	Jan-Dec	1988	101	91	1480	1490
734	2.0	Jan-Dec	1989	127	91	1454	1490
653	1.8	Jan-Dec	1990	120	99	1461	1482
578	1.6	Jan-Dec	1991	130	91	1451	1490
618	1.7	Mar-Oct	1992	100	82	1481	1499
683	1.9	Jan-Dec	1993	122	91	1459	1490

In response to the pumping levels at the City field, the City of Fredericksburg in the summer of 1993, purchased additional property approximately 3 miles to the east of the field. A six test well drilling program and subsequent pumping test indicate that 2-4 million gallons per day capacity is available at this new site. This field will be brought on line by the summer of 1995, and will augment the nearly 2 million per day average currently being produced from six wells in the existing City Ellenburger field. This will reduce the demand presently placed on the existing well field and ensure that pumping levels stay above the cavity zone for the foreseeable future.

Aquifer Characteristics

The Ellenburger aquifer is the most significant aquifer within Gillespie County, where it is used largely for municipal, irrigation, domestic and stock purposes. The City of Fredericksburg produces 85-90% of its demand from six Ellenburger wells. Average daily demand of 1.8 to 2.0 million gallons per day is met by these wells.

The yield from the Ellenburger can vary widely depending on the presence of cavities within the unit. If the unit contains significant cavity development then very high yields (>1000 gpm) are possible. Figure 4-21 is a contour map of Ellenburger yield and shows the areas within the southeastern part of the County where the Ellenburger is a prolific water producer. In the previous section on the Distribution of the Ellenburger, it was pointed out that preferential cavity development is believed to have occurred on the lower lying areas of the Ellenburger, where surface drainage occurred prior to Lower Cretaceous sea transgression. These lower surfaces of the Ellenburger experienced enhanced cavity development which today is responsible for the high yielding wells. Figure 4-17 which is a contour map of the top of the Ellenburger illustrates the high and low areas of the surface. It is interesting to compare this map and the map of Ellenburger yield (Figure 4-21). There is a strong correlation between the areas with high yield and the areas with topographic surface lows. The area where the City's well field is located is on a surface low as is the area three miles to the east where the City recently tested a 2-4 million gallon per day potential from three test wells. There is also an area along Jenschke Lane where several Ellenburger wells are estimated to give high water yields. On Figure 4-17, other areas where preferential cavity development may have occurred are south of Stonewall and east of the Cave Creek area. Both areas may prove to provide high yielding Ellenburger wells in the future.

FIGURE 4-21
ELLENBURGER AQUIFER YIELD (GPM)
GILLESPIE COUNTY

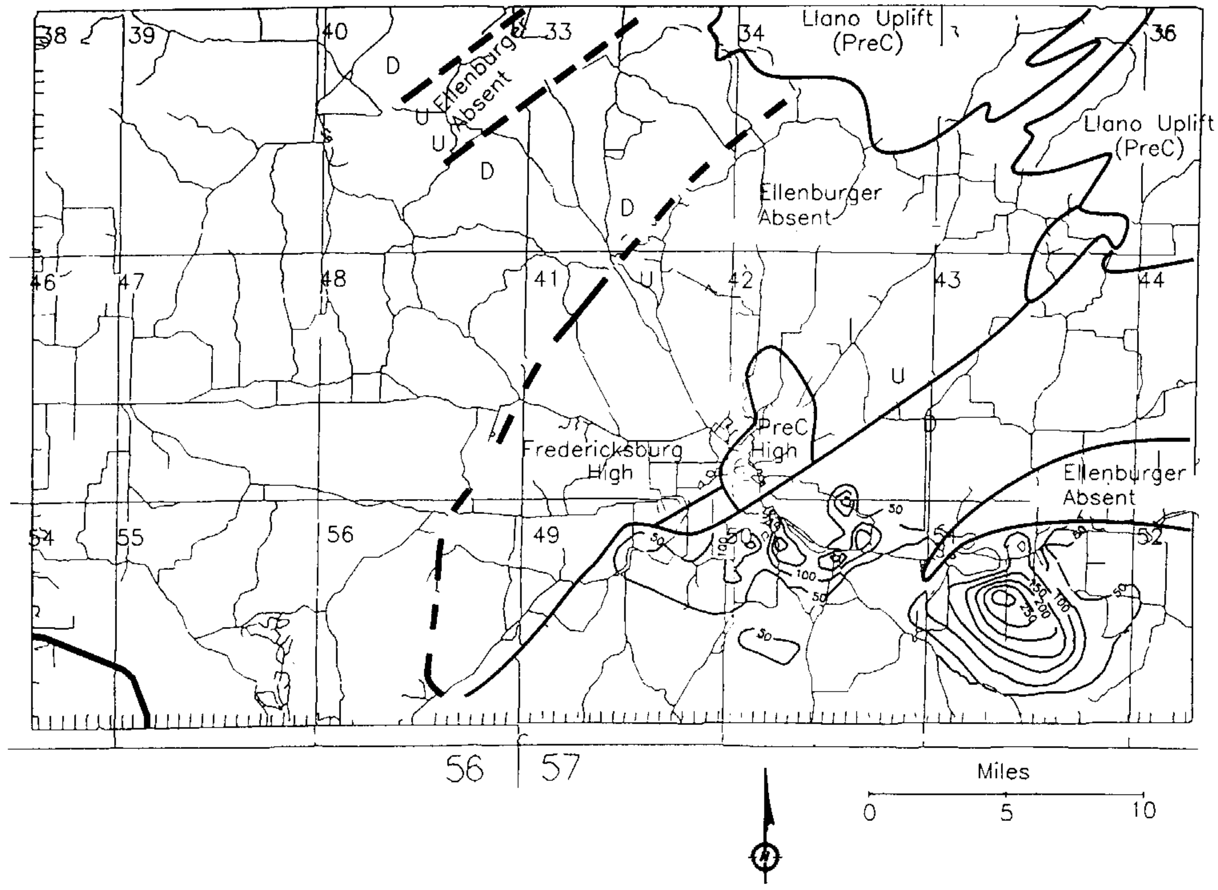


Figure 4-21
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Although the Ellenburger can produce high water yields, in many areas it is only marginal at best. On Figure 4-21 only the wells with yields in excess of 50 gpm are contoured. Consequently many of the Ellenburger wells on Figure 4-16 are only moderate water producers, and are probably reflecting the absence of cavity development.

The following are hydraulic characteristics of the Ellenburger summarized by the TWDB in Report 339.

Ellenburger Aquifer
Hydraulic Characteristics in the Texas Hill Country Area

Specific Capacity	14 gpm/ft
Hydraulic Gradient	11 feet - 39 feet/mile
Hydraulic Conductivity	550-678 gpd/ft^2
Transmissivity	56,000-96,000 gpd/ft
Storage Coefficient	0.0022
Porosity	1-17 percent

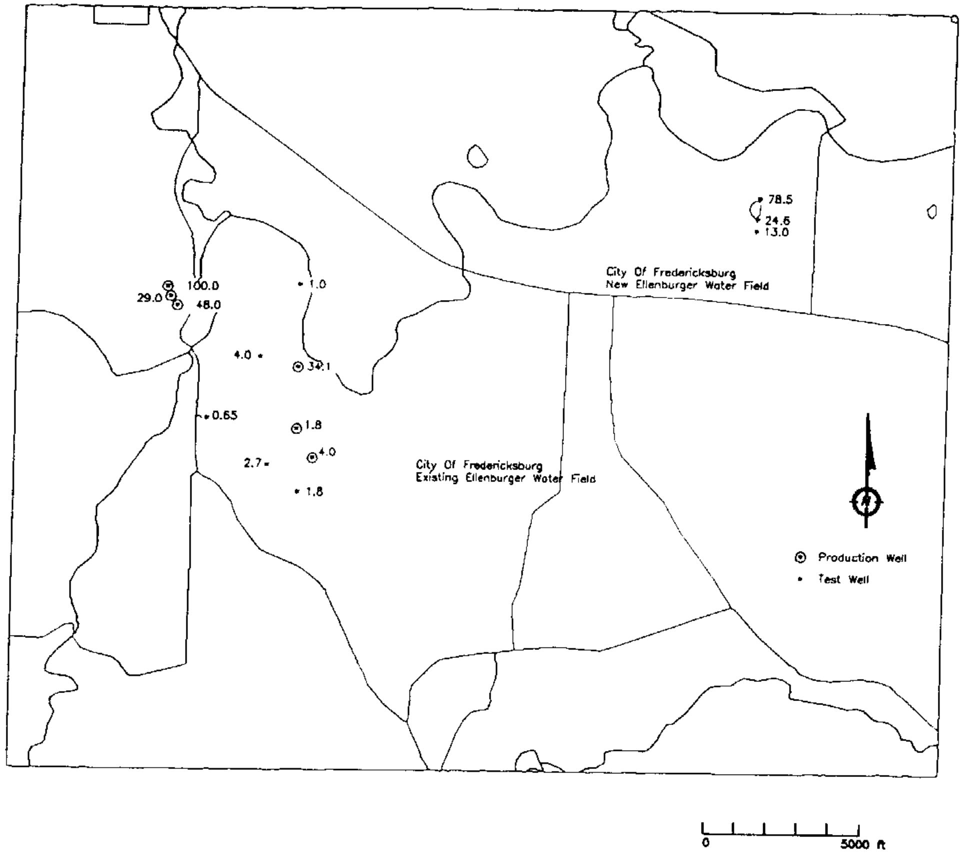
The City of Fredericksburg has performed many pump tests over the years on several of their production and test wells. One parameter used to evaluate yield is specific capacity, which is as follows:

Specific Capacity and Transmissivities
Fredericksburg Production and Test Wells

Well #	Production Wells	Specific Capacity gal/min/foot	Transmissivity gal/day/foot
ER-00068	Boerner #5	100.0	
ER-00066	River #3	48.0	
ER-00067	River #4	29.0	
ER-00083	Hahn #1	34.1	55,775
ER-00082	Hahn #2	1.8	
ER-00086	Weimers #1	4.0	
Well #	**Test Wells**	**Specific Capacity gal/min/foot**	**Transmissivity gal/day/foot**
ER-00076	Hahn Test #1	1.0	
ER-00081	Hahn Test #2	.65	
ER-00080	Hahn Test #3	4.0	
ER-00085	Weimers Test #2	2.7	
ER-00087	Weimers Test #4	1.8	
M-00002	Knauth Test #1	13.0	25,800
M-00003	Knauth Test #2	24.6	
M-00004	Knauth Test #3	78.5	37,714

Specific capacity is the discharge of a well expressed as the rate of yield per unit of drawdown, generally in gallons per minute per foot of drawdown. The above values are present on Figure 4-22. This map shows the location of the new City field. This map also shows the variation in specific capacity of the Ellenburger which is a function of cavity development.

FIGURE 4-22
SPECIFIC CAPACITIES (GPM/FT)
ELLENBURGER AQUIFER



Water Quality

The water quality of the Ellenburger is very good quality but high in calcium, magnesium and bicarbonate. It is very similar to the quality present in the Edwards and Hensell aquifers, however, it lacks high concentrations of nitrate that are sometimes found in the Hensell. Figure 4-23 is a contour map of nitrate concentrations within the Ellenburger. These are wells that the HCUWCD has analyzed since acquiring its water quality testing lab in 1990. As the map shows, all nitrate values are below 10 mg/l (nitrate as N), the upper limit considered safe by health authorities. The fact that the Hensell overlies the Ellenburger and acts as a filter is probably the reason for the good quality of water present within the Ellenburger.

GROUND WATER DEVELOPMENT AND AQUIFER CRITICALITY

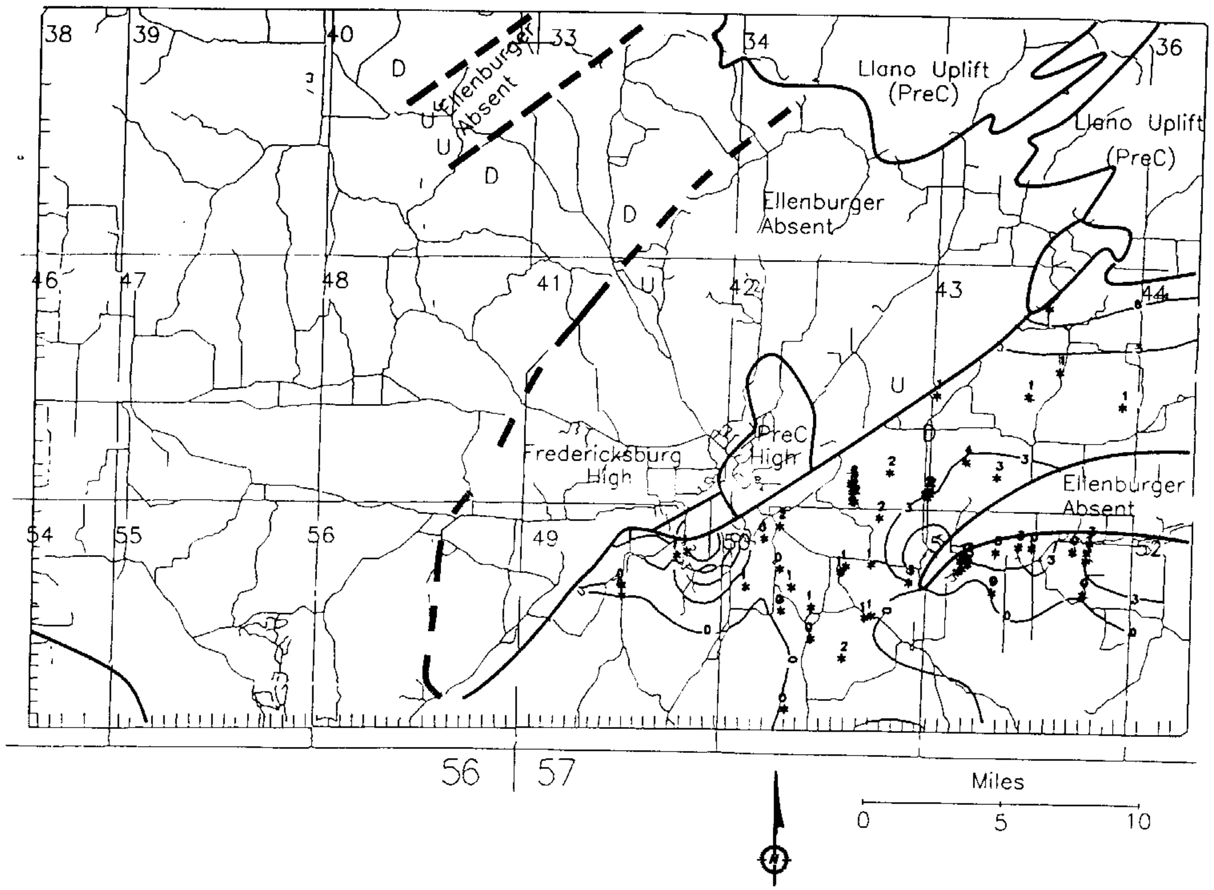
Due to the carbonate nature of this aquifer storage calculations are often times not very meaningful. However using the formula Q=TiW, sustained yield for the Ellenburger can be calculated, as shown by the following:

T = Transmissibility 31,757 gpd/ft = 4245 ft^3/day/ft.
i = Hydraulic gradient 11 feet/mile = .002 ft/ft
W = 26,400 feet = 5 miles

Q = 4245 X 0.002 X 26,400
Q = 224,083 ft^3/day
Q = 1,676,142 gal/day
Q = 5.1 acre feet/day
Q = 1,876 acre feet/year

The above calculation of 1876 acre feet per year is representative of water flow through a 5 mile wide cross section of the Ellenburger towards its discharge area along the river. This 5 mile width is roughly the width of the Ellenburger present north of the river where it is between the two fault blocks. (Figure 4-18). The T value is an average value of the two transmissivity calculations (25,800-37,714 gpd/ft) made from pump tests conducted on the new Ellenburger well field during the Summer of 1993. The hydraulic gradient was the lower value measured from wells within the monitoring programs of the HCUWCD away from the influence of the City's municipal wells. If we assume that 1876 acre feet/year is moving through the Ellenburger from both the north and south sides of the river where recharge is occurring (Figure 4-18), then we can assume that a total of 3750 acre feet per year of sustainable yield is present in this part of the Ellenburger where the City's present and future well fields are located. This is the area on Figure 4-21 where Ellenburger yields are shown to be high.

FIGURE 4-23
ELLENBURGER AQUIFER NITRATE LEVELS (MG/L)
GILLESPIE COUNTY



Presently the City produces approximately 2,000 acre feet of water per year from this area. The pump test conducted last summer on the new Ellenburger well field indicated that an additional 2 million gallons per day, or 2,239 acre feet per year, could be recovered from this part of the Ellenburger. However, this may be high since pumpage of 1.8 - 2.0 million gallons per day at the existing well field has caused some significant water level declines. Consequently, if we take a conservative value of only 1 million gallons per day produced from this new field, then the City will be able to produce 3100 acre feet from this part of the Ellenburger. In addition to municipal demand, there is also irrigation occurring in the area. From 1977 to 1989 Countywide irrigation demand ranged from 125 acre feet in 1988 to 1,954 acre feet in 1989, with an annual average of 1,130 acre feet per year. If we assume that in this part of the County, where 3750 acre feet of calculated sustainable Ellenburger yield is available, and irrigation there accounts for 1/3 of all county irrigation, then 375 acre feet per year is utilized here for irrigation. As a result, within this portion of the Ellenburger aquifer, a total of approximately 3500 acre feet out of the estimated 3750 acre feet per year of sustainable yield will be utilized within the foreseeable future. The remaining 250 acre feet is probably currently being utilized for stock and rural domestic needs in this part of the County.

In report 339 the TWDB estimated that the sustained yield for the Ellenburger within Gillespie County was 4,000 acre feet per year. This is probably conservative, since the above discussion indicates that 3750 acre feet may probably be available in the northern area of grid 57-50 where the City is currently producing over 2000 acre feet per year (Figure 4-18).

There are other areas in the County where substantial yields within the Ellenburger have been observed. Figure 4-21 shows the area along Jenschke Lane between Fredericksburg and Stonewall to be a favorable area for high yielding Ellenburger wells. This area is south of the fault block where Ellenburger is absent. If we assume that recharge to Ellenburger along Jenschke Lane occurs mainly from the south, the calculations used above for sustained yield can be utilized. However the flux is only occurring from the south with little to no flux from the north. This would give 1876 acre feet per yield of sustainable yield from this other prolific water yielding area of the Ellenburger. If these estimates are correct, then the sustained yield for the Ellenburger is approximately 5600 acre feet per yield or 40 percent more than the estimate made by the TWDB in Report 339.

In 1985 estimated ground water use for Gillespie County was put at 5124 acre feet. Of that figure 2,413 acre feet or 47 percent of the total pumped came from the Ellenburger. In this study, water demand projections have been made to the year 2030. Without conservation 10,076 acre feet will be required , whereas 9,192 acre feet will be needed if conservation practices are followed. Should the Ellenburger continue to provide 47 percent of the ground water pumped in Gillespie County, then in the year 2030 high demand on the Ellenburger will be 4735 acre feet. This is 865 acre feet less than the 5600 acre feet estimated in this study to be available annually. However, it is 735 acre feet more than the 4000 acre feet available annually as determined by the TWDB. If it is assumed that the TWDB estimate is on the low end and the 5600 acre feet estimated in this study represents the high end of the scale, then a prudent value of Ellenburger sustained yield may be an average of the two. This would give 4800 acre feet per yield of sustained yield from the Ellenburger. If this value is accurate, then by the year 2030 all sustained Ellenburger yield will be accounted for by demand. In which case this aquifer will be in critical status.

Distribution

The Cambrian-age Hickory Member of the Riley Formation covers the majority of Gillespie County with the exception of the extreme northeastern portion of the County where it has been eroded off of the Llano Uplift. It is also absent over an area under the City of Fredericksburg and Stonewall. Due to the complex nature of the position of the fault blocks that developed after the Ouachita Uplift, the Hickory has been displaced at varying depths within the County. In the central part of the County the unit is generally on a high that trends northeast to southwest. This high has been referred to as the Fredericksburg High in TWDB Report 339. Depths for the unit are generally between 300 feet - 400 feet below land surface on the High, where many of the younger overlying rock units have been removed by the erosion that occurred after the Ouchita Uplift. The Hickory often serves as an aquifer on the High where the overlying younger Hensell Sand is comprised of very fine grained sediments and lacks ground water or is very thin. Figure 4-24 shows the location of wells producing from the Hickory on the High. To the east and west of the High, Hickory wells are absent since it is deeply buried and younger shallower aquifer are present. One exception is in the Cherry Springs area where the Hickory is faulted up near the surface.

On the Fredericksburg High, the top of the Hickory ranges from 1450 feet above sea level to over 1850 feet above sea level. (Figure 4-25). The base of the unit is projected to range from 1350 feet to 1650 feet above sea level (Figure 4-26). Thicknesses are estimated to reach a maximum of 300 feet in the grabens present on the High. Generally, Hickory thickness varies considerably from less than 50 feet to 300 feet (Figure 4-27), which reflects the irregular surface of the underlying Precambrian rocks.

FIGURE 4-24
HICKORY AQUIFER WELLS
GILLESPIE COUNTY

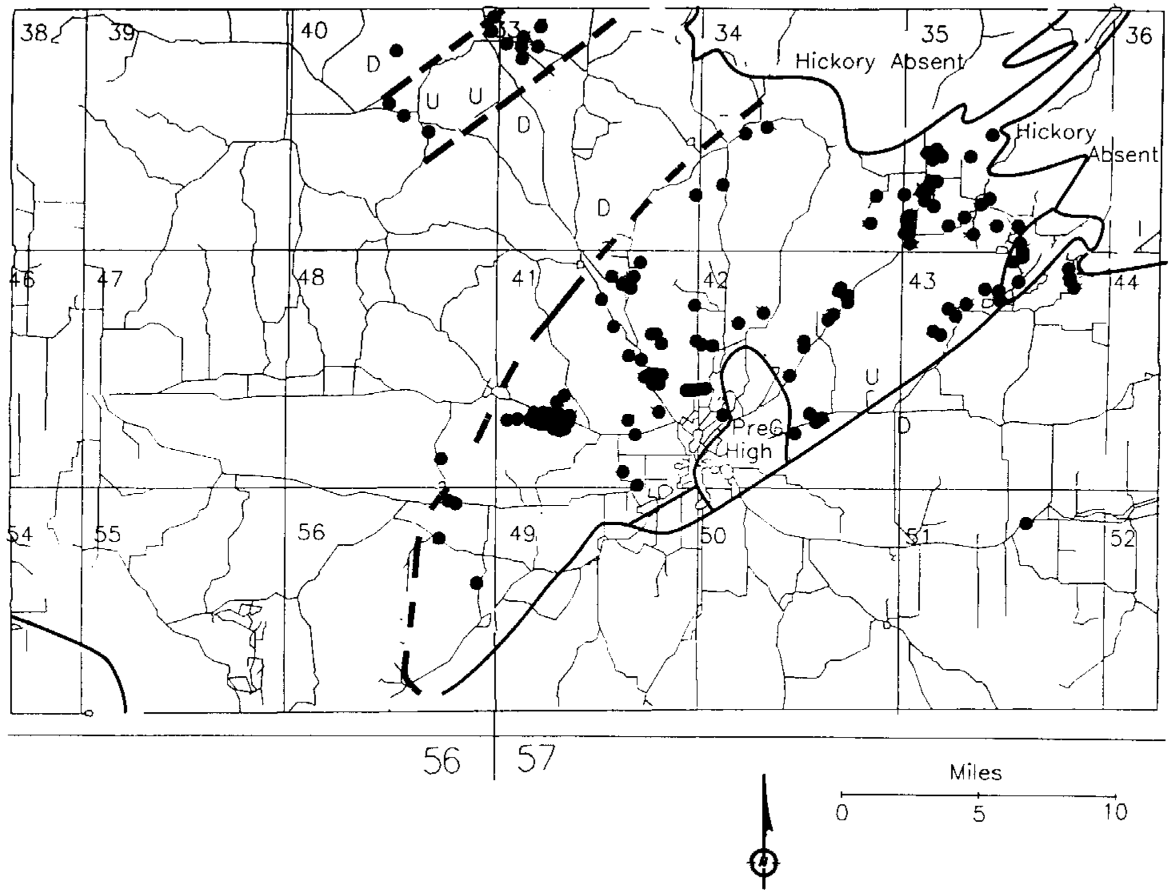


FIGURE 4-25
TOP ELEVATION OF HICKORY MEMBER IN GILLESPIE COUNTY (FEET ABOVE SEA LEVEL)

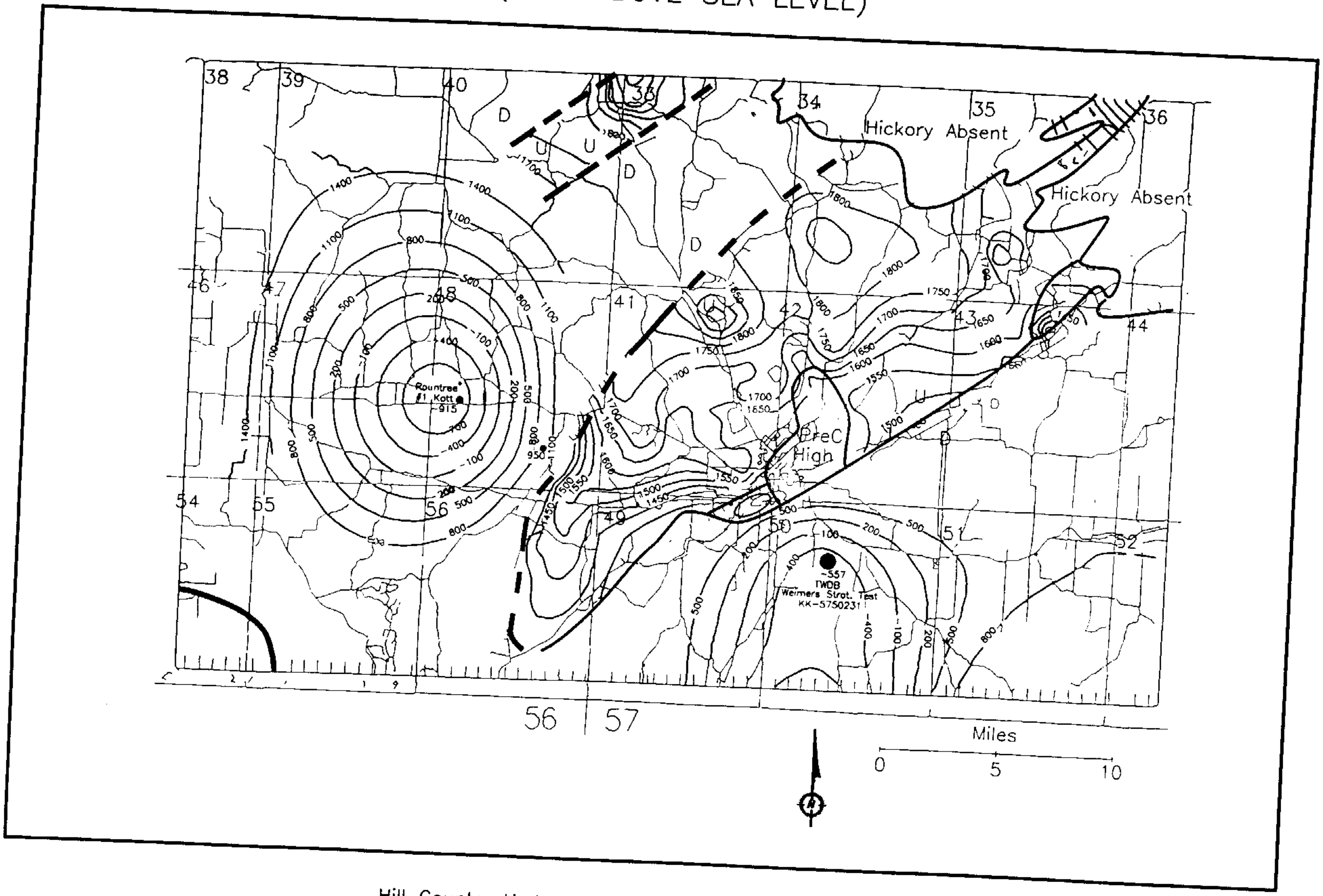


Figure 4-25
Page 4-57

FIGURE 4-26
BASE ELEVATION OF HICKORY MEMBER IN GILLESPIE COUNTY
(FEET ABOVE SEA LEVEL)

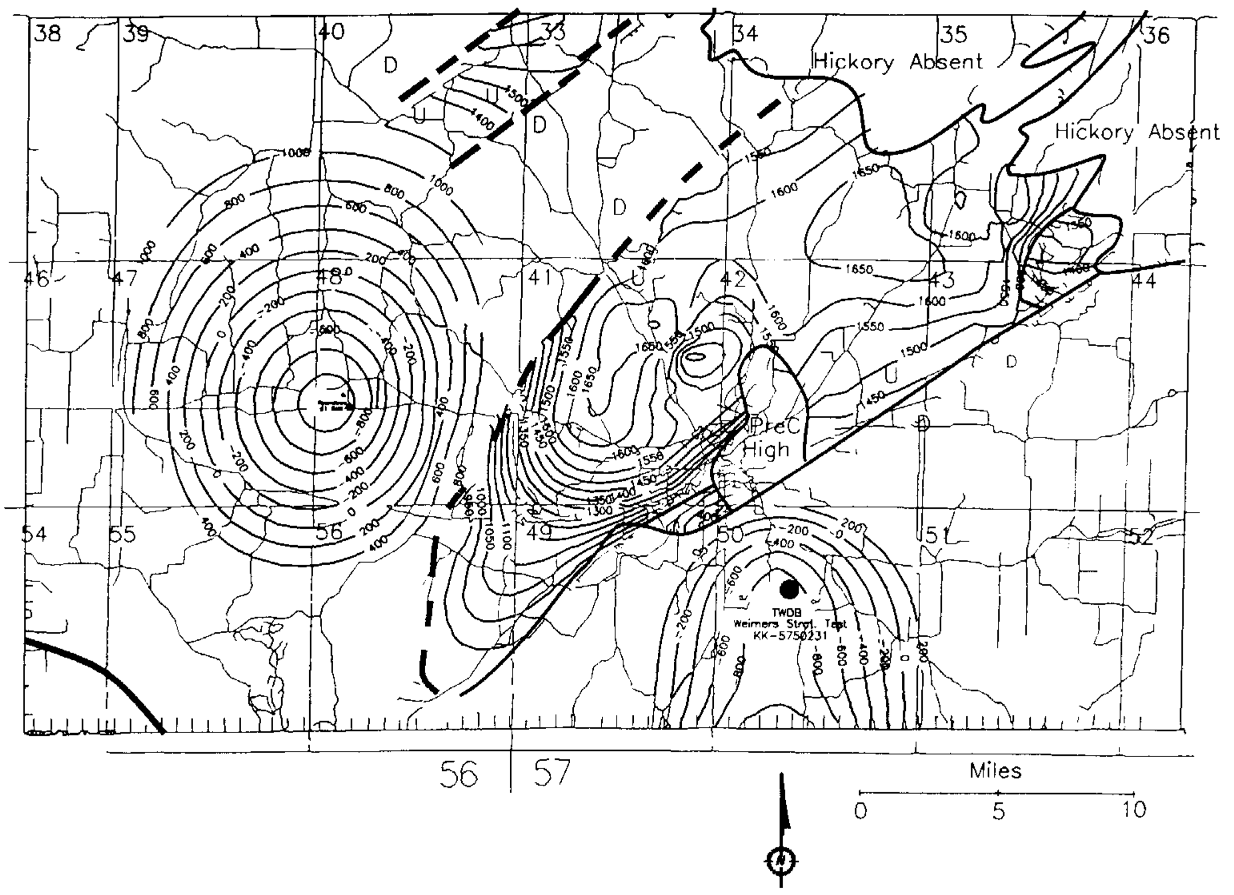
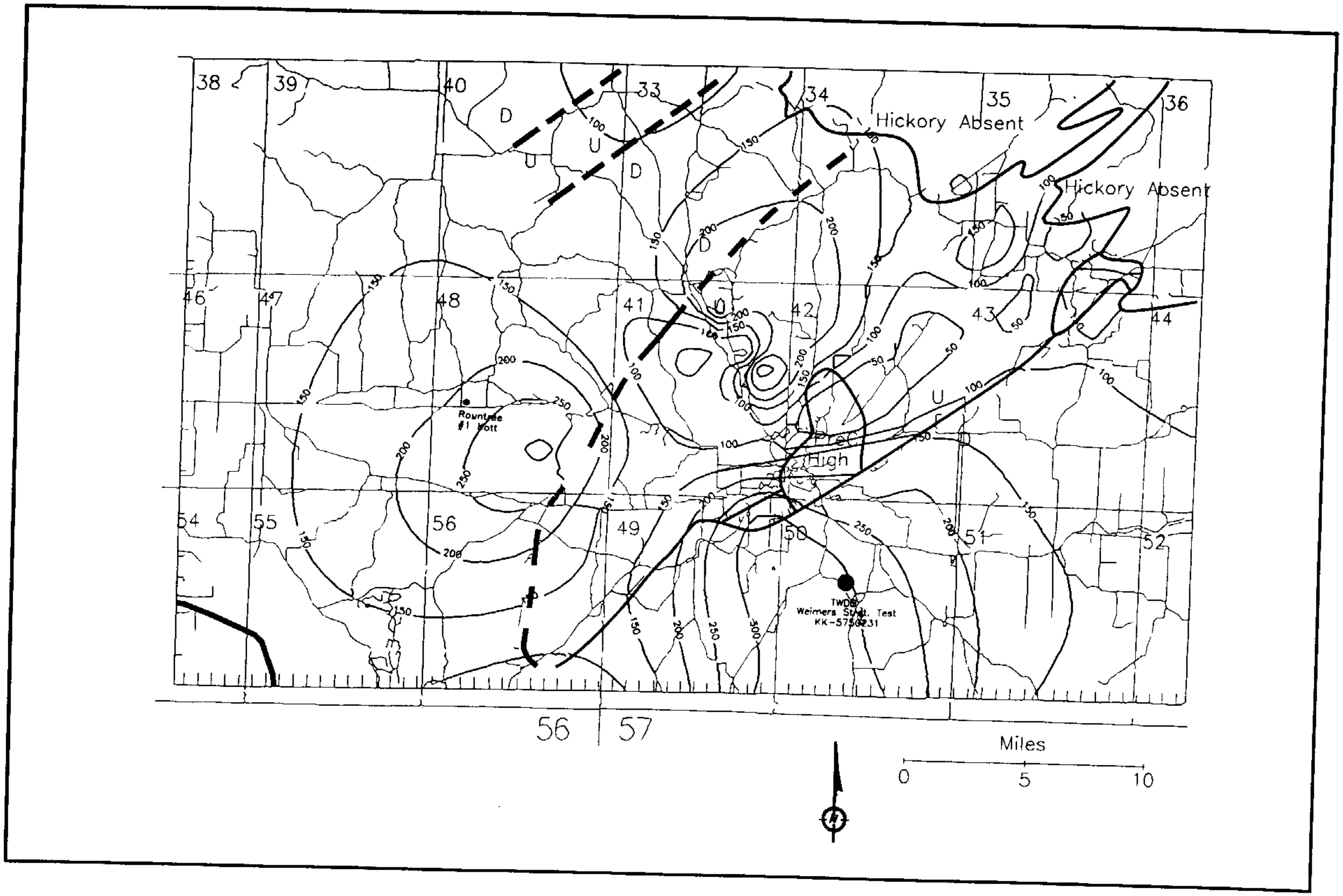


FIGURE 4-27
THICKNESS OF HICKORY MEMBER (FT)
GILLESPIE COUNTY



Hill Country Underground Water Conservation District
Regional Water Plan

Adjacent to the High, depths to the Hickory can be extreme. In western Gillespie County, in the oil test well Rountree #1 Kott located at the corner of 290W and Doss Spring Creek Road (2067 feet land surface elevation), the top of the Hickory was encountered at 2985 feet below land surface or 918 feet below sea level (Figure 4-25). Hickory thickness at this site was 202 feet. Recently, the TWDB undertook the drilling of a deep stratigraphic test well within the City's Ellenburger well field just to the east of the Fredericksburg High (Figure 4-25). Here the Hickory top was penetrated at 2132 feet below land surface, which is 1575 above sea level. At this location the Hickory top is 557 feet below sea level. (Figure 4-25). Hickory thickness here is estimated to be in excess of 200 feet since the rig used by the TWDB was unable to reach the bottom of the unit and stopped at 2335 feet below land surface.

Flow Direction and Water Levels

The Hickory is generally under confined aquifer conditions due to the fact that for the most part it does not outcrop. It is exposed along the northern edge of the County where it is in contact with the Llano Uplift. In the areas around Cherry Springs and Eckert the unit is exposed and is under unconfined conditions. The unit is recharged at its outcrop and by vertical percolation through the overlying units. Since the Hickory is overlain by younger rock units and its distribution is poorly understood due to its complicated structural geology, it is difficult to determine hydrologically its storage and recharge potential.

The HCUWCD monitors water levels in eighteen (18) Hickory wells in its biannual water level monitoring program. All 18 wells with the exception of one well near Cherry Springs are located on the Fredericksburg High (Figure 4-28). Water levels measured during the Spring of 1993 indicate that water movement within the Hickory is towards the east-southeast on the Fredericksburg High (Figure 4-28). Water levels range from a low of 1571 feet above sea level south of Willow City, to a high of 1836 feet above sea level in an area northeast of Fredericksburg near the edge of the Edwards Plateau extension. There appears to be a ground water high in the Hickory associated with the overlying Edwards Plateau extension that runs from the west to the east in this part of the County. This area on Figure 4-28 where the Hickory ground water high is present also correlates with the Hickory top topographic high on Figure 4-25. In fact when comparing the two maps of the Hickory Top (Figure 4-25) and the Hickory water levels (Figure 4-28) a very good correlation can be seen in the configuration of the contours on the two maps. This type of correlation is generally seen in an unconfined aquifer where the unit outcrops and the water levels conform to the surface topography. However, in this case, the Hickory is generally confined and buried.

The hydraulic gradients appear to range from a high of over 100 feet/mile to the northeast of Fredericksburg to a low of 16 feet/mile to the southwest of Fredericksburg. The area with the steep gradient is located where a significant amount of topographic surface relief is present due to its location on and off of the edge of the Edwards Plateau. The surface elevations change several hundred feet over short distances (ER-00027: 2024 feet to ER-00380: 1780 feet; 244 feet per 2.5 mile; Table 4-8). This correlation of hydraulic gradient and surface relief is substantiated by the flatter hydraulic gradients within the Hickory in the wells located in the Pedernales River Valley to the southwest of Fredericksburg. There topography is subdued and hydraulic gradients are flatter. However, the steep gradients present in the northeast part of the County may be also controlled by faulting which is very prevalent within the Hickory.

TABLE 4-8
HICKORY WATER LEVELS (1990-1993)

#	Grid	Top Elev	Land Elev	Water Level Elevation		
				Low	High	Avg
ER-00049	KK-57331	1646	1700	1653	1658	1656
ER-00726	KK-56486	1640	1915	1717	1723	1721
ER-00854	KK-5741205	1768	1908	1769	1771	1770
ER-00853	KK-5741206	1743	1875	1769	1769	1769
ER-02730	KK-5741502	1703	1962	1753	1755	1754
ER-00256	KK-5741503	1675	1840	1738	1760	1750
ER-00158	KK-5741615	1805	1960	1702	1753	1729
ER-00962	KK-5741616	1704	1865	1723	1761	1738
ER-00053	KK-5741903	1591	1757	1632	1715	1669
ER-02385	KK-57417	1704	1860	1701	1712	1703
ER-00001	KK-5742303	?	1890	1834	1860	1839
ER-00027	KK-5742306	?	2024	1780	1812	1797
ER-00028	KK-5742502	?	1663	1645	1653	1647
R-00144	KK-57357	1722	1722	1698	1714	1706
ER-00916	KK-57358	1705	1705	1674	1679	1676
ER-00380	KK-57431	1585	1780	1571	1583	1580
ER-00311	KK-56563	1536	1780	1693	1700	1696
ER-00045	KK-5656601	?	1710	1678	1681	1680

As mentioned previously, flow is generally towards the east-southeast direction. There is a feature on the eastern edge of the Fredericksburg High which may also influence flow direction within the Hickory. Beneath the eastern half of Fredericksburg and to the east is a Precambrian high upon which no Hickory is present. The water level contours on Figure 4-28 bend around this high which possibly serves as a no flow barrier, and may have an impact on where enhanced yield occurs within the Hickory.

Aquifer Characteristics

The Hickory is probably the least understood aquifer within the County; however, it is extensively utilized for municipal, domestic, irrigation and stock needs. Water yields within the Hickory are generally moderate (20-40 gpm) to good (>50 gpm) (Figure 4-29). The City of Fredericksburg acquires up to 15 percent of its total demand from three Hickory wells which produce between 100-200 gpm.

On Figure 4-29, yields in gpm are contoured for the Hickory in Gillespie County. On that map the areas with high yield (> 50 gpm) are generally located to the west and southwest of the Precambrian high that is situated to the east of Fredericksburg. As was mentioned in the preceding section on flow direction, the water level contours appeared to bend around this Precambrian high, suggesting that it influences flow direction. If this is the case, then flow from the Hickory to the north of the Precambrian high, where the Hickory top and water levels are at their highest elevation (Figures 4-25, 4-28) may be directed to areas west and east of the Precambrian high.

FIGURE 4-28
HICKORY AQUIFER WATER LEVELS
SPRING 1993

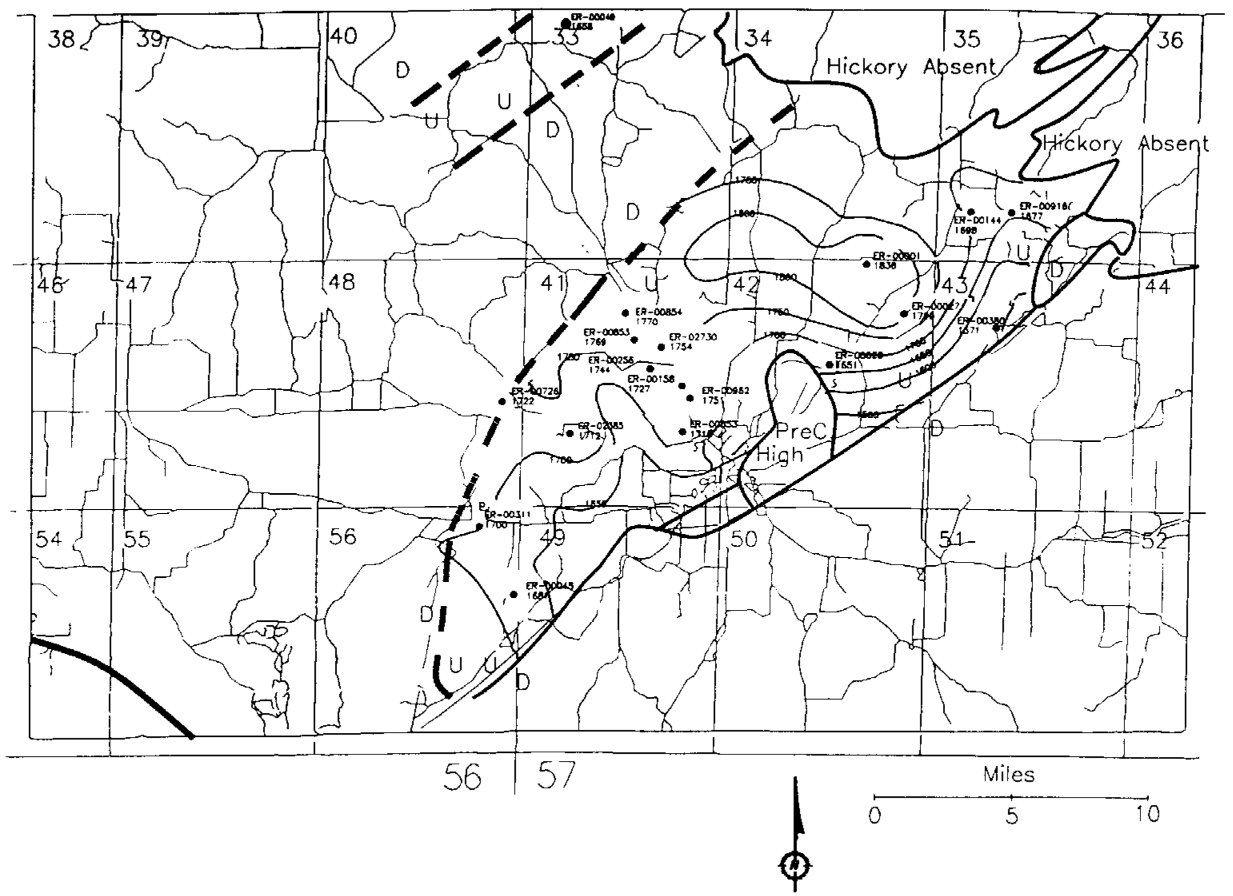
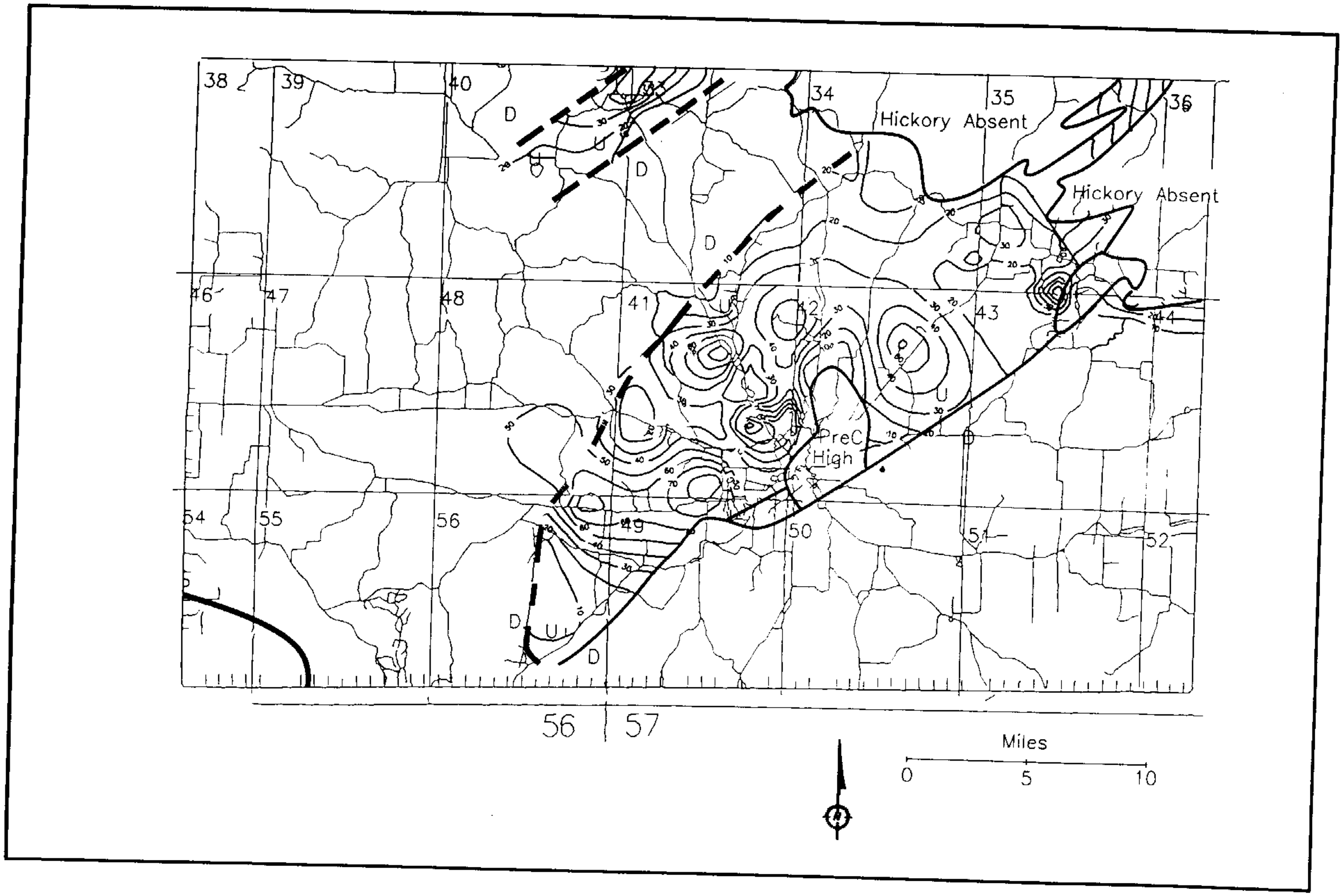


FIGURE 4-29
HICKORY AQUIFER YIELD (GPM)
GILLESPIE COUNTY



The surface configuration of the Hickory top may also have an influence on flow. In the preceding section, it was also pointed out that water level contours (Figure 4-28) correlate fairly closely with the Hickory top (Figure 4-25). That is, where the Hickory top is at a high elevation, so too are the water levels, and vice versa, where the Hickory top is low, the water levels are low. Ground water flow often occurs in aquifers from elevated areas where head potential is highest to topograhically lower areas where head potential is lower. In the Hickory the correlation between surface configuration and water levels indicate that flow will more likely be directed to the west and southwest of the Precambrian high where the Hickory top and water levels are topographically low. (Figures 4-25 and 4-28) This could suggest that this area may have enhanced ground-water yielding characteristics since flow is being directed there. The Hickory aquifer yields contoured on Figure 4-29 tend to substantiate this since higher yields are generally present in the area to the west and southwest of the Precambrian high.

The hydraulic characteristics of the Hickory Aquifer within the Texas Hill Country, summarized in TWDB Report 339 are as follows:

HICKORY AQUIFER
HYDRAULIC CHARACTERISTICS IN THE TEXAS HILL COUNTRY

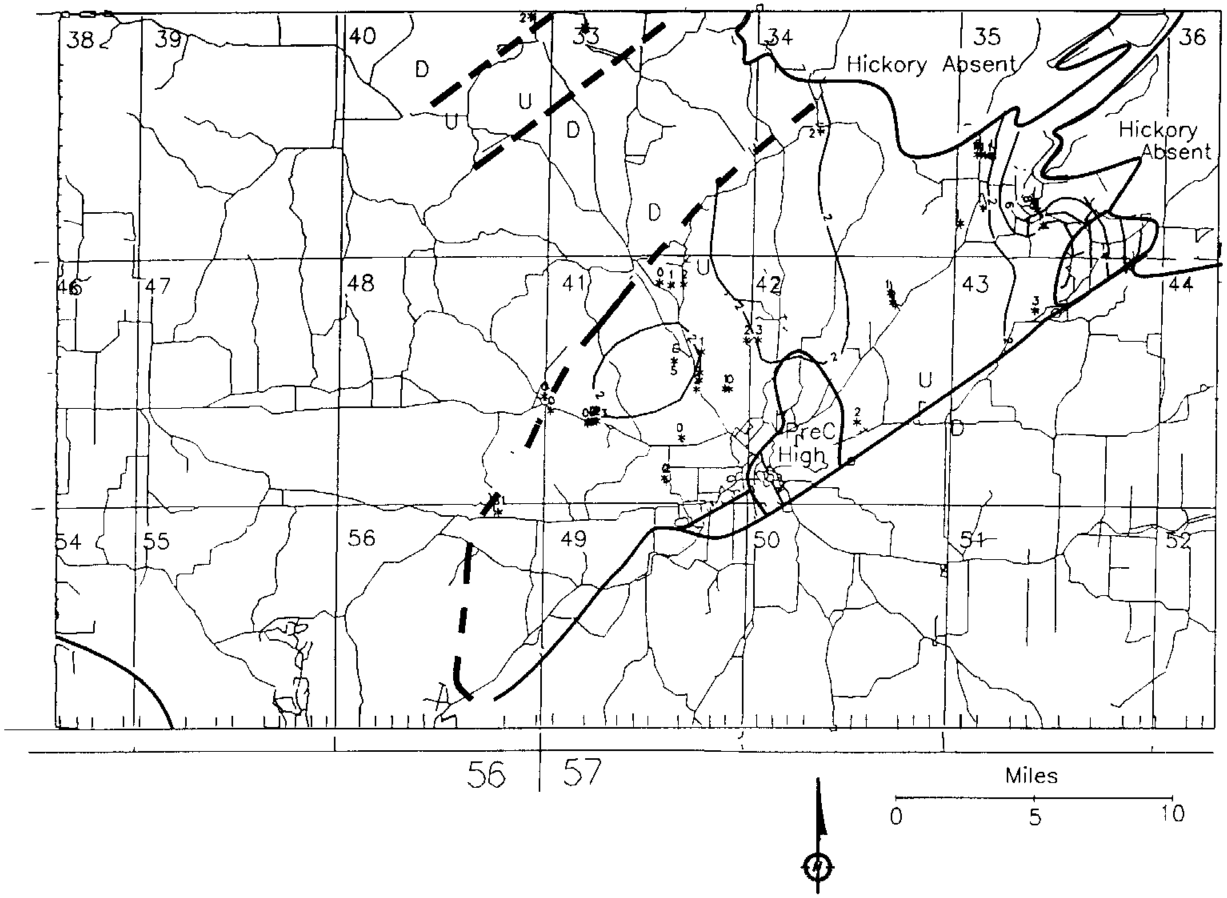
Specific Capacity	4 gpm/ft
Hydraulic Gradient	16 feet->100 feet/mile
Hydraulic Gradient	38-1,038 gpd/ft^2
Transmissivity	5,000-44,000 gpd/ft
Storage Coefficient	0.00004-0.0001
Porosity	3-42 percent

Water Quality

The water quality of the Hickory Aquifer in the Hill Country area is generally very good; however, like most of the Hill Country aquifers, it contains very hard water enriched in calcium and magnesium, and high in bicarbonate. Contaminant indicators such as chlorides and nitrates are low. Figure 4-30 is a map of nitrate concentrations showing that generally all Hickory wells, analyzed by the HCUWCD are below 5 mg/l NO_3 as N. One exception, is around the Willow City area where nitrate concentrations exceed the upper limit (10 mg/l NO_3 as N) considered safe by health authorities. At Willow City, the Hickory Sand outcrops and is very thin sitting upon granite. Here ground water is very shallow, (<50 feet below land surface) and some wells are high in nitrates (>10 mg/l NO_3 as N). However, county-wide, the Hickory is usually very low in nitrates and other contaminants.

The greatest water quality concern within the Hickory are radionuclides, in particular the radium isotopes Radium-226 and Radium-228. Both isotopes are daughter products, formed by the nuclear decaying process of uranium and thorium. These elements originated from the granites in the Llano Uplift and were incorporated into the Hickory during deposition and more recently by ground-water movement. These isotopes are very similar to calcium, and consequently are easily incorporated into ground water. Currently the upper safe limit for Radium-226 and Radium-228 in drinking water is 5 picocuries/liter for both isotopes added together. Within Gillespie County some wells are in excess of 20 picocuries/liter for both radionuclides. Radioactive logs can identify the zones within the Hickory where these isotopes are concentrated. In most cases they are limited to the silty clay

FIGURE 4-30
HICKORY AQUIFER NITRATE LEVELS (MG/L)
GILLESPIE COUNTY



zones within the unit. The HCUWCD is participating in a study being conducted by Texas A&M to provide a detailed evaluation of the Hickory. The results of the study will show why and how the high radioactive zones have occurred within the Hickory. This will provide answers as to how Hickory wells should be completed so that radionuclide enriched water will be sealed off.

GROUND WATER DEVELOPMENT AND AQUIFER CRITICALITY

Sustained yield for the Hickory aquifer within Gillespie County has been placed at 2000 acre feet per year, by the TWDB (Report 339). An attempt to calculate sustained yield is difficult for the Hickory due to its wide range of hydraulic properties (ie: hydraulic gradient, transmissivities) and its highly faulted nature. Generally only the Hickory present on the Fredericksburg High produces water within Gillespie County. This leaves a very large unexplored area adjacent to the High where the Hickory is deeply buried. There sizable amounts of ground water may be present. In other counties around the Llano Uplift high capacity municipal and irrigation wells are completed in deeply buried Hickory wells. Some of the areas within Gillespie County may also have deeply buried Hickory sediments with good ground water potential. However, exploration will prove costly, where expensive geophysical seismic surveys may be required prior to drilling wells. This will highlight certain areas for drilling. This very expensive type of exploration may occur in the future when additional ground water is needed to augment supplies.

In 1985, the TWDB ((Report 339) estimated that 201 acre feet of ground water was produced from the Hickory Aquifer. This amounted to 14 percent of the total 5124 acre feet produced from all aquifers within the County for that year. Projected demand for Gillespie County to the year 2030 has been placed at 10,076 acre feet without conservation and 9,192 acre feet with conservation. Should the Hickory continue to provide 14 percent of the total county wide demand, then in the year 2030 demand from the Hickory will reach 1410 acre feet per year without conservation, and 1287 acre feet with conservation. If the 2000 acre feet per year sustainable yield is accurate then it appears that the Hickory will not be in critical status in the year 2030. However, the Hickory is present around the City of Fredericksburg where future growth is projected to occur. Consequently the amount of demand on the Hickory may increase beyond the 14% county wide total currently supplied by this aquifer, especially since the overlying Hensell is projected to be in critical statues around Fredericksburg by the year 2030. This may require that more wells around Fredericksburg be deepened into the Hickory thereby increasing demand upon this aquifer. In addition, there may be less water available from the Hickory since certain zones may need to be sealed off from production due to high radionuclide concentrations.

Consequently, in the year 2030 the Hickory aquifer present on the Fredericksburg High may be in critical status, especially if we experience a repeat of the drought conditions of the 1950's. However, as was pointed out earlier, the Hickory is the least understood aquifer within the County and potentially could contain large amounts of ground water in the areas of the County where it is deeply buried. Additional study of this aquifer is warranted before its full potential can be assessed. This aquifer may also be a good candidate for Aquifer Storage and Recovery for storing treated surface water like the project currently underway in the Lower Trinity Group Aquifer in Kerrville, Texas.

SUMMARY

The four main aquifers within Gillespie County and usage information are as follows:

Aquifer	Typical Use	Area of Use	Amount Used in '85	% of Total in Co. in '85
EDWARDS	Stock Domestic	Western Gillespie Co.	557 ac.ft.	11%
HENSELL	Domestic Stock Irrigation	Throughout Gillespie Co.	1415 ac.ft.	28%
ELLENBURGER	Municipal Domestic/Stock Irrigation	Southeastern Gillespie Co.	2413 ac.ft.	47%
HICKORY	Municipal Domestic/Stock Irrigation	Central to Northeastern Gillespie Co.	701 ac.ft.	14%

Estimated sustained yields and projected future demands for the year 2030 are provided as follows for the four main aquifers within Gillespie Co.

Aquifer	TWDB (339) Sustained Yield	This Study Sustained Yield	Projected Demand 2030 High (10,076)	Low (9,192)	% Total
Edwards	1400 ac.ft.	1500 ac.ft.	1108	1011	11%
Hensell	3400 ac.ft.	3400 ac.ft.	2821	2574	28%
Ellenburger	4000 ac.ft.	5600 ac.ft.	4736	4320	47%
Hickory	2000 ac.ft.	2000 ac.ft.	1410	1287	14%
Total	10,800 ac.ft.	12,500 ac.ft.	10,075	9192	

The above data shows that the sustain yield of the four main aquifers within the County should be able to meet demand through the year 2030. However, in the preceding sections on each of the major aquifers, it was concluded that all aquifers, with the exception of the Edwards, could be at critical status by the year 2030. The demand from the Hensell and Hickory aquifers, currently providing 28% and 14% respectively of the County wide ground water totals, will probably increase due to their position near the City of Fredericksburg where growth is projected to occur. The Ellenburger is considered to be critical in 2030 due to the large discrepancy between the TWDB and the HCUWCD estimates of its sustainable yield (4000 TWDB vs 5600 HCUWCD acre feet). An average of the two yields gives 4800 acre feet per yield of sustainable Ellenburger yield. This is very close to high projected Ellenburger demand of 4736 acre feet in the year 2030, hence a critical status was assigned to this aquifer.

The Edwards does not appear to be in critical status due to the use and demand projection for that aquifer. It is believed that the Edwards will continue to serve mainly domestic and livestock needs in the western part of the County and currently provides 11 percent of the County ground water total. This percentage is not projected to increase, but if growth and demand increase significantly in this part of the County, then the Edwards may also become critical. In particular the area around Harper could become critical from a ground water availability and water quality standpoint by the year 2030.

SECTION 5

WATER RESOURCE MANAGEMENT OPTIONS

INTRODUCTION

The purpose of this section of the report is to present options for managing the available water resources. In order to establish a basis for the formulation of water supply alternatives in Gillespie County, two key management options considered were:

1. Role of Water Re-use
2. Role of Conjunctive Management

WATER RE-USE

The City of Fredericksburg currently discharges about 1.0 mgd (1,120 ac-ft/yr) of treated wastewater. This is expected to increase to approximately 1.6 mgd (1,800 ac-ft/yr) in 2030. The water quality in the Pedernales River may be affected when wastewater discharges become excessive.

The following paragraphs discuss the potential for use of reclaimed water in Gillespie County, by considering the quantity and quality of reclaimed water available for re-use, identifying public lands that may be available for irrigation with reclaimed water, and identifying agricultural consumptive uses currently relying on ground water that may be replaced with re-use. The complications of using bed and banks for transport to agricultural users will be addressed as well as the option of piping reclaimed water to the end users. The present quality of reclaimed water and the need for improving quality to meet various demands will be considered.

SOURCES OF RECLAIMED WATER

Existing Sources

The City of Fredericksburg operates a wastewater treatment plant which serves the City of Fredericksburg immediate area. The majority of the plant effluent is currently discharged into Barons Creek, which enters the Pedernales River immediately downstream.

The City of Fredericksburg also uses the plant effluent to irrigate the City Golf Course. The Golf Course has existing holding ponds which hold the effluent until ready for irrigation. However, the golf course is not capable of consuming all of the city's effluent. Therefore, a considerable amount of water re-use may be obtained from the effluent of the City of Fredericksburg wastewater treatment plant.

Increased supplies of reclaimed water will be available from the Fredericksburg wastewater treatment plant as the City of Fredericksburg grows. Reclaimed water might be used to replace ground water for irrigation and to bring new irrigated acres into production. The City of Fredericksburg owns and operates several city parks in addition to its one golf course. These facilities have varying degrees of need for irrigation water, which might be supplied by reclaimed water in the same manner that the golf course is.

The larger parks within the City of Fredericksburg may also be considered for installation of conveyance piping to deliver water to each facility. The smaller parks would be economical to serve with reclaimed water, only if they were adjacent to the conveyance line to the larger parks.

Future Sources

Increased supplies of reclaimed water will be available from the Fredericksburg wastewater treatment plant as the City of Fredericksburg grows. However, when return flows to the Pedernales River grow, water quality and nuisance algae problems could occur.

Irrigation of Agricultural Land

All of the irrigatable land in Gillespie County is irrigated with either surface or ground water. Reclaimed water can be used to replace ground water for irrigation and to bring new irrigated acres into production.

Hay/Land/Disposal

Production of hay and forage crop are other uses for reclaimed water. However, if water cannot be transported inexpensively such as by bed and banks, or the water source is not very close to the point of use, it is not economical to apply reclaimed water to these crops. The City of Fredericksburg has used land application to dispose of effluent from the wastewater treatment plant. Currently the City has approximately 20 acres of land that could be used to grow hay or forage crops. Reclaimed water could be applied to this land by the City or it could be leased out to a private operator.

Dual Distribution System

The ultimate water reuse option would provide reclaimed water for lawn irrigation to the City's residents and businesses. This would require installation of a reclaimed water distribution system alongside the existing potable water system. It is not usually cost effective or practical to retrofit a dual-distribution system to a developed area except under extreme conditions. These costs typically range from $300 to $1,000 per acre-foot, making the cost of this water comparable to the cost of potable water.

POTENTIAL AQUIFER STORAGE AND RECOVERY IN GILLESPIE COUNTY

It has been observed in certain areas of Gillespie County that some streams lose flow as they move downstream, indicating that there are stream reaches where significant amounts of recharge are occurring. A study currently being conducted by TWDB has revealed several areas where recharge is occurring.

A potential water management option would be to entrap surface water in a manner that maximizes the amount of recharge in these known areas of recharge occurrence. Enhanced recharge is utilized very effectively in southern California. Water is ponded in large upstream flood control lakes and then released at rates that maximize the effective recharge. The groundwater is then utilized as water supply for the heavily populated urban areas.

The Barton Springs/Edwards Aquifer Conservation District, in conjunction with TWDB, recently completed a study of potential artificial recharge enhancement for Onion Creek in Hays County, Texas. The area along Onion Creek was found to have numerous hydrogeologic features that were found to be significant recharge features including faults, fracture zones, solution channels, sinkholes and caves. The study included an engineering and environmental assessment of five artificial recharge enhancement projects. It was estimated that a 570 ac-ft of recharge along Onion Creek would result in a 1.0 ft rise in wells at Buda and would also increase water level elevations in the San Leanna area and eventually increase discharges through Barton Springs. It was concluded that artificial recharge enhancement on Onion Creek's Recharge Zone was feasible from an engineering, geologic, economic and environmental viewpoint. Potential average annual recharge ranged from 760 ac-ft per year up to 5,700 ac-ft per year depending the alternative chosen. Estimated costs for artificial recharge ranged from $0.10 to $0.34 per 1,000 gallons.

If the potential for significant volumes of artificial enhanced recharge exists within Gillespie County, it could offer several advantages over ASR and/or direct utilization of surface water supplies. The chief advantage is that enhanced recharge would not require treatment of the surface water. It is probable that with ASR, the surface water would have to be treated prior to injection. Detailed investigations would be required to adequately analyze the costs and benefits of artificial enhanced recharge projects in Gillespie County.

CONJUNCTIVE MANAGEMENT IN GILLESPIE COUNTY

Total water demand in Gillespie County will increase over the next twenty years, and as previously discussed, the City of Fredericksburg's demands can be met through a conjunctive management approach. The City Fredericksburg is the largest demand area in the County. The primary source of water used in the City is the Ellenburger Aquifer which has an estimated sustained yield of about 4,800 ac-ft/yr. Future demands on the Ellenburger will probably exceed 4,800 ac-ft/yr and water levels will decline if the demand is not partially met by other sources.

SECTION 6

WATER SUPPLY CONCLUSIONS AND RECOMMENDATIONS

The comparison of supply and demand provides a basis for the formulation of four basic conclusions/alternatives that have optional implementation strategies. These alternatives can be defined as:

Alternative 1	Continue present policies or no action
Alternative 2	Treat and Import water from the Lower Colorado River Authority with an interbasin transfer agreement
Alternative 3	Purchase Additional Water Rights and Develop Surface Water Storage
Alternative 4	Range and Brush Management

The population forecasts and estimates of future water usage established earlier in this report were used to determine the size and selection of water facilities needed for each of the alternatives (Table 6-1).

TABLE 6-1
PROJECTED TOTAL WATER USE IN GILLESPIE COUNTY
(Acre Feet/Year)

	Without Conservation				**With Conservation**			
	2000	**2010**	**2020**	**2030**	**2000**	**2010**	**2020**	**2030**
City of Fredericksburg								
Municipal	2,236	2,402	2,721	2,907	2,134	2,195	2,373	2,509
Manufacturing	540	677	904	1,150	540	677	904	1,150
Totals	2,776	3,079	3,625	4,057	2,674	2,872	3,277	3,659
Outside Fredericksburg								
Municipal	2,166	2,397	2,746	2,982	2,055	2,148	2,336	2,496
Irrigation	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Mining	12	9	5	2	12	9	5	2
Livestock	1,535	1,535	1,535	1,535	1,535	1,535	1,535	1,535
Totals	5,213	5,441	5,786	6,019	5,102	5,192	5,376	5,533
Gillespie County								
Totals	**7,989**	**8,520**	**9,411**	**10,076**	**7,776**	**8,064**	**8,653**	**9,192**

ALTERNATIVE 1 - CONTINUE PRESENT POLICIES

This alternative is predicated on the assumption that regional surface and ground-water supply systems are adequate throughout the life of the plan. Furthermore, a regional water supply system will not be developed. The City of Fredericksburg will continue to be the primary user of ground water in the County. The ground-water users outside of Fredericksburg will continue to draw from their water supply aquifers.

In the future, ground-water management will become a very important component to any regional water supply plan. This would entail the development and pumpage of future ground-water fields in some coordinated manner to maximize yield while minimizing the effect on ground-water depletion. The City of Fredericksburg will be doing this in the beginning of the Summer of 1995 when their new Ellenburger well field will be brought on line. Presently, the City gets nearly 90% of its water from six Ellenburger wells in a well field to the south east of Fredericksburg. Over the years this has caused some significant water level declines there. Their new field will allow the City to better manage their water resource by pumping from one field and allowing the other to recover.

This type of ground-water management will need to be utilized to a greater degree in the future and may need to be adopted by those who commercially irrigate. The various growers in the area who irrigate could in the future coordinate by forming some type of irrigation cooperative that could develop irrigation schedules within the County to maximize yield and minimize depletion.

Within Gillespie County some aquifers would be better suited to this type of management than others. As an example, the high yielding Ellenburger and Hickory aquifers could be developed more efficiently than the low to moderate yielding Edwards and Hensell aquifers. Apart from preferentially developing those areas where these aquifers have moderate ground-water yielding characteristics into small population (i.e. subdivisions) and commercial centers it is doubtful that these units could be managed on a regional basis. On the other hand, the Ellenburger and possibly the Hickory could be developed and managed regionally. In this Study, various areas within the County have been highlighted to show where these aquifers have good ground-water yielding potential. These areas could be developed into well fields from which water could be transported to areas that have little to no ground water, or to the highly populated centers within the County.

This type of ground-water management in conjunction with conservation and utilization of surface water either as a secondary drinking water source or as recharge to the aquifers within the County will ensure that water is available through the next century.

The City of Fredericksburg will continue to pump from the Ellenburger Aquifer and will store water in storage tanks as they do today. With the development of a good conservation program coupled with a good water reuse program/system, the City of Fredericksburg should be able to meet the demands of the future.

As previously mentioned in Chapter 4, the City produces annually on the average of 1.8-2.0 million gallons per day from six wells within the Ellenburger field. The HCUWCD estimates that to keep pumping levels above the cavity zone in the Boerner #5 well, annual pumpage should be limited to an average of 1.6 - 1.8 million gallons per day. Therefore, in response to the pumping levels at the City field, the City of Fredericksburg in the summer of 1993, purchased additional property approximately 3 miles to the east of the field. A six test well drilling program and subsequent pumping test indicate that 2-4 million gallons per day capacity is available at this new site. This field will be brought on line by the summer of 1995, and will augment the nearly 2 million per day average currently being produced from six wells in the existing City Ellenburger field. This will reduce the demand presently placed on the existing well field and ensure that pumping levels stay above the cavity zone for the foreseeable future. If additional ground-water resources are developed separate from the two fields described above, this should provide the City of Fredericksburg with an additional water supply that should accommodate their needs through the year 2030.

ALTERNATIVE 2 - TREAT AND IMPORT EXCESS WATER FROM LCRA

The central Texas region typically receives low amounts of precipitation while having relatively high evapotranspiration rates. These conditions, combined with soils possessing a low permeability rate, result in only small amounts of continuous runoff. Heavy runoff for limited periods during times of intense storms is also representative of the area. The intense ground-water use throughout the region has significantly reduced both the levels of and well pumpage yields from the available aquifers. These events have increased the public's awareness of the fact that our water resources are limited and the trends of its use is changing. The State's total yield of ground and surface water resources is estimated to be 16 million acre feet per year and are currently 75 to 80 percent developed. Texas has experienced a state-wide decline in the total irrigated acreage (approximately 670,000 acres during the period between 1985 and 1989) while the population has continued to increase, causing a shift in water use from agricultural to municipal and industrial (M&I).

In the past, ground water has been utilized to satisfy the demands for M&I uses throughout the region, however, the aquifer can only supply a limited amount of water before it is in danger of depletion.

The basic tenet of this alternative is that a water treatment plant and transmission line from LCRA to the City of Fredericksburg can be developed and constructed to supply the city with an additional water supply.

The assumptions for this alternative are:

1. The city would utilize waters from LCRA that would equal 50% of their demand.
2. LCRA would treat the water at Marble Falls and deliver treated water to the City of Fredericksburg.
3. A transmission main would be constructed in the Highway Right of Way of US Highways 281 and 290 to deliver the water to the City.
4. Ground waters not utilized by the City would be available for non city use.

Table 6-2 is a summary of the projected connections, customers to be served, WTP capacity and projected water usage for the City of Fredericksburg. Water Treatment Plant sizing is based on the Texas Natural Resource Conservation Commission's (TNRCC) minimum criteria of 0.6 Gallons Per Minute per Connection, for peak day water needs. Average water usage through the plant, was based on the average daily demand of 390 Gallons per Connection per Day, plus a 10% add on factor for system water loss in the delivery system. The average water use in this situation equates to approximately one-half of the peak day usage requirements.

TABLE 6-2

PROPOSED TREATMENT PLANT CAPACITY

YEAR	TOTAL SERVICE CONNECTIONS	50% OF SERVICE CONNECTIONS	TNRCC CRITERIA FOR CAPACITY [1] (MGD)	AVERAGE WATER USE [2] (MGD)
2000	3,370	1,685	1.50	0.725
2010	3,560	1,780	1.54	0.765
2020	4,030	2,015	1.75	0.865
2030	4,300	2,150	1.85	0.920

1) Projection based on TNRCC criteria of 0.6 Gallons per Minute per Connection for minimum peak day production
2) Projection based on 1993 average usage of 390 Gallons per Connection per Day with 10% water loss through the proposed system.

Based on the projected demands a 2 Million Gallon per Day initial water treatment plant is required to meet the proposed demands.

The initial treatment capacity of 2 MGD will provide system capacity until the year 2040. Key components of the treatment facility are sized in Table 6-3.

On-site storage of approximately seven (7) days has been planned for it to provide flexibility in the operation of the delivery system from Marble Falls. Sizing of the treatment units is based on TNRCC criteria for public water system design. Coagulant chemicals of aluminum or iron salts (alum or ferric chloride) and polymer are proposed for sedimentation. The turbidity and sediments will be removed by addition of the coagulant chemicals and settling through an upflow, solids contact clarifier. This unit minimizes process sizing, while saving chemical costs, by its ability to recirculate settled sludge to aid in water treatment. Final treatment will be through mixed media gravity filters to insure thorough treatment performance. Chlorine and ammonia will be used as disinfectants prior to on-site storage of the treated water in a clearwell.

TABLE 6-3
KEY COMPONENT SIZING

COMPONENT	SIZING
Max Flow Rate	2 MGD = 1,400 Gallons per Minute
Number of Connections (@ 0.6GPM/Connection)	2,333 Connections
Average Water Usage	390 Gallons/Day/Connection = 0.91 MGD ~1 MGD
On-Site Raw Water Storage	7 Days = 3 Million Gallons

BOOSTER PUMP AND GROUND STORAGE FACILITIES

The third stage of the treatment process is the Ground Storage and Booster Pump Station Facilities. Although it is proposed to deliver water to existing users (City of Fredericksburg) who already have storage facilities and pumping stations, additional booster pumps and storage facilities are needed

Table 6-4 indicates the improvements required for this phase of construction. These improvements have been sized for demands in the year 2040.

TABLE 6-4
BOOSTER PUMP / GROUND STORAGE FACILITIES

ITEM #	DESCRIPTION	QUANTITY	COSTS
1	Marble Falls Treatment Plant	2 MGD	3,250,000
2	16" Transmission Main	275,000 LF	13,200,000
3	Booster Pump/Storage Facilities	3 MGD	4,000,000
	Total Capital Costs		**20,450,000**

TREATED WATER DELIVERY SYSTEM

Delivery of the water to the City of Fredericksburg will be through a 16" transmission mains. Sizing is based on delivery of 1 gpm/connection with minimum pressure maintenance of 40 PSI residual. Design year is projected at 2040. Final sizing and location will depend on system requirements. The delivery points to each customer will be to their existing water production facilities. Preliminary sizing is based on $3/in-ft pipe diameter. Unit costs include contingency, engineering and survey.

TABLE 6-5

OPERATIONAL COSTS

Description	Costs	
Raw Water Costs *	0.17	Per 1,000 Gallons
Delivery Costs	0.15	Per 1,000 Gallons
Chemical Costs	0.06	Per 1,000 Gallons
Electric Costs	0.28	Per 1,000 Gallons
Labor Costs	0.75	Per 1,000 Gallons
Other Operational Costs	0.20	Per 1,000 Gallons
Total Operational Costs	**$1.61**	**Per 1,000 Gallons**

* excess yield

TABLE 6-6

CAPITAL COSTS/ COSTS PER 1,000 GALLONS

Description	Costs	
Marble Falls Treatment Plant	$0.63	Per 1,000 Gallons
Transmission Main	$2.57	Per 1,000 Gallons
Booster Pump/Storage Facilities	$0.78	Per 1,000 Gallons
Total Capital Costs	**$3.98**	**Per 1,000 Gallons**

Note : If capitalized over a multi-year bond period, costs per 1,000 gallons will be reduced.

The total capital and operational costs to deliver water is $5.59 per 1,000 Gallons.

ALTERNATIVE 3 - PURCHASE ADDITIONAL WATER RIGHTS AND DEVELOP SURFACE WATER STORAGE

This alternative will require the City of Fredericksburg to purchase additional water rights and develop a surface water impoundment. As previously mentioned, the City of Fredericksburg currently has water rights for 200 ac-ft/year for recreational use only. Using surface water as a municipal source will require obtaining additional water rights and/or purchasing water from a holder of existing rights.

Based upon the records available from the Texas Natural Resource Conservation Commission there are some 80 existing water rights authorizing the annual diversion of up to approximately 2,260.91 acre-feet per year.

All or a portion of these rights could be acquired by one or more of the Study Co-Sponsors by purchase, donation, condemnation of under limited circumstances the implementation of Section 11.028, of the Texas Water Code, which is commonly known as the Wagstaff Act. There are several legal limitations to the exercise of this alternative, as well as political and economic limitations.

The District conducted a survey of the 80 identified surface water rights in Gillespie County to determine their interest, if any, in the possible sale or donation for use in developing the County's future municipal water supply. Thirty-seven (37) surface water rights holders responded to the survey. Of those thirty-seven (37), seven (7) indicated an interest in selling their rights, which had a combined total of 416.87 acre-feet. Three (3) of the seven (7) who expressed interest in selling their water rights, which total 44.81 acre-feet, also indicated that they would consider donating them under certain conditions.

The legal limitations include the following:

The City of Fredericksburg can legally serve customers within its corporate boundaries and within its ETJ, and can acquire water rights outside of its boundaries to do so. However, the City would not be able to develop a water supply to serve the entire County.

Similarly, the County has the ability to develop a county-wide water supply and serve customers within the County outside of the incorporated boundaries of municipalities such as the City of Fredericksburg. The County would not, however, be providing uniform service to the entire County as a result. Accordingly, the most practical solution is the development of a County-wide water supply, capable of conjunctively managing available surface and ground-water supplies on both a wholesale and retail basis. Such an entity could serve unincorporated areas on a retail basis and sell water wholesale to municipalities such as the City of Fredericksburg or to any other municipal retail water purveyors within the County.

An entity such as the District, which is knowledgeable about water matters would be best suited for this purpose. However, the District's enabling legislation, as presently enacted, does not allow the District to develop and sell the proposed water supply.

First. the District is a ground-water District operating with the power enumerated in Chapter 52, Texas Water Code. Accordingly, as a general matter it lacks specific authority to acquire and sell surface or State water like a District operating pursuant to Chapter 51, Texas Water Code. Additionally, Section 19 of its enabling legislation expressly prohibits the District from entering "into any contract or engage[ing] in any action to supply underground water inside or outside the district."

Due to the conflict in the District's authority to develop ground-water resources, it is recommended that the District consider seeking an amendment to its enabling legislation to repeal the existing prohibition in Section 19 relating to ground water, at least within Gillespie County.

If Alternative Three is acted upon, in either whole or part, it should be undertaken in a manner deemed fit by all governmental entities involved to insure the development and delivery of a municipal water supply adequate to meet the demands of the residents of Gillespie County in both the incorporated and unincorporated areas of the County.

Two large water rights holders would likely be willing to consider selling water to the City of Fredericksburg. The LBJ Company, as previously mentioned, holds rights to large quantities of water in the Pedernales basin and does not currently utilize all of the water. Also, the LCRA holds water rights within the Colorado River Basin and recently passed legislation which allows them to sell water outside of their ten-county service area, but within the lower river basin. LCRA holds water rights that are senior to the LBJ Company rights.

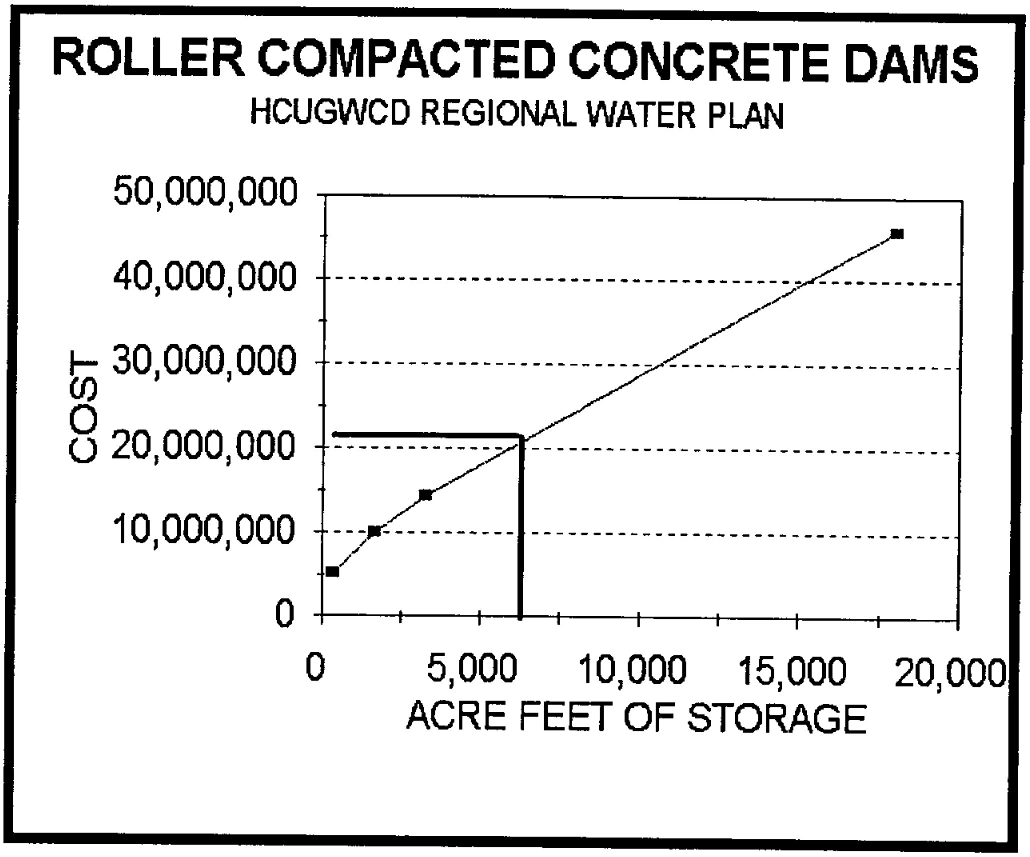
Engineering options for utilizing surface water include Surface Impoundment, ASR and Enhanced Recharge. ASR and enhanced recharge are methods for storing surface water as ground water for later utilization. Development of an on-channel reservoir would require environmental impact studies and extensive permitting, and is probably not an economically feasible alternative. In 1988 Espey, Huston & Associates, Inc. prepared the "Interim Status Report Engineering and Environmental Studies in Support of the Upper Guadalupe River Authority Application to the Texas Water Commission for Increased Diversions from the Guadalupe River". Within this report are cost comparisons for Roller Compacted Concrete Gravity Dams. Figure 6-1 applies the Espey Huston Graphs and inflates them for costs based on todays factors.

The City of Fredericksburg would require a firm yield of 2,240 acre-feet per year to supply a 2 MGD water treatment plant, and a storage capacity of 6,720 acre-feet (3 X Firm Yield). Costs for the reservoir would be as follows:

TABLE 6-7
CAPITAL COSTS / SURFACE WATER IMPOUNDMENT STRUCTURE

ITEM #	DESCRIPTION	QUANTITY	COSTS
1	Fredericksburg Treatment Plant	2 MGD	3,250,000
2	Surface Water Impoundment Structure	6,720 Acre Feet	21,700,000
3	Booster Pump/Storage Facilities	3 MGD	4,000,000
	Total Capital Costs		**28,950,000**

FIGURE 6-1



The preferred option would be utilizing tanks for off-channel storage, however, the supply from the Pedernales River is such that this alternative is also not feasible because there is not enough water to provide a dependable water supply. Surface water could only partially serve the County's water demands and it would be necessary to rely on groundwater during even minor droughts.

However, using surface water as a supply source when it is available may help to prevent depletion of the groundwater supplies so that adequate amounts of ground water will be available during periods of drought.

ALTERNATIVE 4 - RANGE AND BRUSH MANAGEMENT

Among other conservation efforts available to increase surface water supplies are range and brush management practices. The Soil Conservation Service, U.S.D.A., has implemented such practices in a pilot project in the Seco Creek Watershed. The project focuses on the clearing of non-productive high water consuming vegetation, particularly cedar trees. The project, which has been hailed by Environmental Concerns as one that is sensitive as the Golden Cheek Warbler, "increases surface water run-off by selectively removing large stands of cedar and other high water consuming vegetation. The increase run-off may be available to be used for recharge of ground-water formations and/or to firm-up available surface water rights. The project leaves mature cedar trees in areas that are not suitable for cultivation, such as along hillsides and rocky terrain, which based upon study results provides sufficient suitable habitat for various affected species.

While the total number of acre-feet of water potentially available for sale and/or donation is not significant, the entity ultimately identified to implement the county-wide strategy to develop the County's future water supply should investigate the acquisition of these rights. Issues which should be considered include the location of the water, how much would be available for municipal use, and whether the water would be available at the location it was needed. The answer to each of these questions would impact the price and economic feasibility of acquiring the water rights.

RECOMMENDATIONS

1) Due to a lack of enough surface water within Gillespie County to provide a dependable water supply, the Hill Country Underground Water Conservation District should continue to develop and enforce sound ground-water management policies. These should include thorough hydrogeologic studies of all aquifers within the District, with the intent of accurately estimating annual sustainable yield and how best to develop and maintain regional aquifer management.

2) Actively promote water conservation practices, proper well construction techniques, and plugging abandoned wells. Investigate the feasibility and effectiveness of increasing the amount of ground water and surface water through range and brush management.

3) The District in conjunction with all local entities continue to investigate and monitor the availability of surface water from sources outside of the District for the purpose of acquiring surface water in the future for the eventual conjunctive use of surface and ground water within the District. This would involve continuous dialogue with the River Authorities in both the Colorado and Guadalupe River Basins that currently hold surface water rights within these basins. The District should monitor water needs on a regional basis to determine whether future water needs within Gillespie County can be developed in conjunction with future water supply programs underway outside of the District.

4) Due to the fact that some areas within the county may experience water shortages in the future, the District should aid the residents in these areas in the development of regional water supply systems.

APPENDIX

WATER CONSERVATION
AND
DROUGHT MANAGEMENT PLAN

CITY OF FREDERICKSBURG

Prepared for the

CITY OF FREDERICKSBURG

By the

HILL COUNTRY UNDERGROUND WATER CONSERVATION DISTRICT

March 1992

WATER CONSERVATION AND DROUGHT MANAGEMENT PLAN

CITY OF FREDERICKSBURG

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WATER CONSERVATION AND DROUGHT MANAGEMENT PLAN

FREDERICKSBURG, TEXAS

CHAPTER 1

1.1 INTRODUCTION

The City of Fredericksburg is a Home Rule City operated with a Mayor/Council form of government in which a Mayor and four Council members are elected from the general public. All matters relating to City activities are approved by the Council. The City Manager ensures all work approved by Council is carried out.

The City of Fredericksburg provides water to approximately 2918 customers inside the city limits and to 235 customers outside the city limits. All water is obtained from nine water wells. Six wells produce water from the Ellenburger Limestone which comprises approximately 85% of the City's total production. Three Hickory Sandstone wells make up the difference and are used during peak demand months.

From the summer of 1989 to the summer of 1991, the city imposed water rationing. This was in response to water demand surpassing the City's capibility to deliver water through the distribution system and the subsequent decline in water levels in the City Ellenburger Water Field, located along the Old San Antonio Road. In that aquifer, water is derived from cavities located within an interval thirty to fifty feet from the top of the formation. Since 1989, pumping levels have fallen within this cavity zone during the summer months. This along with the population growth and water demand projections for the City of Fredericksburg (Appendix 1), has necessitated the development of a water conservation/drought management plan.

The Water Conservation Plan involves the implementing of permanent water use efficiency or reuse practices, while the Drought Management Plan established temporary programs designed to be used only as long as a water emergency exists.

1.2 GOALS

The goals of this plan will be the following:

- To limit annual water production to the point that water levels will not drop into the cavity zone of the Ellenburger aquifer. At present, it appears that if annual production from the six Ellenburger wells is limited to less than 600 million gallons, then water levels should, under average rainfall conditions, remain above the cavity zone.
- Achieving a significant reduction of water usage through a water conservation/drought management plan will provide a cushion before any additions to water service facilities are in place.

1.3 UTILITY EVALUATION

The following utility evaluation is provided as an aid in evaluating the potential effectiveness of the proposed conservation measures:

WATER SUPPLY AND DISTRIBUTION SYSTEM INFORMATION

A. Population of Service Area 7,500

B. Size of Service Area 4.54 (Sq.mi.)

C. Water Production and Sales Information

(1) Water Supplied (water produced from your own wells, diverted and treated from a lake or stream, purchased from another utility, etc.) during the Last Year 701,267,000 (gal/yr)

(2) Average Water Supplied for Last 3 years 745,419,667 (gal/yr)

(3) Estimated Monthly Water Sales by User Category for the Last Year in 1,000's of gallons (based on customer meters)

Month	Residential	Institutional	Industrial	Total
January	22,789.700	13,225.600	2,775.300	38,790.600
February	16,645.000	9,674.300	4,039.600	30,358.900
March	24,949.200	11,951.300	6,059.100	42,959.600
April	31,731.600	16,724.300	5,852.400	54,308.300
May	30,348.400	16,900.600	5,823.700	53,072.700
June	37,449.700	20,850.400	5,354.700	63,654.800
July	40,710.500	20,807.100	6,644.800	68,162.400
August	53,244.900	27,967.200	6,045.600	87,257.700
September	24,456.700	14,879.300	6,326.700	45,662.700
October	35,719.200	19,368.800	6,643.100	61,731.100
November	20,075.900	12,449.800	5,551.100	38,076.800
December	21,166.500	13,538.000	5,829.400	40,533.900
Total	359,287.300	198,336.700	66,945.500	624,569.500

(4) Highest Daily Water Use (production) on Record for System
4,077,000 (gal/day)
August, 1985

(5) Peak Daily Use (production) for the Last Year
3,019,000 (gal/day)
(August)

(6) Unaccounted for Water
(Production - Sales) ÷ production x 100 = 10.94%
Unaccounted for water

D. Number and Type (Residential, Commercial, or Industrial) of Meter Connections in Service Area
3228 (Res.) 605 (Comm.) 1 (Ind.) 0 (Wholesale)

E. Net Gain/loss of New Connections per year
(New Connections less disconnects)
36 (Res.) 20 (Comm.) 0 (Ind.) 0 (Wholesale)

F. Source of Water (List the sources and relative volumes of water used from each source on an annual basis)

Source 1. Wells Volume of Water 701,267,000 (Gal/yr)

G. Safe Annual Yield of Water Supply ? (Gal/yr)

H. Design Capacity of Water System 4,000,000 (Gal/day)

I. Major High-Volume Customers

	NAME	USE (in 1,000 gallons per year)
1.	Sunday House Foods	66,945.5
2.	Lady Bird Johnson Park	22,928.1
3.	Fredericksburg Public School	13,605.7
4.	Hill Country Mem. Hospital	8,001.6
5.	City of Fredericksburg (multiple meters)	7,169.3
6.	Knopp Nursing Home # 1	6,830.6
7.	City of Fredericksburg Sewer	6,667.6
8.	Gillespie Co. Fair Assoc.	5,653.0
9.	Browns Rest Home	4,245.6
10.	Fredericksburg Nursing Home	3,966.0

CHAPTER 2

WATER CONSERVATION PLAN

Chapter 2 comprises the various facets which make up the water conservation plan. A water conservation plan is a report that describes the methods and means by which water conservation is to be achieved. The various methods are employed throughout the year regardless of water demand.

The plan employs the following nine methods to ensure a successful year round water conservation program:

2.1 Public education and information program
2.2 Water conservation plumbing and plumbing retrofit program
2.3 Water Conservation Rate Structure
2.4 Universal metering and meter repair/replacement program
2.5 Water Audits and Leak Detection
2.6 Water Conserving Landscaping and Watering
2.7 Summer Lawn Watering Conservation Program
2.8 Recycling and Reuse
2.9 Plan Implementation and Enforcement

2.1 PUBLIC EDUCATION AND INFORMATION PROGRAM

The City of Fredericksburg is in a portion of Texas which receives on the average 28" of rainfall per year (Appendix 2). The years in which water rationing was imposed were years that received average to slightly below than average rainfall. Consequently, public education as to the need to practice water conservation is a very important component to this plan, especially since this area in the past has experienced very severe droughts (i.e. 1956 received only 11.3").

The City and the Water Conservation District will promote water conservation by informing the public of ways to conserve water. The following are examples of programs that will be utilized:

- A letter to all customers explaining the new water conservation/drought management plan will initially be sent

- An article in the local newspaper will appear explaining the plan

- Regular articles will appear in the local paper concerning water conservation

- Customers who are regularly high water users will be contacted and provided with water conservation information

- New customers will receive general conservation information when applying for service

- Approach the City's commercial customers about ways to reduce water usage. For example, restaurants could conserve water by providing water only to their customers who request it.

- Public speaking programs promoting water conservation will be given to civic groups. A significant portion of the groundwater hydrology course given annually by the Water Conservation District in conjunction with the community Education Program will highlight the need for water conservation.

- Programs such as Water Conservation Week will be utilized as a water conservation promotion. This would include newspaper articles and public service announcements aired on the radio.

2.2 WATER CONSERVATION PLUMBING AND PLUMBING RETROFIT PROGRAM

As of January 1, 1992, Texas law (Senate Bill 587) requires that only water conserving plumbing fixtures be manufactured, imported or supplied for sale in Texas. By September 1, 1992, labels with estimated water use for the fixtures will be required.

The maximum water use standards for specific types of fixtures are as follows:

Toilets	1.6 Gallons per flush (GPF)
Wall-mounted toilets	2.0 GPF
Shower Heads	2.75 Gallons per Minute (GPM)
Faucet aerators	2.2 GPM
Urinals	1 GPF

The City will adopt these standards in their plumbing code. The City will also inform and encourage customers of using water efficient appliances. Water conservation dishwashers which use only 6 gallons per load are now available. Efficient clothes washing machines use only 35 gallons per load, where as the average machine uses 45 to 55 gallons per load. The public will be informed of these water efficient appliances and encouraged to use them.

The City has participated with the Lower Colorado River Authority in distributing water saving plumbing retrofit devices. This program should be continued on a permanent basis. This would ensure that all plumbing fixtures, whether they are new or old, would eventually be water conserving. The hotel/motel industry will be advised of the benefits of retrofitting existing plumbing fixtures.

2.3 WATER CONSERVATION RATE STRUCTURE

As of January 23, 1992, the City has implemented a new water rate pricing structure which will encourage water conservation. The old rate was based on a declining block structure and is as follows:

Inside City Limits:

First 2,000 Gallons	$3.00 min.
Next 18,000 Gallons	$0.75/1000 gal.
Over 20,000 Gallons	$0.65/1000 gal.

Outside City Limits:
Double the above rates

The new rates are based on an increasing block schedule and are as follows:

RESIDENTIAL MONTHLY RATE

0-2000 gallons	$ 3.65 min.
2,001-15,000	$ 0.75/1000 gal.
15,001-25,000	$ 1.00/1000 gal.

25,001-30,000	$ 1.25/1000 gal.
30,001-40,000	$ 1.50/1000 gal.
over 40,000	$ 2.00/1000 gal.

Outside City Limits is double the above rates

GENERAL SERVICE COMMERCIAL MONTHLY RATE

0-2000	$ 5.00 min.
over 2000	$ 0.70/1000 gal.

Outside City Limits is double the above rates

INDUSTRIAL MONTHLY RATE

Service exceeds 2 million gallons/month
Next 11 months exceed 2 million gallons/month

0-2000	$75.00/min.
over 2000 gal.	$ 0.70/1000 gal.

Outside City Limits is double the above rates

2.4 UNIVERSAL METERING AND METER REPAIRS/REPLACEMENT PROGRAM

The City is 100 percent metered; however, some water usages such as fire hydrants go unmetered. The City has a policy of testing all meters which appear to have abnormally high or low water usage.

The City has established the following meter testing and replacement schedule:

- Production meters - tested once a year
- Meters larger than 1" - replaced every ten years
- Meters 1" and smaller - replaced every seven years

2.5 WATER AUDITS AND LEAK DETECTION

The Water Conservation District conducted a water audit for the year 1991 (Appendix 3). This audit broke out the various commercial users along with the residential. This audit will be conducted on an annual basis and includes an unaccounted for water loss evaluation.

The City in the past has performed leak detection surveys in conjunction with LCRA, in which a sonic leak detection device was used. This leak detection survey will be run on a periodic basis and additionally, should the annual audit identifies an increase in unaccounted - for water loss.

2.6 WATER CONSERVING LANDSCAPING AND AUTOMATIC LAWN SPRINKLERS

Water Conserving Landscape literature is available from the City, the Water Conservation District and the County Agricultural Extension Office. The Gillespie County Agricultural Building has been landscaped using native shrubs and ground covers. This serves as a xeriscape demonstration project. In addition, the city will use low water tolerant landscaping plants as much as possible on public grounds to limit water usage but also to serve as an example for the general public. The City has a building ordinance that requires a certain amount of green space on commercial developments. The City will encourage that low water tolerant plants be utilized wherever possible to satisfy this green space requirement.

The Water Conservation District conducted a survey of households with automatic lawn sprinklers. The survey computed annual water usage prior to the installation of the system as well as water usage after installation. This survey is shown on Appendix 4. The results indicate that average annual water usage after sprinkler installation increased by 28%. Additional surveys of this nature will be done by the City and the Water Conservation District.

In the future, any customer who applies for a building permit for an automated water sprinkler will be advised that their water usage may increase and that the automatic cycling should be set so that no more than 1" of water is applied per week. Sprinkler gauges will be available to aid in determining how long the system should be allowed to run to provide 1" of water.

The automated water sprinkler installers will also be advised of the survey results and provided with sprinkler gages to aid in the setting of the water cycles.

2.7 SUMMER LAWN WATERING CONSERVATION PROGRAM

Each summer between the months of June through September, the City will promote a summer lawn watering conservation program. The program will be voluntary until the trigger conditions outlined in the following Drought Management Plan are reached, then it will become mandatory. The program is designed to create a mind set for conserving water throughout the summer months, whether drought conditions are present or not. This should help to flatten the peak demand curve which normally develops under mandatory rationing measures.

The program would be structured so that people could water their lawn on specified days of the week based on the last digit of their street address. The last digit of the address will correspond to the following days for which lawn watering may occur.

Last digit of the address	Lawn Watering Day
0 - 3	Tuesday & Saturday
4 - 7	Wednesday & Sunday
8 - 9	Thursday & Saturday

This will allow for watering at least twice a week. If this schedule is followed, the quality of lawns will improve since this will promote deeper root penetration. Those customers with automatic sprinklers should be encouraged to switch their system from automatic to manual, so that the twice weekly watering schedule can be followed. Watering should occur only between the hours of 7 p.m. and 10 a.m.

2.8 WATER RECYCLING AND REUSE

The city has recently changed from using ground water to recycled water for watering the City's golf course. This has had the immediate savings of over 20 million gallons used annually on the City's nine hole golf course. However, an additional future savings will be seen beginning in the summer of 1992 when the course is expanded to eighteen holes.

In addition, the City will study where recycled water could be appropriately used for other landscape irrigating applications, (i.e. racetrack, cemeteries).

2.9 PLAN IMPLEMENTATION AND ENFORCEMENT

The plan will be adopted by the City Council. The City Manager and his staff will oversee the execution and implementation of all elements of the plan. He will also be responsible to oversee the keeping of records for program verification.

The plan will be implemented by the following documents:

- A resolution by the city stating its water conservation goal through the adoption of this plan

- An Ordinance by the City which will provide the necessary legal documents to enforce this water conservation plan

The Resolution and Ordinance adopted by the City Council may be found in Appendix 5 and 6.

Any contract with another political subdivision of the state of Texas will be approved only if that entity adopts the City of Fredericksburg's Water Conservation and Drought Management Plan.

CHAPTER 3

DROUGHT MANAGEMENT PLAN

A Drought Management Plan is an emergency water demand management plan which includes measures to be implemented to cause a significant, but temporary, reduction in water use due to drought conditions. Other uncontrollable circumstances that can disrupt the availability of a City's water supply are contamination or disaster. There is a significant difference between a drought management plan and a water conservation plan. Water conservation involves the implementing of permanent water use efficiency or reuse practices, while the Drought Management Plan establishes temporary programs designed to be used only as long as a water emergency exists.

This Drought Management Plan includes the following programs:

3.1 Trigger conditions which indicate when the necessary drought contingency measures will be put into effect

3.2 Drought contingency measures

3.3 Education and information concerning when initiation procedures for contingency measures are met

3.4 Termination notification

3.5 Means of Implementation

3.1 TRIGGER CONDITIONS

The City receives the bulk of its water from the Ellenburger Limestone aquifer. At the City's water field, the Ellenburger limestone is encountered at approximately 90' below land surface. The water is produced from cavities located within an interval 30' to 50' from the top of the formation. The trigger conditions will be based on the pumping level in relation to the cavity zone in the Boerner # 5 well, which is the largest water producing well in the field. The cavity zone in the Boerner # 5 well is encountered at -120' and extends to -140'. Trigger conditions will be set for moderate and severe conditions. During times of drought, the well will be monitored frequently.

MODERATE CONDITIONS - Pumping levels in the Boerner # 5 will fall within -115' and -125'

SEVERE CONDITIONS - Pumping level in the Boerner # 5 falls below -125'

3.2 DROUGHT CONTINGENCY MEASURES

Drought contingency measures will be used to flatten the peak demand curve as required by the drought conditions.

Moderate Conditions

When the trigger conditions indicate moderate drought conditions have been reached. The City Manager can restrict the use of water through the following:

- Notify the public through the news media that the trigger condition for moderate drought conditions have been reached. Steps will be provided which will allow for the reduction of water use.

- Major commercial water users will be notified of the situation and request to voluntarily reduce water use.

- As moderate conditions intensify, mandatory lawn watering schedules will be implemented. The two day watering cycle outline in Section 2.7 of the Water Conservation Plan will become mandatory. Watering shall occur only between the hours of 7:00 p.m. to 10:00 a.m.

- Waste of water will be prohibited. Water waste will include water from landscape irrigation or other uses to escape into gutters, ditches, streets, sidewalks and other surface drains. Waste of water will also include the failure to promptly repair a leak due to detective plumbing after it is discovered, along with any other obviously wasteful uses as determined by the City.

- Penalties for noncompliance with any of the drought contingency measures will be set by the Council and enforced by the City.

Severe Conditions:

Under sever conditions, the City Manager may further restrict or ban the use of water totally for outdoor purposes. When the trigger condition indicates that severe drought conditions have been reached, the City Manager will implement the following:

- Notify the public through the news media that the trigger conditions for a severe drought have been reached. The public will be advised daily of the trigger condition.
- Outdoor water usage such as lawn and shrub watering will be further restricted or totally banned.
- Car washing prohibited except when a bucket is used.
- Private swimming pool filling may be banned.
- Public water uses not essential for public health or safety may be prohibited.

3.3 EDUCATION AND INFORMATION

Once Trigger Conditions and emergency measures have been reached. The public will be informed of the conditions and measures to be taken. The process for notifying the public includes:

- Posting the Notice of Drought conditions
- Notifying the local radio station & cable TV
- General circulation to the local newspaper

The public will be informed about the drought contingency plan periodically through the education and information activities of the long-term water conservation program.

3.4 TERMINATION NOTIFICATION

Termination of the drought measures will take place when the Trigger Condition which initiated the drought measures have subsidized, and an emergency situation no longer exists. The public will be informed of the termination of the drought measures in the same manner that they were informed of the initiation of the drought measures.

3.5 MEANS OF IMPLEMENTATION

The City Manager will be responsible for administering the drought contingency plan. The City will adopt a drought contingency resolution that (1) provides the city with the pre-assigned authority to implement any or all of the mandatory water use restrictions from the approved drought contingency plan whenever a specified trigger condition is reached and (2) provides enforcement procedures and penalties for noncompliance with the restrictions.

1992 WATER AUDIT
OF THE
CITY OF FREDERICKSBURG'S
WATER DEMAND

Prepared by the Hill Country Underground
Water Conservation District

INTRODUCTION

This report presents a water audit of the total water supplied by the City of Fredericksburg. The total amount supplied has been broken down by category and the water usage of these various categories is presented in the tables below. In addition to 1992 water usage, a comparison to 1991 water usage is also given. This comparison provides an increase or decrease in gallons that each category used in 1992 as compared to that of 1991. This increase or decrease in water usage is also presented as a + \- percentage.

Category	Table
Summary of All Water User Categories	I
Residential Water Use	II
Food Processing Water Use	III
City, County, Public Facility Water Use	IV-A, IV-B, IV-C
Non-Water Dependent Commercial Water Use	V
Hospital/Nursing Home, Clinic Water Use	VI
Motel Water Use	VII
Restaurant Water Use	VIII-A, VIII-B
School Water Use	IX
Water Dependent Water Use	X
Church Water Use	XI

DISCUSSION

In 1992, a total of 678,195,540 gallons of water were metered for sale across Fredericksburg. This represents a 3% increase over 1991, when 655,916,184 gallons were sold (Table I). This 3% increase amounts to 22,279,356 gallons of water. This increase occurred in a year when near record amounts of rainfall occurred (40.63").

The greatest increase in water use occurred in the residential category. A 6% increase in water use occurred in 1992 over that used in 1991 (Tables I & II). This increase amounted to 24,033,876 gallons.

The other categories which recorded increase water use over the previous year included:

Non-Water Dependent Ind.	+ 4,388,160 gal.	(+ 11%)	Tables I, V
Motel	+ 3,520,812 gal.	(+ 19%)	Tables I, VII
Restaurant/Industrial	+ 6,227,304 gal.	(+ 34%)	Tables I, VIII A&B

The increase in these three categories are all probably related and due to an increase in the amount of tourism in Fredericksburg.

The remaining eight categories (Table I) identified in this audit showed a decrease in water usage in 1992 as compared to 1991. The City, County and Public Facility had a 14% decrease in water (7,515,936 gal.) usage in 1992, which can be attributed in large part to the use of treated water to irrigate the golf course. A savings of 15,479,100 gallons was seen at Lady Bird Johnson Park in 1992, where treated water was used to irrigate the golf course (Table IV-B). However, the City of Frederickburg and the Pedernales Youth Soccer recorded substantial increases in their water usage in 1992. Fredericksburg used 5,311,212 gallons more in 1992 than in 1991, a 73% increase, and the Pedernales Youth Soccer Association used 1,488,948 gallons more in 1992, which represents a 237% increase over 1991. Both increases are apparently due to the irrigation of soccer fields. Table IV-C lists all the City's meters and the amount of water used for 1992 and 1991 along with a comparison.

RECOMMENDATIONS

The following provides some suggestions which may be used to reduce water usage in the areas where an increase in demand was recorded in 1992.

Residential

1) The high residential water users should be tagged and contacted either by letter or some other form of mail out and notified of their high water use. An evaluation of their water use should be attempted and the user advised of any water conservation methods available which will help in lowering their water requirements.

2) Implementation of the lawn watering conservation program outlined in the Water Conservation/Drought Management Plan provided for the City.

3) Review of water rate structure.

4) Promotion of plumbing retrofit programs and water conserving landscaping.

Tourism

1) Contact all motels and promote plumbing retrofiting for showers, faucets and toilets.

2) Contact all restaurants and promote plumbing retrofiting for all restrooms and kitchens.

3) Encourage restaurants to serve water only on request.

City, County and Public Facility

1) The increases in water usage in this category results mainly from irrigation. All irrigation by City, County or Public Facilities should be monitored very closely. Irrigation should be controlled manually and not on automated timers. Irrigate only when it is necessary and only in the cool hours of the day. Schools, hospitals and churches should also follow these guidelines.

2) Ensure all public facility plumbing is water conserving.

The Hill Country Underground Water Conservation District is available to assist the City in promoting any and all water conservation programs the City wishes to promote.

Paul Tybor
Manager

WATER DEPENDENT INDUSTRIAL
WATER USE - 1991

COMPANY	MONTHLY AVG.	ANNUAL TOTAL
V & R Inc. Laundermat	212,191	2,546,292
E. Main Launderette	136,508	1,638,096
Wunderlich	70,899	850,788
George Ready Mix	61,274	735,288
Culligan	49,983	599,796
Kwik Car Wash	47,500	570,000
S & S Car Wash	20,016	240,192
	598,377	7,180,452

NON-WATER DEPENDENT COMMERCIAL WATER USE - 1991

COMBINED MONTHLY TOTAL	COMBINED ANNUALTOTAL
3,202,345	38,428,140

CHURCH WATER USAGE
1991

CHURCH	MONTHLY AVG.	ANNUAL TOTAL
Zion Lutheran	59,772	717,264
Holy Ghost	47,540	570,480
Fredericksburg Bible	47,025	564,300
Fred United Methodist	40,224	482,688
Church of Christ	37,591	451,092
Memorial Presbyterian	34,111	409,332
Bethany Lutheran	32,608	391,296
St. Mary's	27,591	331,092
United Penecostal	26,241	314,892
Emanuel Gospel	19,308	231,696
First Baptist	19,050	228,600
Assembly of God	16,250	195,000
St. Barnabas Episcopal	13,233	158,796
Fbg. Cong. Jehovah	12,233	146,796
Resurrection Lutheran	9,583	114,996
Baptist Spanish	9,450	113,400
New Hope Baptist	6,316	75,792
Our Lady of Guad.	3,500	42,000
Fredericksburg SDA	3,416	40,992
Hill Co. Evang.	2,558	30,696
Living Water	1,800	21,600
Fredericksburg Baptist	1,733	20,796
First Christian	633	7,596
	471,766	5,661,192

SCHOOL WATER USAGE
1991

SCHOOL	MONTHLY AVG.	ANNUAL TOTAL
Fredericksburg Public	1,133,807	13,605,684
St. Mary's	277,513	3,330,156
Fredericksburg Christian	2,941	35,292
	1,414,261	16,971,132

RESTAURANT WATER USAGE
1991

RESTAURANT	MONTHLY AVG.		ANNUAL TOTAL
Andy's	196,199		2,354,388
Friedhelm Baverian	151,725		1,820,700
Mamacita's	132,125		1,585,500
The Gallery	114,195		1,370,340
Golden Corral	108,700		1,304,400
Dairy Queen	98,833		1,185,996
Sunday House Inn	96,191		1,154,292
Plateau	85,625		1,027,500
Sonic Drive-Inn	72,991		875,892
Fenner & Beans	51,433		617,196
Altdorf	51,325		615,900
Austlander	43,150		517,800
Bircks	37,950		455,400
Fredericksburg Cafe	36,666		439,992
Mr. Gatti's	32,716		392,592
Georges German Bakery	29,816		357,792
Pizza Management Inc.	28,575		342,900
Engel's	26,000		312,000
Linden Baun	23,150		277,800
Fredericksburg Bakery	18,233		218,796
Danny's Fried Chicken	17,183		206,196
Deluxe Restaurant	16,750		201,000
Burger Inn	15,891		190,692
Delux Icebox	13,808		165,696
Bunzy's	13,574		162,888
The Cookie Jar		11,941	143,292
Alfredo's	9,916		118,992
Korner Koffee	4,966		59,592
	1,539,627		18,475,524

MOTEL WATER USAGE
1991

MOTEL	MONTHLY AVERAGE	ANNUAL TOTAL
Catering of C. Texas/ Sunday House	319,433	3,833,196
Comfort Inn	191,258	2,295,096
Save Inn	165,183	1,982,196
Econo Lodge	152,775	1,833,300
The Peach Tree	147,432	1,769,184
Sunset Inn	139,074	1,668,888
Tourist, Inc.	104,316	1,251,792
Deluxe Motel	100,083	1,200,996
Dietzel Motel	94,891	1,138,692
Miller Courts	78,316	939,792
Frontier Inn	34,050	408,600
Frederick Motel	24,800	297,600
Barons Creek Inn	16,750	201,000
	1,568,361	18,820,332

HOSPITAL/NURSING HOME/CLINIC
WATER USAGE - 1991

ESTABLISHMENT	MONTHLY AVG.	ANNUAL TOTAL
Hill Country Mem. Hosp.	666,798	8,001,576
Knopp Nursing # 1	569,181	6,830,172
Browns Rest Home	353,799	4,245,588
Fbg. Nursing Home	330,500	3,966,000
Knopp Nursing # 2	264,094	3,169,128
Fredericksburg Clinic	111,016	1,332,192
Dr. Raleigh A. Smith	28,560	342,720
Dr. Michael Jones	26,425	317,100
Dr. Tim Barsch	13,866	166,392
Keidel Mem. Hosp.	12,250	147,000
Cornerstone Clinic	8,400	100,800
Dr. John S. Hoerster	8,041	96,492
Mid-Tex Health Care	5,241	62,892
Dr. Steve Kroger	4,866	58,392
Dr. Phillip Kothman	2,166	25,992
Kerrville State Hospital	600	7,200
	2,405,803	28,869,636

CITY, COUNTY & PUBLIC FACILITY
WATER USAGE - 1991

ENTITY	MONTHLY AVG.		ANNUAL TOTAL
Lady Bird Johnson Park	1,910,675		22,928,100
City of Fredericksburg	597,445		7,169,340
City of Fbg. Sewer	555,633		6,667,596
Gillespie Co. Fair Assoc.	471,083		5,652,996
City of Fredericksburg Water	161,300		1,935,600
Nimitz Center	153,811		1,845,732
St. Mary's Cemetary	137,285		1,647,420
Greenwood Cemetary	112,033		1,344,396
Gillespie Co. Historical Soc.		65,629	787,548
Ped. Youth Soccer	52,458		629,496
Gillespie Co. Courthouse		42,000	504,000
Texas Highway Dept.	37,266		447,192
Gillespie Co. Law Enf.	34,708		416,496
U. S. Post Office	33,025		396,300
Central TX Elect. Coop	26,966		323,592
Gillespie Co. Farm Bureau	17,833		213,996
V.F.W.	17,800		213,600
American Legion	13,216		158,592
Gillespie Co.	12,216		146,592
Gillespie Co. Com. on Aging	9,175		110,100
Texas Dept. of Human Res.		7,866	94,392
Ft. Martin Scott	5,716		68,592
Fredericksburg Chamber	5,075		60,900
Fredericksburg Gene. Soc.	800		9,600
	4,481,014		53,772,168

FOOD PROCESSING WATER USAGE
1991

COMPANY	MONTHLY AVG.	ANNUAL TOTAL
Sunday House Foods	5,578,791	66,945,492
Fredericksburg Lockers	230,366	2,764,392
Dutchmans Market	52,066	624,792
	5,861,223	70,334,676