Report 321

Evaluation of Water Resources of Fort Bend County, Texas

January 1990

Texas Water Development Board

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by
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Published and Distributed
by the
Texas Water Development Board
P.O. Box 13231, Capitol Station
Austin, Texas 78711-3231

ABSTRACT

This evaluation of water resources in Fort Bend County is in response to the 1985 passage of House Bill 2 by the Sixty-ninth Texas Legislature. This Legislation called for the identification of study areas in the state that are experiencing, or are expected to experience within the next 20 years, critical underground-water problems. The study area is located on the Gulf Coastal Plain in southeast Texas. Climatic conditions are subtropical-humid, characterized by high rainfall. Agribusiness dominates the economy, with petroleum production, sugar refining, and small petrochemical plants also contributing.

In 1985, water demands in Fort Bend County were met with approximately equal amounts of ground water and surface water. Groundwater needs, including all municipal and domestic requirements, were supplied almost entirely from the Chicot and Evangeline aquifers. Annual availability (effective recharge) for the Chicot and Evangeline is approximately 55,581 acre-feet; however, an estimated 120 million acre-feet of fresh water is held in storage within the aquifer system. Heavy ground-water withdrawals, mainly for municipal and irrigation purposes, have resulted in large water-level declines and subsequent land-surface subsidence. In the northeastern part of the county declines in excess of 100 feet have been measured. This same area has experienced up to 2 feet or more of subsidence. Chemical quality of ground water from the Chicot and Evangeline aquifers is generally good and has shown no significant variation since the late 1960's. There are several areas in the vicinity of salt domes, however, where the occurrence of poorer quality ground water is a natural condition.

Surface water from the Brazos River supplies most of the industrial demand which, along with irrigation, makes up the largest portion of total water use in Fort Bend County. Most surface-water supplies are distributed by the Brazos River Authority and the Galveston County Water Authority.

In 1985, total use of ground water and surface water in Fort Bend County was 136,794 acre-feet. Projected demands are expected to reach 205,034 acre-feet by the year 2010. In addition to current surface-water supplies it is estimated that an additional amount of uncommitted surface water, in excess of 100,000 acre-feet per year, could be available for future use in Fort Bend County. Additional long-term future supplies will depend upon the development of future projects within the Brazos River basin or possible purchase of previously committed water from other entities. Ground-water pumpage from the Chicot and Evangeline aquifers has exceeded annual availability since the late 1960's. By 2010, projected municipal and domestic demands alone will be greater than annual availability. Although ground water in storage within the aquifer is sufficient to meet future demands, heavy pumpage in concentrated areas will most likely result in significant water-level declines. Therefore, future ground-water development programs will require careful planning in order to avoid a recurrence of historical ground-water problems.

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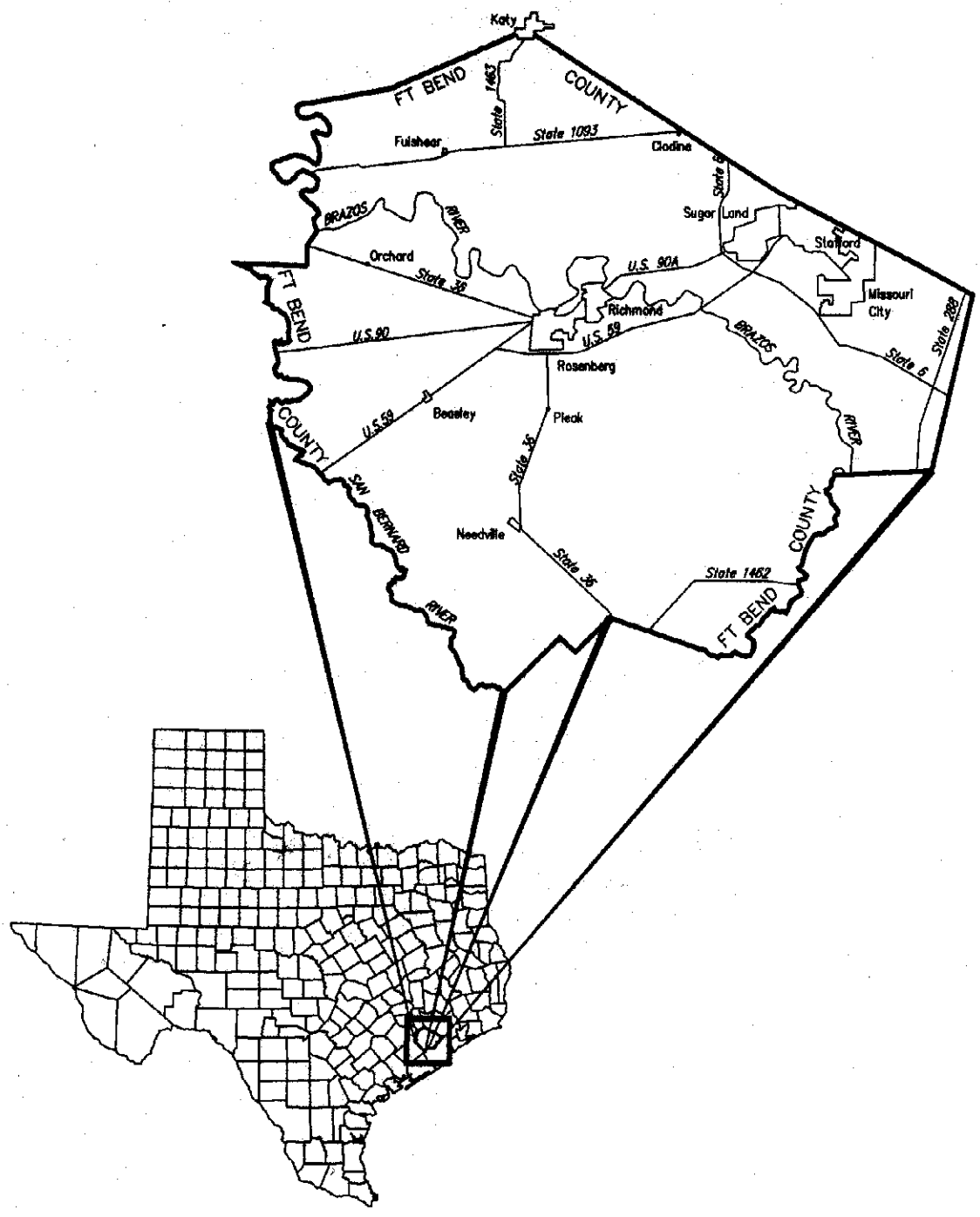

Figure 1

LOCATION OF STUDY AREA

Previous and Current Investigations

Numerous ground-water investigations have been conducted in the Fort Bend County area. The principal investigator for most of these studies has been the U.S. Geological Survey in cooperation with the Texas Water Development Board and its predecessor agencies. Some studies are regional in nature, while other were made on a county scale. The U.S. Geological Survey has recently completed a study in Fort Bend County (G. L. Locke, manuscript in preparation) documenting ground-water withdrawals from 1969 to 1987 and any changes in water levels, water quality, or land-surface subsidence which may have occurred. Publications relating to the geohydrology of the aquifer system in Fort Bend and surrounding counties are listed in the selected references of this report.

Geologic mapping in the area is best presented on the Houston and Seguin Geologic Atlas Sheets published by the University of Texas, Bureau of Economic Geology. The base map for this work was adapted from these sheets.

Currently the U.S. Geological Survey maintains a system of water-level and water-quality observation wells in Fort Bend and other counties which surround the Harris-Galveston Coastal Subsidence District. The data collected through this network is used to publish basic-data reports and periodic maps and reports addressing water-level and water-quality changes in the aquifers and land-surface subsidence in the area. Fort Bend County is also included in the Survey's Gulf Coast regional aquifer system analysis project which is designed to define the hydrogeologic framework of the Gulf Coast aquifer system and to simulate regional flow patterns using a computer model.

Acknowledgements

The authors wish to thank numerous individuals for their cooperation in providing information on the aquifers in their area. More specifically, appreciation is extended to city, county, and water supply district officials who furnished information concerning their municipal water-supply systems, and to the many property owners who allowed access to their wells to measure water levels and sample for chemical quality.

Additionally, special thanks are given to the staff of the U.S. Geological Survey who provided a draft copy of the latest Fort Bend County study with data and results of recent trends in water levels, water quality, and land-surface subsidence. Mr. Tom Ray of the Brazos River Authority provided information on surface-water availability, and his efforts are appreciated.

GEOHYDROLOGY

Geology as Related to Ground Water

Stratigraphy

The geologic units composing the aquifers in Fort Bend County range in age from Miocene to Holocene. They are, from oldest to youngest, the Oakville Sandstone, Fleming Formation, Goliad Sand, Willis Sand, Bently Formation, Montgomery Formation, Beaumont Clay, and the Quaternary alluvium. These units generally consist of alternating beds of sand, gravel, clay, and silt.

Outcrops of the Beaumont Clay, the Montgomery Formation, and Quaternary alluvium occur in Fort Bend County (Figure 2). The older formations crop out in the counties north of Fort Bend County. One or more of the formations may be absent at any specific location due to nondeposition or erosion, and the sand-clay ratio of the formations varies considerably from location to location. Sand occurs in bands which may be either parallel or perpendicular to the coastline. Regionally, all of the formations dip toward the gulf at an angle greater than the slope of the land surface and generally thicken with depth in the downdip gulfward direction.

Earlier investigators in the Gulf Coast region of Texas attempted to delineate aquifer units on the basis of geologic formations. This has proven difficult because in the younger sediments the aquifers generally consist of parts of one or more geologic formations. Because of the difficulty in differentiating the formations in the subsurface, they are commonly grouped together and collectively referred to as the Gulf Coast aquifer.

Wesselman (1967) subdivided the Gulf Coast aquifer in Jasper and Newton Counties into four hydrologic units: The Jasper aquifer, Burkeville aquiclude, Evangeline aquifer, and Chicot aquifer. These subdivisions were also used in Fort Bend County (Wesselman, 1972). Baker (1979) adopted the same subdivisions and correlated the aquifers across the entire coastal plain of Texas. They are also used for this report (Table 1).

Figure 3 is a geologic cross section which illustrates the stratigraphic relationships between the different aquifers within Fort Bend County.

Jasper Aquifer

The Jasper aquifer is composed of terriginous clastic sediments of the Oakville Sandstone which form sand and clay interbeds. In Fort Bend County the aquifer does not contain fresh water, but electrical logs indicate that it contains slightly saline water in the northwest part of the county. Total thickness ranges from approximately 600 to 1,600 feet; however, the maximum thickness of sands containing slightly saline water is about 100 feet. Because ground water of superior quality can be obtained from shallower zones, no water wells have been completed in the Jasper aquifer in Fort Bend County.

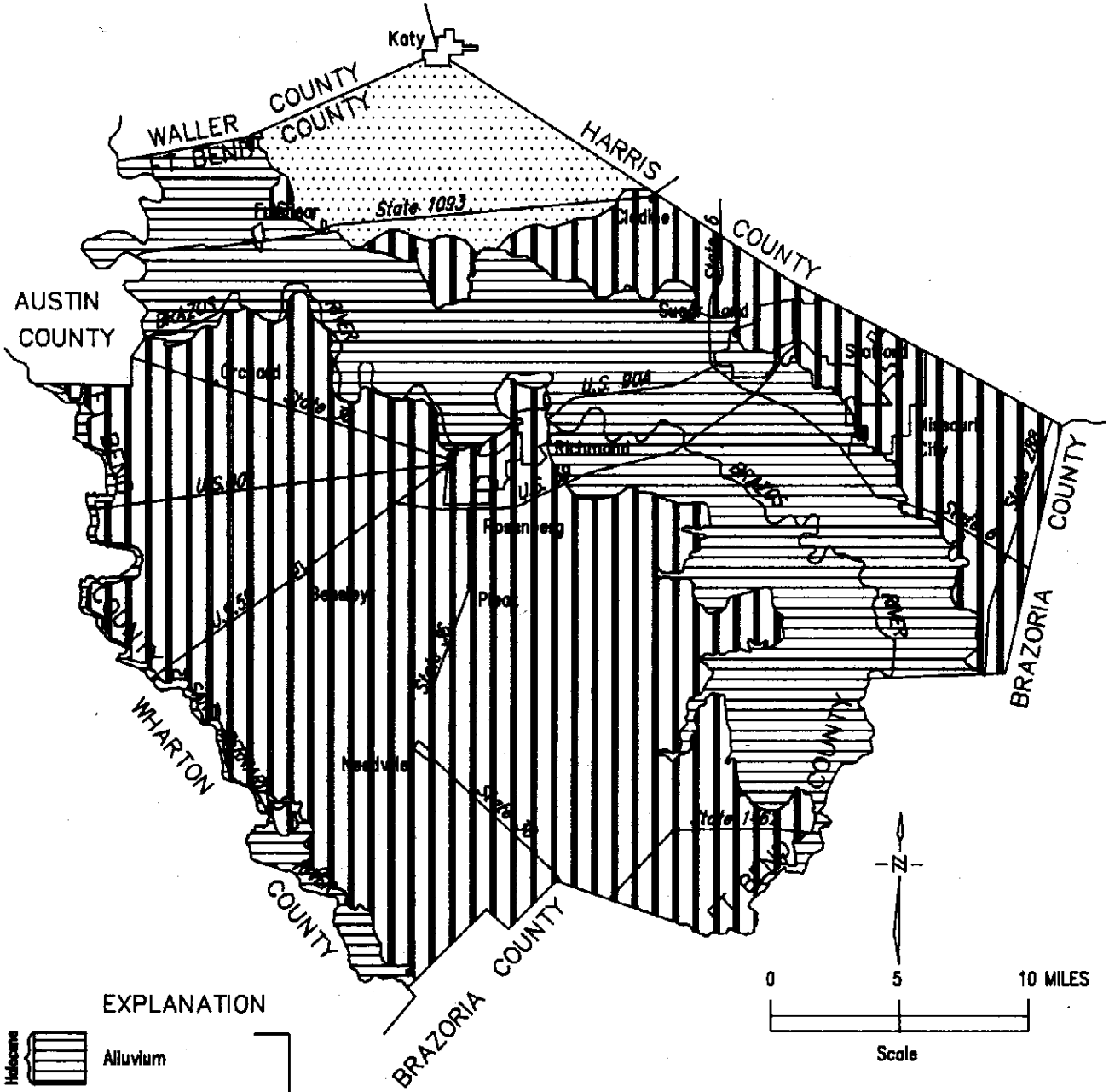

Figure 2

GEOLOGIC MAP OF FORT BEND COUNTY

Base map and geology adapted from Houston and Seguin sheets of the Geologic Atlas of Texas, Bureau of Economic Geology, The University of Texas at Austin

Burkeville Confining System

The Burkeville confining system is composed predominantly of silt and clay of the Oakville Sandstone and Fleming Formation. Its boundaries are somewhat irregular as they are not restricted to a single stratigraphic unit, but transgress the Fleming-Oakville contact and incorporate that portion of each unit which is made up of a relatively large percentage of silt and clay when compared to the underlying and overlying strata.

Typical thickness of the Burkeville ranges from 300 to 500 feet. It separates the Jasper and Evangeline aquifers and functions as a confining unit which retards the flow of water between the two aquifers.

Evangeline Aquifer

The Evangeline aquifer, which overlies the Burkeville confining system and underlies the Chicot aquifer, is composed of sediments of the Goliad Sand and Fleming Formation. In most of Fort Bend County, the Evangeline aquifer contains 400 to 700 feet of sand. The percentage of sand in the section ranges from about 33 to about 40 percent. The thickest sand beds and thickest fresh-water sections occur in the eastern half of the county. Total thickness (except over some salt domes) ranges from 1,200 to 2,200 feet.

The Evangeline is noted for its abundance of good quality water and is considered one of the most prolific aquifers in the Texas Coastal Plain (Baker, 1979). Well yields have been measured in excess of 2,000 gpm.

Chicot Aquifer

The Chicot aquifer is a sequence of sand and clay beds which overlies the Evangeline aquifer. Stratigraphic units which make up the Chicot aquifer are the Willis Sand, Bently Formation, Montgomery Formation, and Beaumont Clay of Pleistocene age and any overlying Quaternary alluvium.

Total aquifer thickness in Fort Bend County ranges from 300 to 800 feet. Sand thickness ranges from about 40 percent of the total thickness in the eastern part of the county to about 70 percent in the northern and northwestern parts.

The Chicot aquifer is subdivided into upper and lower units. In most of the southeastern part of the county, the two units are separated by a layer of clay, which is 200 to 300 feet below the land surface. The two units merge and generally function as a single aquifer in the northwestern part of Fort Bend County.

In southeast Texas, the Chicot aquifer is the source for large amounts of good quality ground water. Wells in Fort Bend County yield as much as 4,200 gpm.

Table 1. Correlation of Stratigraphic and Hydrologic Units in Fort Bend County

<table>
<tr><th>System</th><th>Series</th><th>Stratigraphic Unit</th><th colspan="2">Hydrologic Unit</th></tr>
<tr><td rowspan="5">Quaternary</td><td rowspan="5">Pleistocene</td><td rowspan="3">Quaternary Alluvium</td><td rowspan="5">Chicot Aquifer</td><td>Upper Unit</td></tr>
<tr><td>Beaumont Clay</td></tr>
<tr><td>Montgomery Formation</td><td rowspan="3">Lower Unit</td></tr>
<tr><td>Bentley Formation</td></tr>
<tr><td>Willis Sand</td></tr>
<tr><td rowspan="4">Tertiary</td><td>Pliocene</td><td>Goliad Sand</td><td colspan="2">Evangeline Aquifer</td></tr>
<tr><td rowspan="3">Miocene</td><td>Fleming Formation</td><td colspan="2">Burkeville confining system</td></tr>
<tr><td rowspan="2">Oakville Sandstone</td><td colspan="2">Jasper Aquifer</td></tr>
<tr><td colspan="2"></td></tr>
</table>

(Modified from Wesselman, 1972 and Baker, 1979)

Source and Occurrence

There are several sources of ground water in the Chicot and Evangeline aquifers in Fort Bend County. The primary source is precipitation, which is abundant. A large amount of precipitation is lost to surface evaporation or becomes runoff to local steams and lakes. Other portions which do infiltrate the soil are lost by transpiration through plants. There is a small part however, of the original precipitation which does move slowly downward, by gravity, and becomes part of the saturated zone or water table. Other sources include seepage from streams and lakes, vertical leakage of ground water from one aquifer to another, and lateral movement through the aquifer from areas outside Fort Bend County.

All ground water occurs under either water-table or artesian conditions. In the Chicot aquifer, water-table conditions exist in major stream valleys where the upper unit of the aquifer is in hydraulic continuity with surficial sand deposits. Here, the top of the zone of saturation is under direct atmospheric pressure. Wells in this area are filled with water to the level of the water table, and water levels fluctuate in response to the volume of water in storage. At most locations in Fort Bend County, where the Montgomery Formation and Beaumont Clay crop out, water in the Chicot aquifer occurs under artesian conditions. The Evangeline aquifer is also under artesian conditions throughout the county. Where this condition exists, and the aquifer is tapped by wells, hydrostatic pressure will cause water in the wells to rise above the top of the aquifer and, in some cases, actually flow to the surface.

Recharge, Movement, and Discharge

Recharge to the Chicot and Evangeline aquifers occurs primarily from precipitation on the aquifer outcrops in Austin, Harris, and Waller Counties. With the exception of parts of the upper unit of the Chicot, water moves into the aquifers in Fort Bend County mainly by lateral flow. The Evangeline also receives some additional recharge by vertical flow in areas where it is in contact with basal sands of the overlying Chicot.

Ground water moves under the influence of pressure from areas of recharge to areas of discharge. The general direction of movement of fresh water, before pumping began, was down-gradient toward the coast and toward areas in the major alluvial systems where the aquifers are interconnected vertically. The deeper sands had the highest head and therefore, they discharged into the overlying sands wherever the sands were sufficiently interconnected. The shallower sands, in turn, discharged to the streams (Wesselman, 1972).

Heavy withdrawals from the aquifers, however, have altered the movement patterns. Now the highest head is in the Chicot aquifer and the lowest head is in the Evangeline aquifer. Therefore, in addition to the horizontal component of movement, the water is moving downward instead of upward throughout the county. Recent piezometric maps of the Chicot and Evangeline aquifers (Locke, in preparation) indicate horizontal movement in the north and west parts of the county to be generally in an east-southeasterly direction. Movement in the east and southern parts of the county is to the east and northeast toward major pumpage centers.

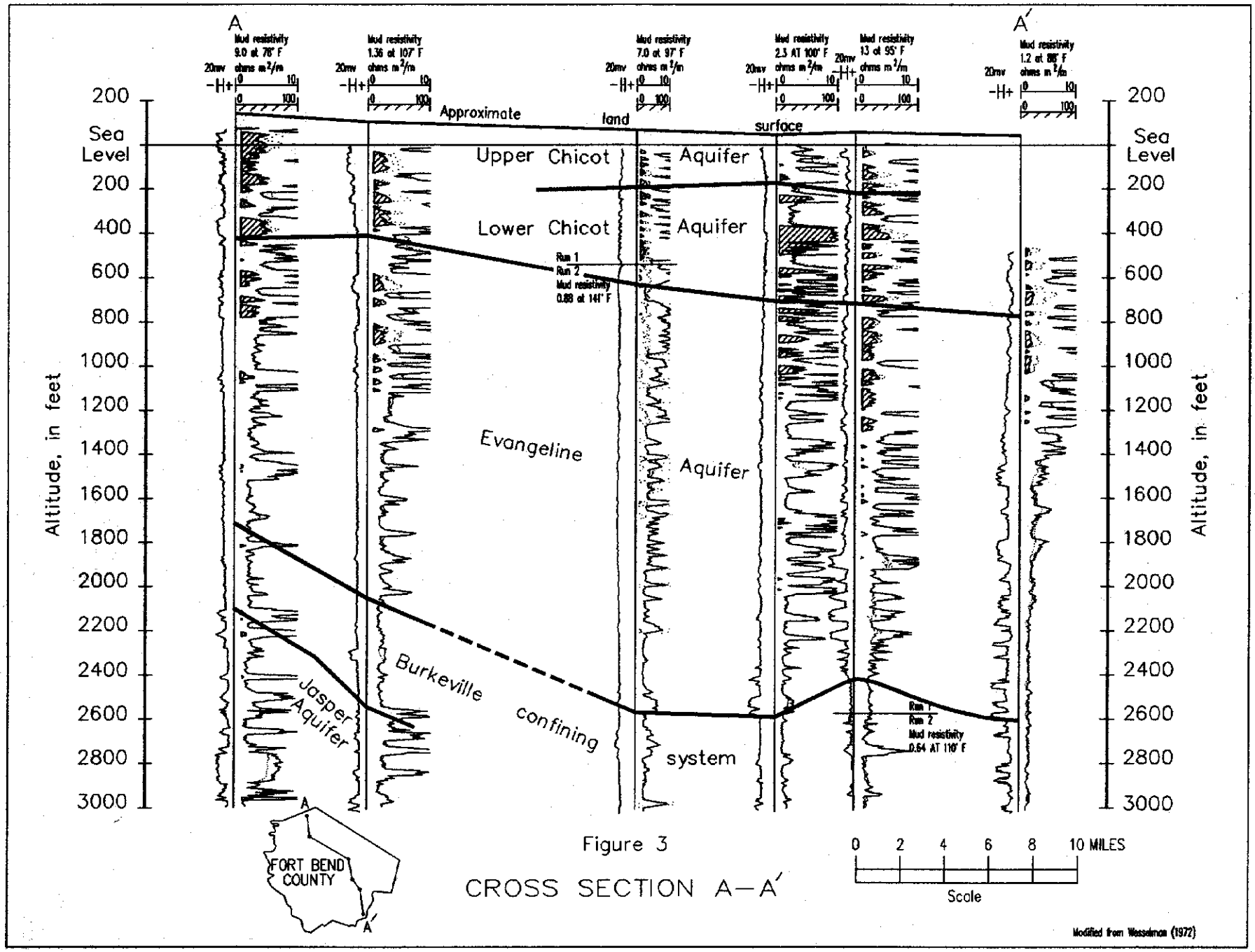

Figure 3

CROSS SECTION A—A′

Ground-water discharge from the aquifer system occurs through both natural and artificial means. Natural discharge occurs as flow to seeps, springs, transpiration by plants, and by evaporation. Some discharge from the Chicot also takes place as leakage to the underlying Evangeline. Ground water is discharged artificially through wells by pumping. In 1985, 68,047 acre-feet of ground water was pumped from wells in Fort Bend County (Texas Water Development Board, 1988).

Hydraulic Characteristics

Hydraulic characteristics of an aquifer are generally expressed in terms of its transmissivity and coefficient of storage. These parameters are determined by the porosities and hydraulic conductivities of the sediments which make up the aquifer and control its capacity to yield water to wells. Through pumping of a test well and the use of repeated measurements of the water levels in the pumping well and nearby observation wells, the transmissivity and coefficient of storage can be determined. Since these values are a measure of the aquifer's ability to transmit and store water, they can be used to determine the effects that a pumping well may have on another well, and to predict water-level drawdowns at various distances from a pumping well after a specified pumping time and at a given pumping rate.

Based on average sand thickness and hydraulic conductivity, Wesselman (1972) reports an average transmissivity for the Chicot aquifer in Fort Bend County of approximately 30,000 square feet per day. The coefficient of storage determined from one test was 0.0001. Wells completed in the Chicot yield as much as 4,200 gallons per minute with specific capacities ranging from 5.5 to 69 gallons per minute per foot of drawdown.

Sands of the Evangeline aquifer in Fort Bend County are similar to those in the Houston district (Wesselman, 1972). Using similar hydraulic conductivity and average fresh water sand thickness, the average transmissivity for the Evangeline is approximately 10,000 square feet per day. Coefficients of storage, based on a large number of tests in the Houston district, range from 0.001 to 0.002. Yields of wells producing from the Evangeline range from less than 200 to more than 2,000 gallons per minute.

GROUND-WATER PROBLEMS

The following sections condense and briefly summarize the results of a recent study conducted by the U.S. Geological Survey in Fort Bend County. The purpose of the study was to document ground-water withdrawals from 1969 to 1987 and any resulting changes in water levels, water quality, and land-surface subsidence which may have occurred. A report of the study (G. L. Locke) is currently in preparation and contains basic data including water-level measurements, water-quality analyses, and land-surface subsidence determinations, and related discussions. Interrpretive maps are also included which illustrate the most current status of ground-water problems within the county. These maps were not included in this report, but will be available upon publication of the Survey's study.

Water-Level Declines

Water-level declines caused by large amounts of ground-water pumpage have been a concern in Fort Bend County for many years. Wesselman (1972) reports declines in wells completed in the upper Chicot ranging from 10 to 40 feet during the period 1947 to 1968-69. Wells completed in the lower Chicot had water-level declines of as much as 130 feet for the same period. From 1900 to 1968-69, water-level declines in the Evangeline aquifer ranged from 60 feet in the northwest part of the county to more than 190 feet in the northeastern part.

Since 1968-69, measurements indicate that there has been little change in water levels in the upper Chicot. Declines and rises were generally less than 4 feet. Between 1968-69 and 1987, water-levels in the lower Chicot declined by amounts ranging from less than 10 feet in the western and southwestern parts of the county to about 90 feet in the northeastern part. It is interesting to note that since 1982, water levels in wells completed in the lower Chicot, and located outside major pumpage centers that are in the northeast area of the county, have generally risen or remained stable as a result of reductions in ground-water pumpage. In the northeastern area however, water levels have declined continuously since 1969 due to increasing municipal pumpage. Water levels in the Evangeline aquifer have declined since 1968-69 by amounts ranging from less than 25 feet in the northwestern part of the county to 125 feet in areas of major pumpage in the northeastern part (Locke, in preparation).

Water Quality

Comparison of chemical analyses for wells in Fort Bend County indicate that there has been no significant change in ground-water quality since 1969. In general, values of total dissolved solids for the upper and lower Chicot and the Evangeline are less than 500 milligrams per liter (Locke, in preparation).

Recent analyses do show some areas in the county were poorer quality water exists. These areas are in the vicinity of salt domes. Where salt domes are shallow and pierce the aquifers, fresh and saline waters come into contact with each other and make poorer quality water in the area a natural condition.

Land-Surface Subsidence

The main cause of land-surface subsidence at some locales in the gulf-coast region of Texas is the production of oil and gas and the withdrawal of ground water associated with them. In the Houston-Galveston and surrounding area, which includes Fort Bend County however, most subsidence is caused by ground-water pumpage for municipal, industrial, and irrigation purposes.

As water is withdrawn from an aquifer under artesian pressure, there is a corresponding decrease in pore pressure. The result is an increase in pressure on the aquifer skeleton to support the weight of the overburden. Differential pressure between the sands and clays causes water to move from the clays into the sands. With the loss of water, the clays become compacted and subsidence of the land surface occurs.

Declining water levels in Fort Bend and Harris Counties have resulted in significant land-surface subsidence. Subsidence is calculated by comparison of bench mark elevations as determined by the National Geodetic Survey. Measured in 1978, subsidence in Fort Bend County ranged from less than 0.5 foot in the southwestern part to more than 2.0 feet in the northeastern corner. The northeastern part of Fort Bend County is most susceptible to land-surface subsidence because of concentrated ground-water development, large water-level declines, and relatively high clay content of the sediments (Locke, in preparation).

PROJECTED WATER DEMANDS

Population

The population of Fort Bend County has shown significant growth, increasing by 37 percent from 1980 to 1985. In 1985, the Cities of Missouri City, Needville, Richmond, Rosenburg, Stafford, and Sugar Land had a combined population of 94,069 or approximately 58 percent of the total for the county. The population for these cities is projected to more than double to 193,569 by the year 2010 (Texas Water Development Board, 1988).

Population in rural areas in 1985 was 68,314 which is a 32 percent increase since 1980. Rural population is projected to increase to 171,639 by the year 2010. The 1980 and 1985 population for cities and rural areas along with projected estimates for the years 1990, 2000, and 2010 are shown in Table 2. Population projections for Fort Bend County were estimated using the revised Texas Water Plan High Series population projection methodology (Texas Water Development Board, 1988).

Water Use

In 1985, total use of ground water and surface water in Fort Bend County was 136,794 acre-feet, of which 78 percent (106,642 acre-feet) was for industrial and irrigation purposes. The amount of water used for all purposes in 1980 and 1985 is shown on Table 3.

Ground water and surface water made up approximately equal portions of total water used in 1985 (68,047 acre-feet of ground water vs. 68,747 acre-feet of surface water). All municipal and domestic demand, however, was met with ground-water sources. This amount, 29,227 acre-feet, was 21 percent of total water use. The bulk of surface-water supplies is provided by the Brazos River Authority and used for all but municipal and domestic purposes. In 1985, 45,892 acre-feet of surface water was used for industrial needs and 22,486 acre-feet for irrigation. Irrigation use in 1985 (54,580 acre-feet) showed the most significant decline since 1980 (30,646 acre-feet). This was due to a combination of several possible factors including increased urbanization, reduced surface-water contracts, a scheduled off year for rice irrigators, and improved irrigation methods.

Projected Water Demands, 1990-2010

Current and projected water demands by use category are shown in Table 3. Projections of future municipal and rural requirements are based on 1988 Texas Water Development Board Revised Data Series population projections and projected high series per capita water use. Future projections of irrigation, industrial, and livestock use are based upon high series projected demands and the apportioned share of total county demands. High series projections take into account the demands that are likely to occur during drought conditions.

Under high series projection conditions, the total annual water requirement for Fort Bend County is expected to increase by 50 percent from 1985 to the year 2010, at which time the annual demand is estimated to be 205,034 acre-feet. Municipal and domestic requirements alone are projected to increase 114 percent to 62,434 acre-feet annually during this period. The largest projected demands under these conditions continue to be for industrial and irrigation purposes which, by 2010, are projected to total 141,149 acre-feet annually. Although demand for irrigation water dropped significantly between 1980 and 1985, future demands are projected to return to amounts consistent with historical use by 1990 (85,901 acre-feet) and then decrease again by 2010 (71,465 acre-feet) as the result of better irrigation techniques changing, cropping patterns, and increased urbanization in Fort Bend County.

Table 2. Current and Projected Population of Fort Bend County [1]

Year	Cities [2]	Rural [3]	Total
1980	67,218	51,714	118,932
1985	94,069	68,314	162,383
1990	121,329	84,811	206,140
2000	158,217	132,026	290,243
2010	193,569	171,639	365,208

[1] 1980 and 1985 population is based on Bureau of Census statistics. 1990, 2000, and 2010 population is based on 1988 Texas Water Development Board Revised High Series population projection.

[2] The term "Cities" include Missouri City, Needville, Richmond, Rosenburg, Stafford, and Sugar Land.

[3] The term "Rural" includes cities and unincorporated areas with a 1980 population of less than 1,000 and all rural population.

Table 3. Current and Projected Water Demands By Use in Fort Bend County [1]

(Units: Acre-Feet)

	1980	1985	1990	2000	2010
Municipal	10,637	15,086	20,872	26,528	31,367
Industrial [2]	42,639	52,062	57,328	63,378	69,684
Irrigation	80,646	54,580	85,901	73,313	71,465
Domestic [3]	9,153	14,141	17,132	25,349	31,067
Livestock	1,056	925	1,252	1,451	1,451
Total	144,131	136,794	182,485	190,019	205,034

[1] 1980 and 1985 water demands are based on reported and site-specific computed use; 1990, 2000, and 2010 water demands are based on Texas Water Development Board High Series Preliminary Draft dated September 1988. Amounts include both surface-water and ground-water sources.

[2] Industrial demand includes water used for manufacturing, power and mining uses.

[3] Domestic includes cities and unincorporated areas with a 1980 population of less than 1,000 and all rural population. It also includes entities which have population residing in Harris County but have ground-water supplies in Fort Bend County.

AVAILABILITY OF WATER

Current Ground-Water Availability

Annual ground-water availability in Fort Bend County, as derived from the reports, "Water For Texas" (Texas Department of Water Resources, 1984) and "Ground-Water Availability in Texas" (Müller and Price, 1979), is divided between the Gulf Coast aquifer and the Brazos River alluvium. In this report, the Brazos River alluvium has been included as part of the upper Chicot aquifer. However, due to its relatively limited extent and development in Fort Bend County, it will be treated as a separate unit for the availability discussion.

In Fort Bend County, the Brazos River alluvium occurs as a band 3 to 10 miles wide along the Brazos River. Annual ground-water availability for the unit is approximately 23,452 acre-feet. Historically, withdrawals from the aquifer have been relatively small. In 1985, total pumpage was 2,054 acre-feet for irrigation purposes. This amount is only 6 percent of total ground-water pumpage for irrigation in Fort Bend County and 3 percent of total ground-water pumpage for all uses.

The Gulf Coast aquifer is equivalent to the Chicot, Evangeline, and Jasper aquifers used in this report. Development of these units in Fort Bend County is limited to the Chicot and Evangeline aquifers. Annual ground-water availability of the Chicot and Evangeline is approximately 55,581 acre-feet. This estimate is based on the results of a digital computer model used to evaluate the long-term regional water-supply capabilities of the Gulf Coast aquifer (Müller and Price, 1979). It is the estimated annual effective recharge derived by utilizing a constant hydraulic gradient in the model and represents the volume of ground water which can be developed on an annual basis without causing large-scale water-level declines, land-surface subsidence, or saline-water encroachment.

It should be noted that effective recharge in Fort Bend County is not a fixed amount, but varies in response to the hydraulic gradient. If the gradient is increased, by lowering water levels, effective recharge will increase to some degree. However, this will also increase the potential for the occurrence of the previously mentioned problems.

Nearly all of Fort Bend County is underlain by sands containing fresh and slightly saline water extending to various depths. The volume of water stored in these sands is considerably more than the annual effective recharge. Wesselman (1972) estimates that the volume of fresh water stored in the Chicot and Evangeline aquifers in Fort Bend County is approximately 120 million acre-feet. Only a small percentage of this total, however, is economically recoverable. The amount of water available to wells in the study area depends upon several factors. In addition to the amount of water in storage, they include the amount of recharge, the ability of the aquifer to transmit water, and the effects that water withdrawals have on water levels and subsidence. Since 1969, withdrawals have exceeded the annual effective recharge, as determined from modeling results

to the Chicot and Evangeline aquifers in Fort Bend County. This has resulted in significant water-level declines, especially in the northeastern part of the county where municipal development is concentrated (Locke, in preparation).

Current Surface-Water Availability

Currently, available surface-water supplies have been sufficient to meet demands in Fort Bend County. In 1985, 68,747 acre-feet of surface water was used in the county, mainly for industrial and irrigation purposes. Nearly all of this amount was obtained from the Brazos River and most of it was distributed by the Brazos River Authority and the Galveston County Water Authority. In addition to surface water under current contract with these two entities, it is estimated that an additional amount of uncommitted water, in excess of 100,000 acre-feet per year, could be available for use in Fort Bend County (J. T. Ray, Brazos River Authority, personal communication).

Potential for Additional Ground-Water Development

Ground-water resources in Fort Bend County have not been fully developed. Although ground-water pumpage (68,047 acre-feet in 1985) has exceeded the annual effective recharge, a substantial volume of water still remains held in storage in the county (Wesselman, 1972). Fresh-water sands in the Chicot and Evangeline aquifers have total thicknesses ranging from 300 to 1,000 feet and are capable of yielding water to high-capacity wells in quantities as large as 4,000 gallons per minute. Wesselman (1972) estimates that of the 120 million acre-feet of total fresh water in storage in Fort Bend County, approximately 23 million acre-feet could be pumped.

Although large quantities of ground water are available for additional development, care must be taken when planning locations and development scenarios for future well fields. Areas in the vicinity of salt domes or where saline-water sands are interbedded with fresh-water sands may produce ground water with higher salinities than at most locations. Also, in areas that are susceptible to land-surface subsidence, if water levels continue to decline in response to heavy concentrated pumpage, additional subsidence can be expected.

Potential Methods of Increasing Aquifer Recharge

There are several factors which influence the amount of recharge to an aquifer. In an unconfined aquifer, one of the most important factors is the amount of precipitation that is not lost by evapotranspiration or runoff and, therefore, is available for recharge. Other factors include the vertical hydraulic conductivity of surficial deposits and the ability of the aquifer to transmit water away from the recharge area.

Recharge to a confined aquifer is also controlled primarily by the amount of precipitation at its outcrop that is available to move laterally into the confined section. Vertical recharge to a confined aquifer is controlled by the hydraulic conductivity and thickness of the confining layer. There must also be a sufficient hydraulic gradient across the confining layer to promote flow into the aquifer.

In areas of severely deficient natural recharge, methods of artificial recharge are often utilized to increase the amount of available water. Some common methods are water spreading, recharge basins, and injection wells.

Water spreading commonly involves the use of control structures such as check dams, pits, furrows, ditches, and field terracing to control streamflow and runoff in order to increase infiltration time over a large area. Wastewater from municipal water systems is a potential source for water-spreading projects in some areas. Recharge basins are similar, but generally cover a smaller area. They are advantageous because a substantial hydraulic head can be created to increase infiltration rates. Injection wells are used where water spreading or recharge basins are not applicable.

Within Fort Bend County, there are several factors which make water spreading or recharge basin methods of recharge questionable. One is the fact that the county receives a substantial amount of annual precipitation (42 to 47 inches). Although total pumpage exceeds the annual effective recharge, large water-level declines have been seen only for the deeper lower Chicot and Evangeline aquifers (Locke, in preparation). Water levels in the upper Chicot have stabilized in recent years which suggests that recharge and discharge are in approximate equilibrium. Also, surface deposits (upper Chicot) generally contain a high percentage of clay. This tends to render surface spreading and recharge basin methods ineffective due to low infiltration rates caused by low vertical hydraulic conductivities.

To supply artificial recharge to deeper confined zones of the lower Chicot and Evangeline would require the use of injection wells. This method might be considered in areas where water levels are very deep and substantial amounts of artesian storage have been removed. The use of injection wells requires the availability of a source of water for injection to the aquifer. A major problem with injection wells is that they are prone to clogging due to a number of factors including filtration of suspended sediment and organic matter, formation precipitates caused by chemical reactions between recharge water and native ground water, and mechanical compaction of aquifer materials due to high injection pressures (Fetter, 1980). Initial capitol costs may be high as well as annual operation and maintenance costs, which must be considered when determining the feasibility of such a program.

Projected Availability Through the Year 2010

Fort Bend County has experienced a significant amount of growth in recent years. This growth is expected to continue along with an accompanying increase in water demand. Water demand in Fort Bend County is projected to reach 205,034 acre-feet annually by the year 2010 (see Table 3). In 1980 and 1985, ground-water and surface-water sources supplied approximately equal portions of total demand.

Annual ground-water availability for the Brazos River alluvium, the Chicot aquifer, and the Evangeline aquifer in Fort Bend County is approximately 79,033 acre-feet. Annual availability for the Brazos River alluvium alone is approximately 23,452 acre-feet. Historically, development of the alluvium has been small. If the same proportion of pumpage from this unit continues into the future, its available supplies will be adequate to meet future withdrawals.

Annual availability (effective recharge) of the Chicot and Evangeline aquifers in Fort Bend County is approximately 55,581 acre-feet. Since the late 1960's, ground-water pumpage from the Chicot and Evangeline has exceeded the annual availability. This has resulted in large water-level declines and some land-surface subsidence. By 2010, the combination of municipal and domestic demands alone is projected to be greater than annual availability (Table 3). There are still however, sufficient quantities of recoverable ground water in the county which can be developed to meet all future demands. Wesselman (1972) estimates that 23 million acre-feet could be pumped. The main problem of increased development, as in the past, is that continued water-level declines and additional land-surface subsidence are likely to occur unless there is careful planning of well locations and pumpage rates.

Surface-water supplies have been adequate to meet current demands. In addition to current surface-water commitments there could be more than 100,000 acre-feet of additional uncommitted water available for development in Fort Bend County for future needs. Additional long-term future supplies will depend upon the development of future projects within the Brazos River basin or possible purchase of previously committed water from other entities. Additional surface-water use in the future, as opposed to increased ground-water pumpage, could help to minimize potential problems associated with additional ground-water development.

SUMMARY

Current water demands in Fort Bend County are met with both ground-water and surface-water supplies. Ground-water needs, including all municipal and domestic requirements, are met almost entirely with water from the Chicot and Evangeline aquifers. Surface water from the Brazos River supplies most of the industrial demands in the county.

Large ground-water withdrawals, particularly in the northeastern part of the county, have exceeded the annual availability (effective recharge) and resulted in significant water-level declines and land-surface subsidence. Although there is a large volume of recoverable water in storage within the aquifers, future development requires careful planning in order to minimize potential water-level decline and subsidence problems.

In addition to the surface-water supplies that are meeting current demands, an additional 100,000 acre-feet, or more of surface water, could be available for development in Fort Bend County. Additional future long-term supplies will depend upon development of future projects in the Brazos River basin, or the purchase of water from other entities.

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