Quick Facts

Even with significant population increase, water demand in Texas is projected to increase by only 22 percent, from about 18 million acre-feet per year in 2010 to about 22 million acre-feet per year in 2060. This smaller increase is primarily due to declining demand for irrigation water and increased emphasis on municipal conservation.

3 Population and Water Demand Projections

The population in Texas is expected to increase 82 percent between the years 2010 and 2060, growing from 25.4 million to 46.3 million people. Growth rates vary considerably across the state, with some planning areas more than doubling over the planning horizon and others growing only slightly or not at all.

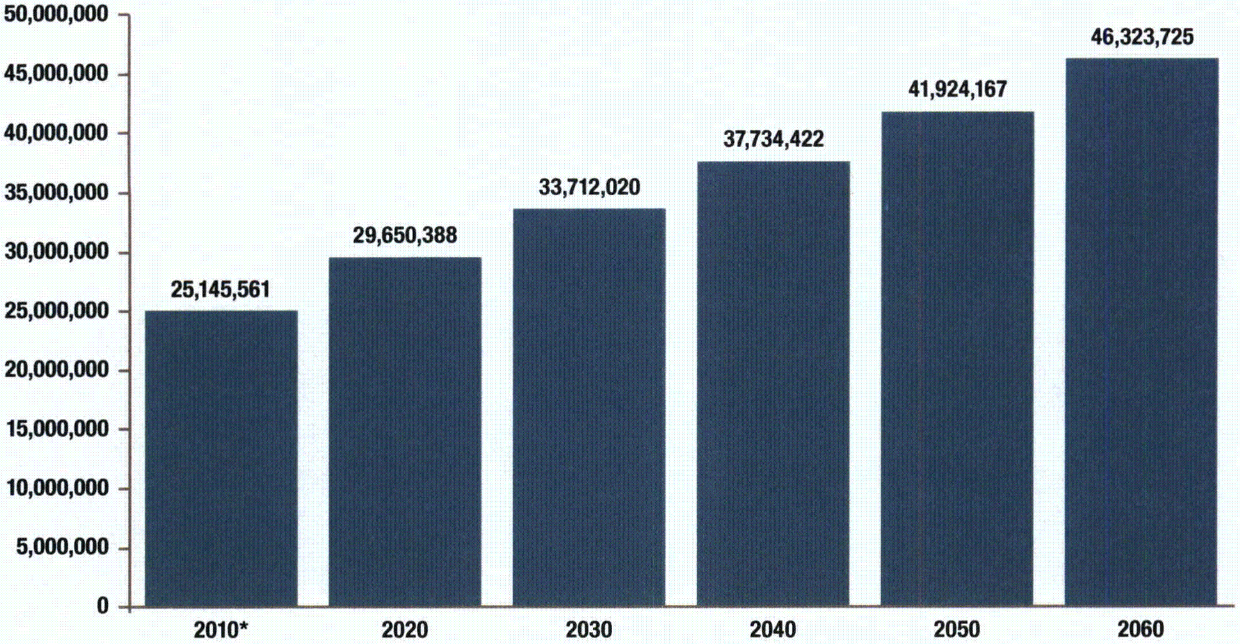
The first step in the regional water planning process is to quantify current and projected population and water demand over the 50-year planning horizon. Both the state and regional water plans incorporate projected population and water demand for cities, water utilities, and rural areas throughout the state. Water demand projections for wholesale water providers and for manufacturing, mining, steam-electric, livestock, and irrigation water use categories are also used in the planning process. TWDB developed projections in coordination with the Texas Commission on Environmental Quality, Texas Parks and Wildlife Department, Texas Department of Agriculture, and the regional water planning groups for inclusion in the regional water plans and the state water plan. The final population and water demand projections are approved by TWDB's governing board.

3.1 POPULATION PROJECTIONS

As noted in every state water plan since the 1968 State Water Plan, Texas is a fast-growing state, and every new Texan requires water to use in the house, on the landscape, and in the food they consume and materials they buy.

Texas is not only the second most populated state in the nation, but also the state that grew the most between 2000 and 2010, increasing from 20.8 million residents to 25.1 million (Figure 3.1). However, such dramatic growth has not occurred evenly across the

FIGURE 3.1. TEXAS STATE POPULATION PROJECTED TO 2060.



*2010 population is the official population count from the U.S. Census Bureau; 2020–2060 represent projected population used in the 2012 State Water Plan.

state. Of 254 counties, 175 gained population and 79 lost population between the 2000 and 2010 censuses. The majority of the growing counties were located in the eastern portion of the state or along the Interstate Highway-35 corridor.

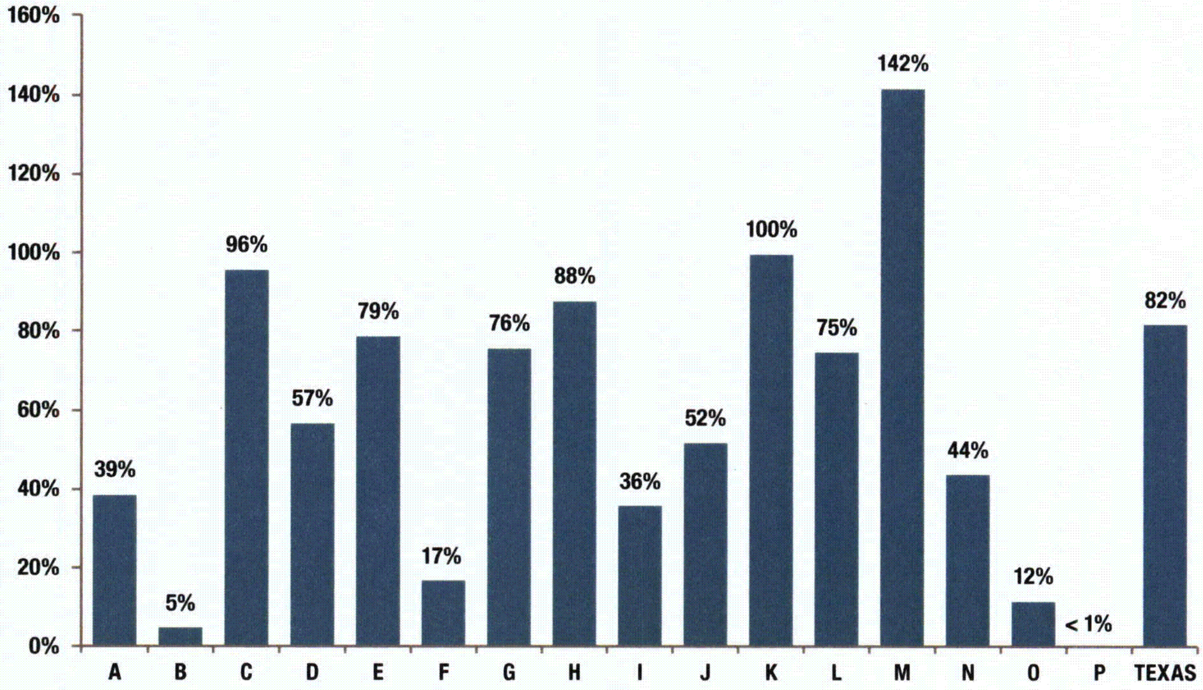
3.1.1 PROJECTION METHODOLOGY

As required in the water planning process, the population of counties, cities, and large non-city water utilities were projected for 50 years, from 2010 to 2060. During the development of the 2011 regional water plans, due to the lack of new census data, the population projections from the 2007 State Water Plan were used as a baseline and adjusted where more recent data was available from the Texas State Data Center.

The population projections for the 2006 regional water plans and the 2007 State Water Plan were created by a two-step process. The initial step used county projections from the Office of the State Demographer and the Texas State Data Center, the agencies charged with disseminating demographic and related socioeconomic data to the state of Texas. These projections were calculated using the cohort-component method: the county's population is projected one year at a time by applying historical growth rates, survival rates, and net migration rates to individual cohorts (age, sex, race, and ethnic groups). The Texas State Data Center projections are only done at the county level, requiring further analysis to develop projections for the sub-county areas.

Sub-county population projections were calculated for cities with a population greater than 500, non-city water utilities with an average daily use greater than 250,000 gallons, and "county-other." County-other is an aggregation of residential, commercial, and institutional water users in cities with less than 500 people or non-city utilities that provide less than an average of 250,000 gallons per day, as well as

FIGURE 3.2. PROJECTED POPULATION GROWTH FOR PLANNING REGIONS FOR 2010–2060.



unincorporated rural areas in a given county. With the county projections as a guide, projections for the municipal water user groups (cities and utilities) within each county were calculated. In general, the projections for these water user groups were based upon the individual city or utility's share of the county growth between 1990 and 2000. TWDB staff developed draft population projections with input from staff of the Texas Commission on Environmental Quality, Texas Parks and Wildlife Department, and Texas Department of Agriculture. Following consultations with the regional water planning groups, these projections were then adopted by TWDB's governing board for use in the 2006 regional water plans.

For the 2011 regional water plans, the planning groups were able to request revisions to population projections for specific municipal water user groups, including cities and large non-city utilities. In certain regions, population estimates suggested that growth was taking place faster in some of the counties and cities than what was previously projected in the 2006 regional water plans. The planning groups could propose revisions, with the amount of upward population projection revision roughly limited to the amount of under-projections, as suggested by the Texas State Data Center's most recent population estimates. Population projections were revised, at least partially, for all changes requested by the planning groups: 352 municipal water user groups in 64 counties and 9 regions. This input from the cities and utilities through the regional water planning groups, combined with the long-range, demographically-driven methods, increases the accuracy of the population projections. The statewide total of the projections for 2010 that resulted from this process were slightly higher than the 2010 Census population.

TABLE 3.1. TEXAS STATE POPULATION PROJECTIONS FOR 2010–2060

Region	2010	2020	2030	2040	2050	2060
A	388,104	423,380	453,354	484,954	516,729	541,035
B	210,642	218,918	223,251	224,165	223,215	221,734
C	6,670,493	7,971,728	9,171,650	10,399,038	11,645,686	13,045,592
D	772,163	843,027	908,748	978,298	1,073,570	1,213,095
E	863,190	1,032,970	1,175,743	1,298,436	1,420,877	1,542,824
F	618,889	656,480	682,132	700,806	714,045	724,094
G	1,957,767	2,278,243	2,576,783	2,873,382	3,164,776	3,448,879
H	6,020,078	6,995,442	7,986,480	8,998,002	10,132,237	11,346,082
I	1,090,382	1,166,057	1,232,138	1,294,976	1,377,760	1,482,448
J	135,723	158,645	178,342	190,551	198,594	205,910
K	1,412,834	1,714,282	2,008,142	2,295,627	2,580,533	2,831,937
L	2,460,599	2,892,933	3,292,970	3,644,661	3,984,258	4,297,786
M	1,628,278	2,030,994	2,470,814	2,936,748	3,433,188	3,935,223
N	617,143	693,940	758,427	810,650	853,964	885,665
O	492,627	521,930	540,908	552,188	553,691	551,758
P	49,491	51,419	52,138	51,940	51,044	49,663
Texas	**25,388,403**	**29,650,388**	**33,712,020**	**37,734,422**	**41,924,167**	**46,323,725**

3.1.2 PROJECTIONS

Due to natural increase and a net in-migration, it is projected that Texas will continue to have robust growth. The state is projected to grow approximately 82 percent, from 25.4 million in 2010 to 46.3 million, by 2060 (Figure 3.2). As illustrated in the growth over the last decade, regional water planning areas that include the major metropolitan areas of Houston (Region H), the Dallas-Fort Worth area (C), Austin (K), San Antonio (L), and the Lower Rio Grande Valley (M) are anticipated to capture 82 percent of the state's growth by 2060 (Table 3.1).

Regions C, G, H, L, and M are expected to grow the most by 2060, while regions B, F, and P are expected to grow at the lowest rates. Individual counties are expected to grow at varying rates (Figure 3.3).

3.1.3 ACCURACY OF PROJECTIONS

At the state level, the 2010 population projections for the 2011 regional water plans were 1 percent greater than the 2010 census results: 25.39 million versus 25.15 million residents (Figure 3.4). Comparisons of 2010 projections and the 2010 census for the previous seven state water plans range from an over-projection of 7.4 percent in the 1968 State Water Plan to an under-projection by 11.3 percent in the "Low" series of the 1984 State Water Plan. The prior two state water plans developed through regional water planning, the 2002 State Water Plan and the 2007 State Water Plan, under-projected the 2010 population by only 2.6 and 1.0 percent, respectively. The 2060 population projection is projected to be slightly higher than what was projected in the 2007 State Water Plan: 46.3 million compared to 45.5 million. While shorter-range projections will always tend to be more accurate, the regional water planning process increases overall projection accuracy because of the use of better local information.

For geographic areas with smaller populations (regions, counties, and water user groups), the relative difference between projected population and actual growth can increase. At the regional water planning area level, 12 regions had populations that were over-projected, most notably Region N at 9.3 percent, Region J at 6.1 percent, and Region B at 5.7 percent

FIGURE 3.3. PROJECTED POPULATION GROWTH IN TEXAS COUNTIES.

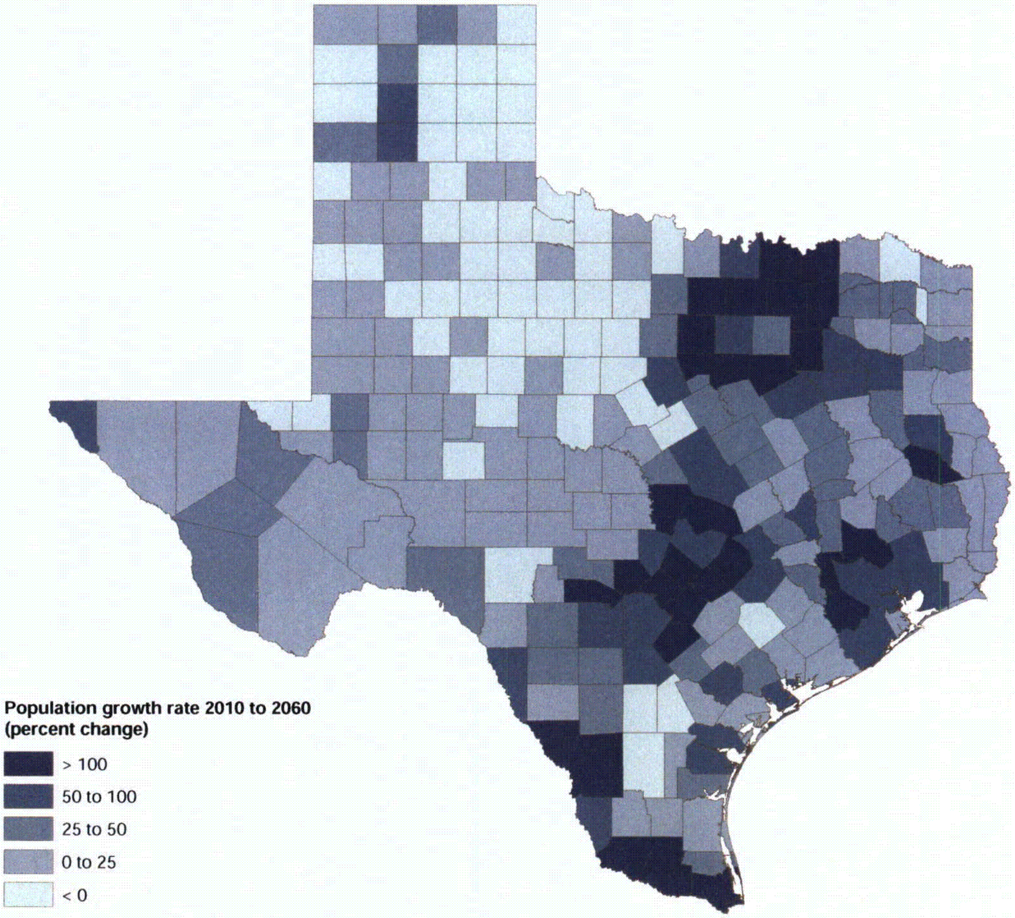
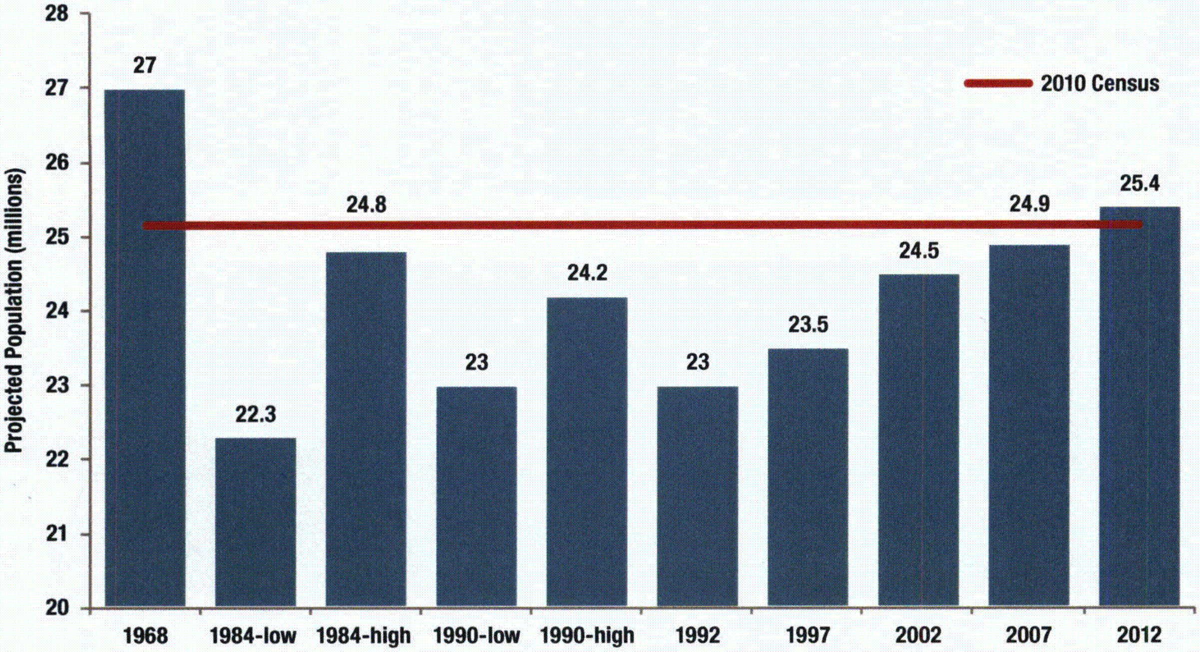


TABLE 3.2. COMPARISON BETWEEN 2010 POPULATION PROJECTIONS AND ACTUAL 2010 CENSUS POPULATION DATA

Region	2000 Census	2010 Census	2010 Projected Population, 2012 SWP	Projection Difference
A	355,832	380,733	388,104	1.9%
B	201,970	199,307	210,642	5.7%
C	5,254,748	6,455,167	6,670,493	3.3%
D	704,171	762,423	772,163	1.3%
E	705,399	826,897	863,190	4.4%
F	578,814	623,354	618,889	-0.7%
G	1,621,965	1,975,174	1,957,767	-0.9%
H	4,848,918	6,093,920	6,020,078	-1.2%
I	1,011,317	1,071,582	1,090,382	1.8%
J	114,742	127,898	135,723	6.1%
K	1,132,228	1,411,097	1,412,834	0.1%
L	2,042,221	2,526,374	2,460,599	-2.6%
M	1,236,246	1,587,971	1,628,278	2.5%
N	541,184	564,604	617,143	9.3%
O	453,997	489,926	492,627	0.6%
P	48,068	49,134	49,491	0.7%
Total	**20,851,820**	**25,145,561**	**25,388,403**	**1.0%**

FIGURE 3.4. COMPARISON OF STATE WATER PLAN POPULATION PROJECTIONS AND ACTUAL 2010 CENSUS POPULATION DATA.*



*In some of the past water plans, both a high and low projection series was analyzed.

(Table 3.2). Some of the larger and faster growing regions were under-projected, including Region L at 2.6 percent, Region H at 1.2 percent, and Region G at 0.9 percent.

At the county level, 23 counties were under-projected by 5 percent or more, the largest of which were Fort Bend, Bell, Smith, Galveston, Brazos, Midland, and Guadalupe (Figure 3.5). One hundred twenty-two counties were over-projected by at least 5 percent, the largest of which were Dallas, Hays, Johnson, Potter, Nueces, and Ellis. Apart from the larger counties in the state, many of the over-projected counties are in west Texas. A complete listing of all county population projections can be found in Appendix B (Projected Population of Texas Counties).

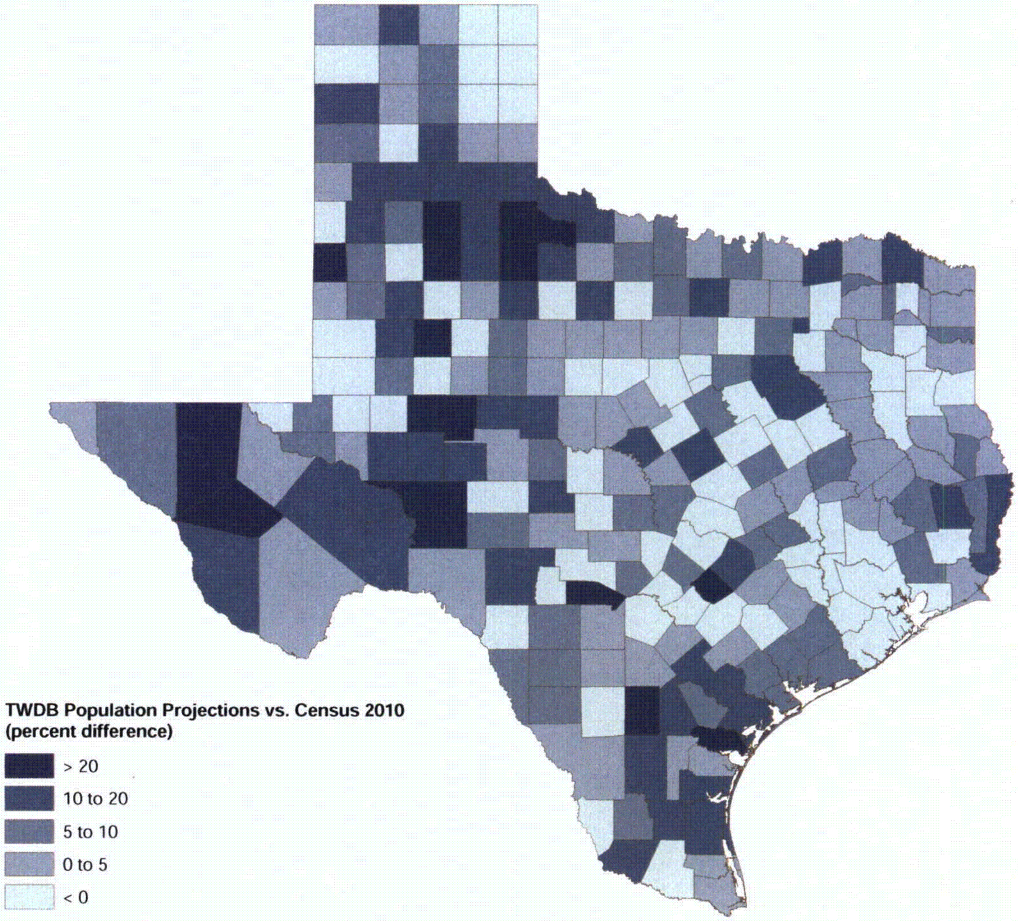
As part of the process for the 2016 regional water plans and the 2017 State Water Plan, population projections for cities, utilities, and counties will be developed anew with the methodology described above, with population and information derived from the 2010 census. As indicated by Figure 3.5, some counties are expected to have their population projections increase while others are expected to have more modest growth than in previous projections.

3.2 WATER DEMAND PROJECTIONS

Determining the amount of water needed in the future is one of the key building blocks of the regional and state water planning process. Projections of water demands are created for six categories, including

- **Municipal:** residential, commercial, and institutional water users in (a) cities with more than 500 residents, (b) non-city utilities that provide more than 280 acre-feet a year (equivalent to 250,000 gallons per day), and (c) a combined

FIGURE 3.5. PERCENT DIFFERENCE BETWEEN 2010 POPULATION PROJECTIONS AND 2010 CENSUS POPULATION DATA.



water user grouping of each county's remaining rural areas, referred to as county-other

- **Manufacturing:** industrial firms, such as food processors, paper mills, electronics manufacturers, aircraft assemblers, and petrochemical refineries
- **Mining:** key mining sectors in the state, such as coal, oil and gas, and aggregate producers
- **Steam-electric:** coal and natural gas-fired and nuclear power generation plants
- **Livestock:** feedlots, dairies, poultry farms, and other commercial animal operations
- **Irrigation:** commercial field crop production

Similar to population projections, the 2011 regional water plans generally used demand projections from the 2007 State Water Plan; revisions were made for the steam-electric water use category and other specific water user groups due to changed conditions or the results of region-specific studies. Water demand projections are based upon "dry-year" conditions and water usage under those conditions. For the 2007 State Water Plan, the year 2000 was selected to represent the statewide dry-year conditions for several reasons:

- For 7 of the 10 climatic regions in the state, the year 2000 included the most months of moderate or worse drought between 1990 and 2000. For the remaining three regions, the year 2000 had the second-most months of moderate or worse drought in that period.

- During the summer months (May to September), when landscape and field crop irrigation is at its peak, the majority of the state was in moderate or worse drought during that entire period.

These water demand projections were developed to determine how much water would be needed during a drought. The regional water planning groups were able to request revisions to the designated dry-year for an area or for the resulting water demand projections if a different year was more representative of dry-year conditions for that particular area.

While the state's population is projected to grow 82 percent between 2010 and 2060, the amount of water needed is anticipated to grow by only 22 percent. (Table 3.3, Figure 3.6). This moderate total increase is due to the anticipated decline in irrigation water use as well as a slight decrease in the per capita water use in the municipal category (though the total municipal category increases significantly due to population growth).

3.2.1 MUNICIPAL WATER DEMAND

Municipal water demand consists of water to be used for residential (single family and multi-family), commercial (including some manufacturing firms that do not use water in their production process), and institutional purposes (establishments dedicated to public service). The water user groups included in this category include cities, large non-city water utilities, and rural county-other. Large-scale industrial facilities, whether supplied by a utility or self-supplied, that use significant amounts of water are included in the manufacturing, mining, or steam-electric power categories. Correlated with a slightly higher 2060 population projection than in the 2007 State Water Plan, the 2060 municipal water demands for the state are projected to be 8.4 million acre-feet compared to 8.2 million acre-feet in the 2007 State Water Plan.

Municipal water demand projections are calculated using the projected populations for cities, non-city water utilities, and county-other and multiplying the projected population by the total per capita water use. Per capita water use, measured in "gallons per capita per day," is intended to capture all residential, commercial, and institutional uses, including systems loss. Gallons per capita per day is calculated for each water user group by dividing total water use (intake minus sales to industry and other systems) by the population served. Total water use is derived from responses to TWDB's Water Use Survey, an annual survey of ground and surface water use by municipal and industrial entities within the state of Texas.

In general, total per capita water use was assumed to decrease over the planning horizon due to the installation of water-efficient plumbing fixtures (shower heads, toilets, and faucets) as required in the Texas Water Saving Performance Standards for Plumbing Fixtures Act of 1991. These fixtures are assumed to be installed as older ones require replacement. Although developed too late to be incorporated into the 2011 regional water plans, additional water-saving requirements have been mandated for dishwashers and clothes washing machines. Such savings will be included in the next regional water plan demand projections.

3.2.2 MANUFACTURING WATER DEMANDS

Manufacturing water demands consist of the future water necessary for large facilities, including those that process chemicals, oil and gas refining, food,

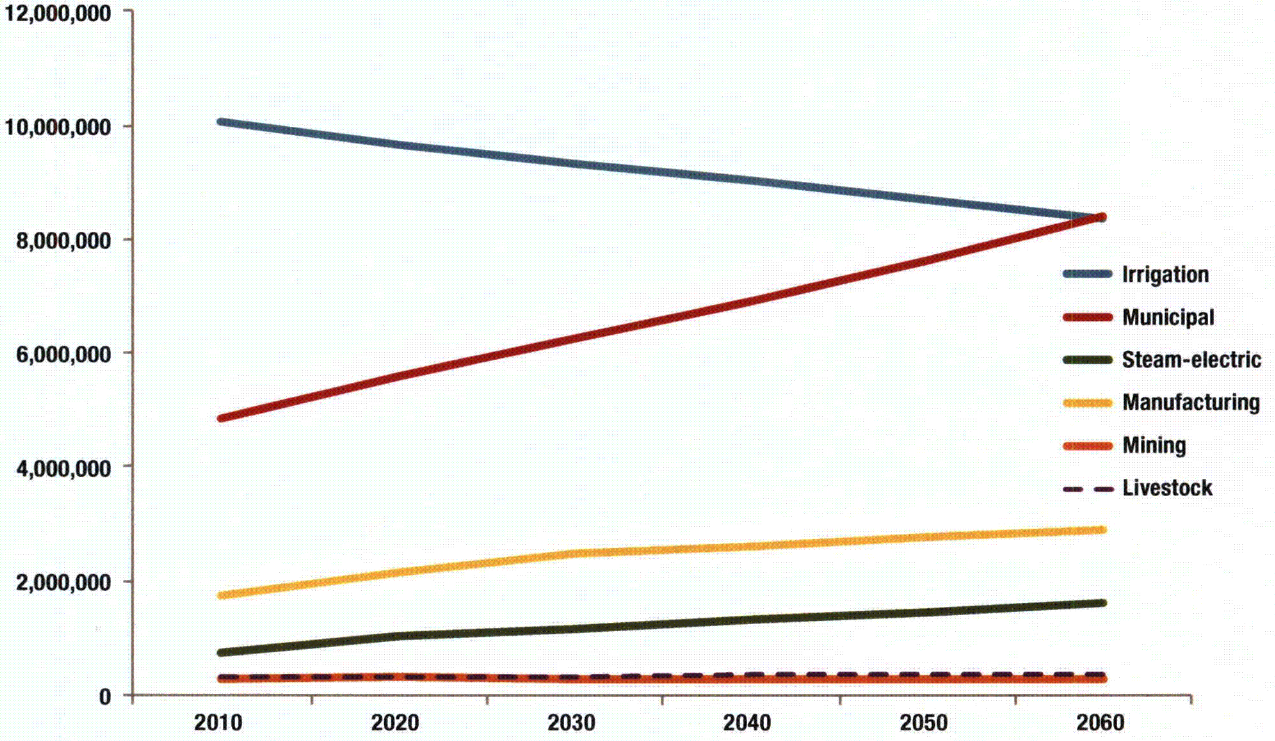
PROJECTED WATER DEMAND CALCULATION, 2010–2060

(Per Capita Water Use for a System in a Dry Year Minus Water Conservation Savings Due to Fixtures) Multiplied By Projected Population

TABLE 3.3. SUMMARY OF WATER DEMAND PROJECTIONS BY USE CATEGORY FOR 2010–2060 (ACRE-FEET PER YEAR)

Category	2010	2020	2030	2040	2050	2060	Percent of 2060 Demand
Municipal	4,851,201	5,580,979	6,254,784	6,917,722	7,630,808	8,414,492	38.3%
Manufacturing	1,727,808	2,153,551	2,465,789	2,621,183	2,755,335	2,882,524	13.1%
Mining	296,230	313,327	296,472	285,002	284,640	292,294	1.3%
Steam-electric	733,179	1,010,555	1,160,401	1,316,577	1,460,483	1,620,411	7.4%
Livestock	322,966	336,634	344,242	352,536	361,701	371,923	1.7%
Irrigation	10,079,215	9,643,908	9,299,464	9,024,866	8,697,560	8,370,554	38.1%
Texas	**18,010,599**	**19,038,954**	**19,821,152**	**20,517,886**	**21,190,527**	**21,952,198**	

FIGURE 3.6. WATER DEMAND PROJECTIONS BY USE CATEGORY (ACRE-FEET PER YEAR).*



*Water demand projections for the livestock and mining water use categories are similar enough to be indistinguishable at this scale.

TABLE 3.4. PER CAPITA WATER USE FOR THE 40 LARGEST CITIES IN TEXAS FOR 2008–2060 (GALLONS PER CAPITA PER DAY)

City or Place Name	2008 Per Capita Use	2008 Residential Per Capita Use	2020 Per Capita Use	2040 Per Capita Use	2060 Per Capita Use
Frisco	254	158	289	289	283
Midland	235	159	254	248	247
Plano	223	113	253	250	249
Richardson	216	128	278	274	272
Dallas	213	95	252	247	246
Beaumont	206	140	209	203	201
McAllen	202	114	197	193	193
College Station	193	92	217	213	212
Irving	193	104	249	246	246
Waco	193	72	183	183	183
Fort Worth	192	75	207	203	202
Longview	190	75	120	115	115
Amarillo	188	108	201	201	201
McKinney	183	122	240	240	240
Tyler	177	103	255	249	248
Austin	171	102	173	171	169
Carrollton	162	102	188	184	183
Odessa	160	108	202	195	194
Arlington	157	100	179	175	174
Sugar Land	155	94	214	211	211
Corpus Christi	154	80	171	166	165
Laredo	154	88	192	189	188
Round Rock	154	96	194	191	191
Grand Prairie	152	89	152	148	148
Denton	150	60	179	176	176
Garland	150	90	160	156	155
San Antonio	149	92	139	135	134
Lewisville	143	75	173	171	170
Lubbock	141	93	202	196	195
Abilene	139	73	161	155	154
Wichita Falls	138	88	172	170	168
El Paso	137	98	130	130	130
Brownsville	134	63	221	217	217
Houston	134	65	152	147	146
Mesquite	134	90	164	168	168
San Angelo	131	91	193	187	186
Killeen	127	82	179	174	167
Pearland	112	105	127	124	124
Pasadena	109	67	110	105	104
Missouri City	86	68	167	167	169

TABLE 3.5. COMPARISON OF 2009 WATER USE ESTIMATES WITH PROJECTED 2010 WATER USE (ACRE-FEET PER YEAR)

Category	2009 Estimated Water Use[1]	2010 Projected Water Use	Estimated Difference from Projection
Municipal	4,261,585	4,851,201	-12.2%
Manufacturing	1,793,911	1,727,808	3.8%
Mining[2]	168,273	296,230	-43.2%
Steam-Electric Power	454,122	733,179	-38.1%
Livestock	297,047	322,966	-8.0%
Irrigation	9,256,426	10,079,215	-8.2%
Total	**16,231,364**	**18,010,599**	**-9.9%**

[1] Annual water use estimates are based upon returned water use surveys and other estimation techniques. These estimates may be updated when more accurate information becomes available.

[2] The 2009 mining use estimates represent an interpolation of estimated 2008 and 2010 volumes (UT Bureau of Economic Geology, 2011)

COMPARING PER CAPITA WATER USE

Since the 2007 State Water Plan, there has been an increasing amount of interest in comparing how much water is used by various cities (Table 3.4). Unfortunately, this measure can often be inappropriate and misleading. There are a number of valid reasons that cities would have differing per capita water use values, including

- climatic conditions;
- amount of commercial and institutional customers;
- construction activities;
- price of water;
- income of the customers;
- number of daily or seasonal residents; and
- age of infrastructure.

Per capita water use tends to be higher in cities with more arid climates; more non-residential businesses; high-growth areas requiring more new building construction; lower cost of water; higher-income residents; more commuters or other part-time residents who are not counted in the official population estimates; and with more aging infrastructure, which can result in greater rates of water loss.

Because of the variations between water providers, the total municipal per capita water use as described earlier is not a valid tool for comparison. As a start to providing more detailed and useful information, the annual residential per capita water use of cities in the state water plan has been calculated since 2007, in addition to the more comprehensive total municipal per capita use. Residential per capita use is calculated using the volume sold directly to single- and multi-family residences. As more water utilities are encouraged to track their sales volumes by these categories, a more complete picture of residential per capita water use across the state will be available in the years to come. Two bills passed in the recent 82nd Texas Legislature in 2011 address this type of water use information: Senate Bill 181 and Senate Bill 660, both of which require standardization of water use and conservation calculations for specific sectors of water use.

paper, and other materials. Demands in the 2012 State Water Plan were based on those from the 2007 State Water Plan. Demand projections were drafted as part of a contracted study (Waterstone Environmental Hydrology and Engineering, Inc. and The Perryman Group, 2003) that analyzed historical water use and trends and projected industrial activity. The projections incorporated economic projections for the various manufacturing sectors, general economic output-water use coefficients, and efficiency improvements of new technology. Future growth in water demand was assumed to be located in the same counties in which such facilities currently exist unless input from the regional water planning group identified new or decommissioned facilities.

Some regions requested increases to the 2007 State Water Plan projections due to changed conditions. Manufacturing demands are projected to grow 67 percent from 1.7 million acre-feet to 2.9 million acre feet. This 2060 projection of 2.9 million acre-feet is an increase of roughly 12 percent over the 2.6 million acre-feet projected in the 2007 State Water Plan.

3.2.3 MINING WATER DEMANDS

Mining water demands consist of water used in the exploration, development, and extraction processes of oil, gas, coal, aggregates, and other materials. The mining category is the smallest of the water user categories and is expected to decline 1 percent from 296,230 acre-feet to 292,294 acre-feet between 2010 and 2060. In comparison, the 2007 State Water Plan mining water demands ranged from 270,845 acre-feet to 285,573 acre-feet from 2010 and 2060. Mining demands increased in a number of counties reflecting initial estimates of increased water use in hydraulic fracturing operations in the Barnett Shale area.

Similar to manufacturing demand projections, the current projections were generated as part of the 2007 State Water Plan and used a similar methodology: analyzing known water use estimates and economic projections. The mining category has been particularly difficult to analyze and project due to the isolated and dispersed nature of oil and gas facilities, the transient and temporary nature of water used, and the lack of reported data for the oil and gas industry.

Due to the increased activity that had occurred in oil and gas production by hydraulic fracturing, in 2009 TWDB contracted with the University of Texas Bureau of Economic Geology (2011) to conduct an extensive study to re-evaluate the water used in mining operations and to project such uses for the next round of water planning. Initial results from the study indicate that, while fracturing and total mining water use continues to represent a small portion (less than 1 percent) of statewide water use, percentages can be significantly larger in some localized areas. In particular, the use of water for hydraulic fracturing operations is expected to increase significantly through 2020. The results of this study will form the basis for mining water demand projections for the 2016 regional water plans. Future trends in these types of water use will be monitored closely in the upcoming planning process.

3.2.4 STEAM-ELECTRIC POWER GENERATION WATER DEMANDS

The steam-electric power generation category consists of water used for the purposes of producing power. Where a generation facility diverts surface water, uses it for cooling purposes, and then returns a large portion of the water to the water body, the water use for the facility is only the volume consumed in the cooling process and not returned. For the 2011 regional water plans, the University of Texas Bureau of Economic

Geology (2008) completed a TWDB-funded study of steam-electric power generation water use and projected water demands. Regional water planning groups reviewed the projections developed in this study and were encouraged to request revisions where better local information was available.

A challenge for the projection of such water use is the very mobile nature of electricity across the state grid. While the demand may occur where Texans build houses, the power and water use for its production can be in nearly any part of the state. Beyond the specific future generation facilities on file with the Public Utility Commission of Texas, the increased demand for power generation and the accompanying use of water was assumed to be located in the counties that currently have power generation capabilities. Steam-electric water use is expected to increase by 121 percent over the planning horizon, from 0.7 million acre-feet in 2010 to 1.6 million acre-feet in 2060. This 2060 projection remains consistent with the projection of 1.5 million acre-feet in the 2007 State Water Plan.

3.2.5 IRRIGATION WATER DEMANDS

Irrigated agriculture uses over half of the water in Texas, much of the irrigation taking place in Regions A, O, and M and in the rice producing areas along the coast. Projections in the current regional water plans were based on those from the 2006 regional plans, with revisions to select counties based upon better information. Region A conducted a study to develop revised projections on a region-wide basis. Irrigation projections have been continually adjusted at the beginning of each planning cycle, with the previous projections being used as a base to be adjusted by factors and trends including

- changes in the amount of acreage under irrigation;
- increases in irrigation application efficiency;
- changes in canal losses for surface water diversions; and
- changes in cropping patterns.

Irrigation demand is expected to decline over the planning horizon by 17 percent, from 10 million acre-feet in 2010 to 8.3 million acre-feet in 2060, largely due to anticipated natural improvements in irrigation efficiency, the loss of irrigated farm land to urban development in some regions, and the economics of pumping water from increasingly greater depths. The projections are slightly reduced from the 2007 State Water Plan, which included a statewide 2010 projection of 10.3 million acre-feet and 8.6 million acre-feet in 2060.

3.2.6 LIVESTOCK WATER DEMANDS

Livestock water demand includes water used in the production of various types of livestock including cattle (beef and dairy), hogs, poultry, horses, sheep, and goats. Projections for livestock water demand are based upon the water use estimates for the base "dry year" and then generally held constant into the future. Some adjustments have been made to account for shifts of confined animal feeding operations into or out of a county. The volume of water needed for livestock is projected to remain fairly constant over the planning period, increasing only by 15 percent over 50 years, from 322,966 acre-feet in 2010 to 371,923 acre-feet in 2060. The livestock use projections from the 2007 State Water Plan ranged from 344,495 acre-feet in 2010 to 404,397 acre-feet in 2060.

3.2.7 COMPARISON OF WATER DEMAND PROJECTIONS AND WATER USE ESTIMATES

Water demand projections for the 2012 State Water Plan and 2011 regional water plans were developed early in the five-year planning cycle and for this reason include projected water demands for the year 2010. To provide a benchmark of the relative accuracy of the projections, the projected 2010 volumes are compared with preliminary TWDB water use estimates from the most recent year available, 2009, an appropriate year for comparison as it was generally considered the second driest year of the last decade statewide, and the projected water demands are intended to be in dry-year conditions.

Overall, the statewide 2009 water use estimates are 10 percent less than the 2010 projections (Table 3.5). Projected water use can in general be expected to represent an upper bound to actual water use. One reason is that, even when a relatively dry year is experienced, not all parts of the state will experience the most severe drought, while the projections are calculated under the assumption that all water users are in drought conditions. Projections also are intended to reflect the water use that would take place if there were no supply restrictions. In practice, especially for municipal water users, water conservation and drought management measures to reduce water demand are implemented. In the context of water planning, such reductions are not automatically assumed to occur and thus reduce projected water use, but are more properly accounted for as water management strategies expected to be implemented in times of drought.

In each of the agricultural categories, estimated water use was 8 percent less than projected. Large differences occurred in the industrial categories of mining and steam-electric power. More recent research has indicated that the mining use projected for 2010 in this plan is overstated, and will be adjusted for the next planning cycle. Some of the difference in electric generation may be explained by increased efficiencies, but incomplete data returns for the 2009 estimates may also be a factor. The 2009 water use estimate for the municipal category is 12 percent less than the projected volume.

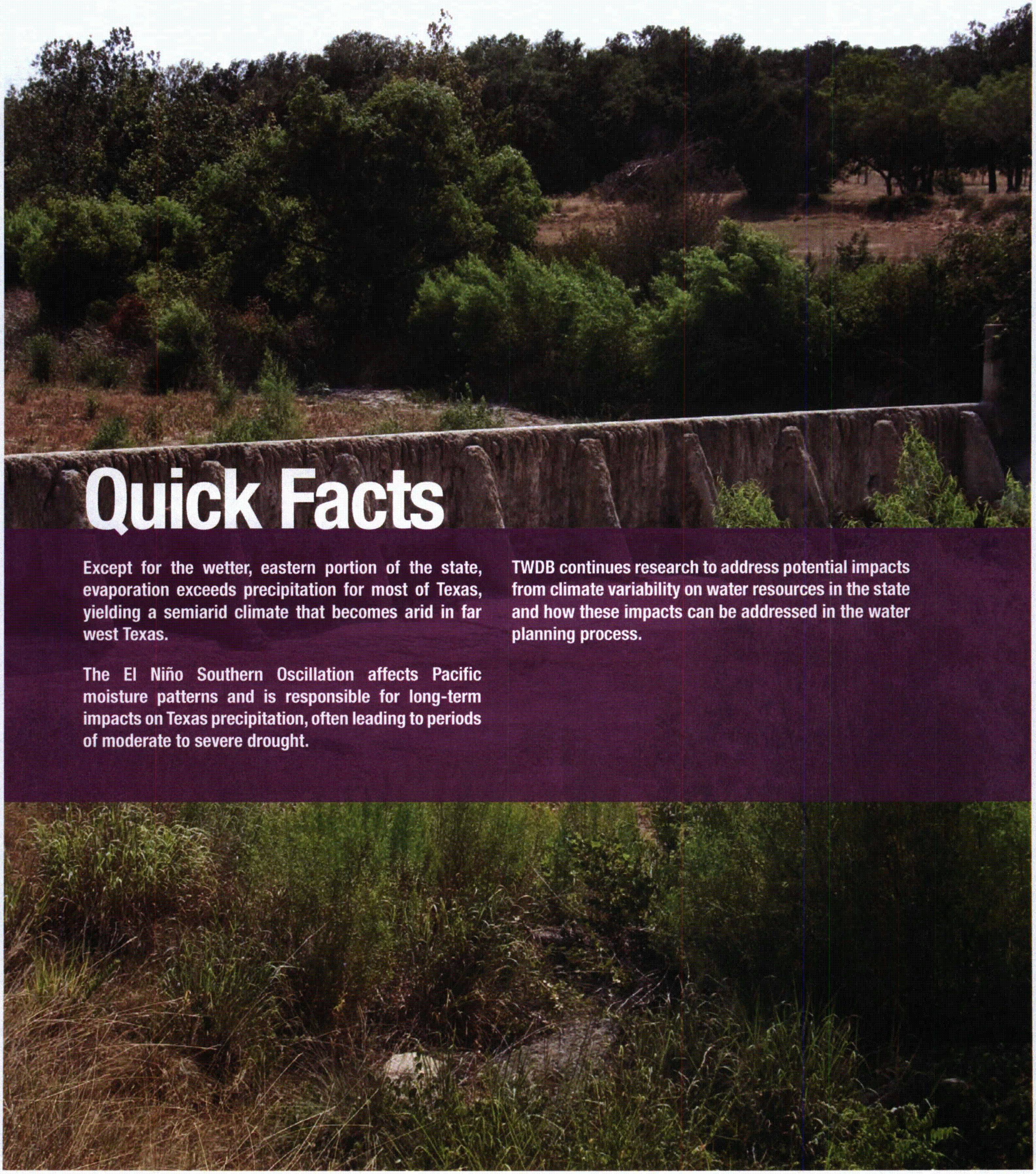
While 2009 was a relatively dry year, it did not approach the severity of drought conditions being experienced by most of Texas in the current year, 2011. Water use estimates for 2011 will provide a more representative comparison with 2010 projections, and will be incorporated into water demand projections for the next planning cycle, when they become available.

REFERENCES

UT (University of Texas) Bureau of Economic Geology, 2008, Water Demand Projections of Power Generation in Texas: Prepared for the Texas Water Development Board, http://www.twdb.state.tx.us/wrpi/data/socio/est/final_pwr.pdf.

UT (University of Texas) Bureau of Economic Geology, 2011, Current and Projected Water Use in the Texas Mining and Oil and Gas Industry: Prepared for the Texas Water Development Board, http://www.twdb.state.tx.us/RWPG/rpgm_rpts/0904830939_MiningWaterUse.pdf.

Waterstone Environmental Hydrology and Engineering, Inc. and The Perryman Group, 2003, Water Demand Methodology and Projections for Mining and Manufacturing: Prepared for the Texas Water Development Board, http://www.twdb.state.tx.us/RWPG/rpgm_rpts/2001483397.pdf.



Quick Facts

Except for the wetter, eastern portion of the state, evaporation exceeds precipitation for most of Texas, yielding a semiarid climate that becomes arid in far west Texas.

The El Niño Southern Oscillation affects Pacific moisture patterns and is responsible for long-term impacts on Texas precipitation, often leading to periods of moderate to severe drought.

TWDB continues research to address potential impacts from climate variability on water resources in the state and how these impacts can be addressed in the water planning process.

4 Climate of Texas

Average annual temperature gradually increases from about 52°F in the northern Panhandle of Texas to about 68°F in the Lower Rio Grande Valley. Average annual precipitation decreases from over 55 inches in Beaumont to less than 10 inches in El Paso.

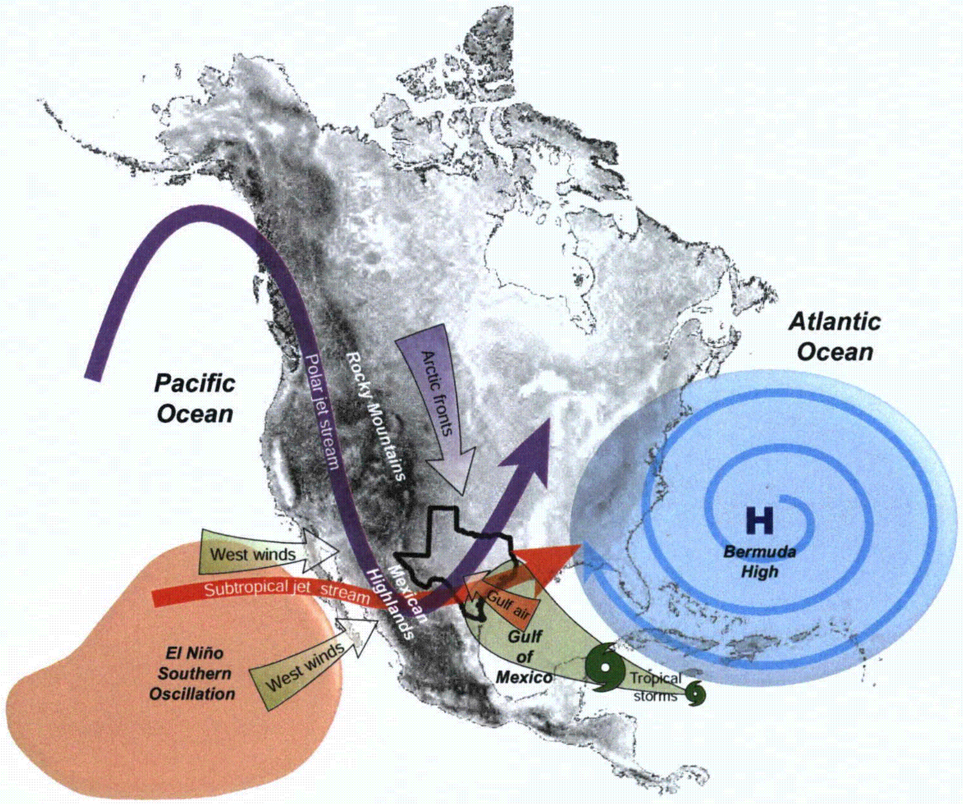
Because of its size—spanning over 800 miles both north to south and east to west—Texas has a wide range of climatic conditions over several diverse geographic regions. Climate is an important consideration in water supply planning because it ultimately determines the state's weather and, consequently, the probability of drought and the availability of water for various uses. The variability of the state's climate also represents both a risk and an uncertainty that must be considered by the regional water planning groups when developing their regional water plans (Chapter 10, Risk and Uncertainty).

4.1 OVERVIEW OF THE STATE'S CLIMATE

The variability of Texas' climate is a consequence of interactions between the state's unique geographic location on the North American continent and several factors that result because of the state's location (Figure 4.1):

- the movements of seasonal air masses such as arctic fronts from Canada
- subtropical west winds from the Pacific Ocean and northern Mexico
- tropical cyclones or hurricanes from the Gulf of Mexico
- a high pressure system in the Atlantic Ocean known as the Bermuda High
- the movement of the jet streams

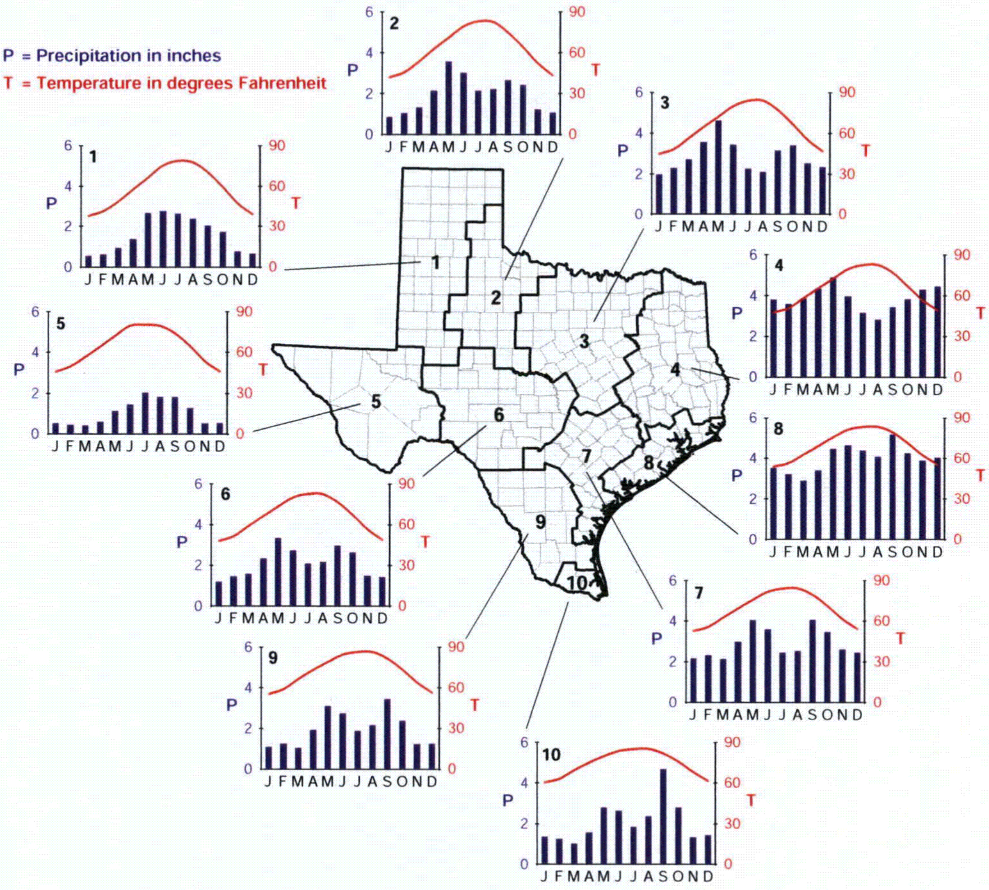
FIGURE 4.1. THE GEOGRAPHIC LOCATION OF TEXAS WITHIN NORTH AMERICA AND ITS INTERACTION WITH SEASONAL AIR MASSES AFFECTS THE STATE'S UNIQUE CLIMATE VARIABILITY (SOURCE DIGITAL ELEVATION DATA FOR BASE MAP FROM USGS, 2000).



The Gulf of Mexico is the predominant geographical feature affecting the state's climate, moderating seasonal temperatures along the Gulf Coast and more importantly, providing the major source of precipitation for most of the state (TWDB, 1967; Larkin and Bomar, 1983). However, precipitation in the Trans-Pecos and the Panhandle regions of Texas originates mostly from the eastern Pacific Ocean and from land-recycled moisture (TWDB, 1967; Slade and Patton, 2003). The 370 miles of Texas Gulf Coast creates a significant target for tropical cyclones that make their way into the Gulf of Mexico during the hurricane season. The Rocky Mountains guide polar fronts of cold arctic air southward into the state during the fall, winter, and spring.

During the summer, the dominant weather feature in extreme west Texas is the North American (or Southwest) Monsoon, as the warm desert southwest draws moist air northward from the Gulf of California and the Gulf of Mexico to produce summertime thunderstorms. In the rest of Texas, summertime thunderstorms form along the sea breeze or in response to tropical or subtropical disturbances. Warm dry air masses from the high plains of northern Mexico are pulled into the state by the jet stream during the spring and fall seasons, colliding with humid air from

FIGURE 4.2. CLIMATE DIVISIONS OF TEXAS WITH CORRESPONDING CLIMOGRAPHS (SOURCE DATA FROM NCDC, 2011).



the Gulf of Mexico, funneled by the western limb of the Bermuda High system—producing destabilized inversions between the dry and humid air masses and generating severe thunderstorms and tornadoes.

4.2 CLIMATE DIVISIONS

The National Climatic Data Center divides Texas into 10 climate divisions (Figure 4.2). Climate divisions represent regions with similar characteristics such as vegetation, temperature, humidity, rainfall, and seasonal weather changes. Climate data collected at locations throughout the state are averaged within each of the divisions. These divisions are commonly used to assess climate characteristics across the state:

- Division 1 (High Plains): Continental steppe or semi-arid savanna
- Division 2 (Low Rolling Plains): Sub-tropical steppe or semi-arid savanna
- Division 3 (Cross Timbers): Sub-tropical sub-humid mixed savanna and woodlands
- Division 4 (Piney Woods): Sub-tropical humid mixed evergreen-deciduous forestland
- Division 5 (Trans-Pecos): Except for the slightly wetter high desert mountainous areas, sub-tropical arid desert
- Division 6 (Edwards Plateau): Sub-tropical steppe or semi-arid brushland and savanna

- Division 7 (Post Oak Savanna): Sub-tropical sub-humid mixed prairie, savanna, and woodlands
- Division 8 (Gulf Coastal Plains): Sub-tropical humid marine prairies and marshes
- Division 9 (South Texas Plains): Sub-tropical steppe or semi-arid brushland
- Division 10 (Lower Rio Grande Valley): Sub-tropical sub-humid marine

4.3 TEMPERATURE, PRECIPITATION, AND EVAPORATION

Average annual temperature gradually increases from about 52°F in the northern Panhandle of Texas to about 68°F in the Lower Rio Grande Valley, except for isolated mountainous areas of far west Texas, where temperatures are cooler than the surrounding arid valleys and basins (Figure 4.3). In Far West Texas, the average annual temperature sharply increases from about 56°F in the Davis and Guadalupe mountains to about 64°F in the Presidio and Big Bend areas. Average annual precipitation decreases from over 55 inches in Beaumont to less than 10 inches in El Paso (Figure 4.4). Correspondingly, average annual gross lake evaporation is less than 50 inches in east Texas and more than 75 inches in far west Texas (Figure 4.5).

Although most of the state's precipitation occurs in the form of rainfall, small amounts of ice and snow can occur toward the north and west, away from the moderating effects of the Gulf of Mexico. The variability of both daily temperature and precipitation generally increases inland across the state and away from the Gulf, while relative humidity generally decreases from east to west and inland away from the coast. The range between summer and winter average monthly temperatures increases with increased distance from the Gulf of Mexico. Except for climatic divisions 1 and 5 in far west Texas, the state climate divisions show two pronounced rainy seasons in the spring and fall. Both rainy seasons are impacted by polar fronts interacting with moist Gulf air during those seasons, with the fall rainy season also impacted by hurricanes and tropical depressions.

Most of the annual rainfall in Texas occurs during rain storms, when a large amount of precipitation falls over a short period of time. Except for the subtropical humid climate of the eastern quarter of the state, evaporation exceeds precipitation—yielding a semi-arid or steppe climate that becomes arid in far west Texas.

4.4 CLIMATE INFLUENCES

Texas climate is directly influenced by prominent weather features such as the Bermuda High and the jet streams. These weather features are in turn influenced by cyclical changes in sea surface temperature patterns associated with the El Niño Southern Oscillation, the Pacific Decadal Oscillation, the Atlantic Multidecadal Oscillation, and the atmospheric pressure patterns of the North Atlantic Oscillation.

The Bermuda High, a dominant high pressure system of the North Atlantic Oscillation, influences the formation and path of tropical cyclones as well as climate patterns across Texas and the eastern United States. During periods of increased intensity of the Bermuda High system, precipitation extremes also tend to increase. The jet streams are narrow, high altitude, and fast-moving air currents with meandering paths from west to east. They steer large air masses across the earth's surface and their paths and locations generally determine the climatic state between drought and unusually wet conditions.

The El Niño Southern Oscillation, a cyclical fluctuation of ocean surface temperature and air pressure in the tropical Pacific Ocean, affects Pacific moisture patterns

FIGURE 4.3. AVERAGE ANNUAL TEMPERATURE FOR 1981 TO 2010 (DEGREES FAHRENHEIT) (SOURCE DATA FROM TWDB, 2005 AND PRISM CLIMATE GROUP, 2011).

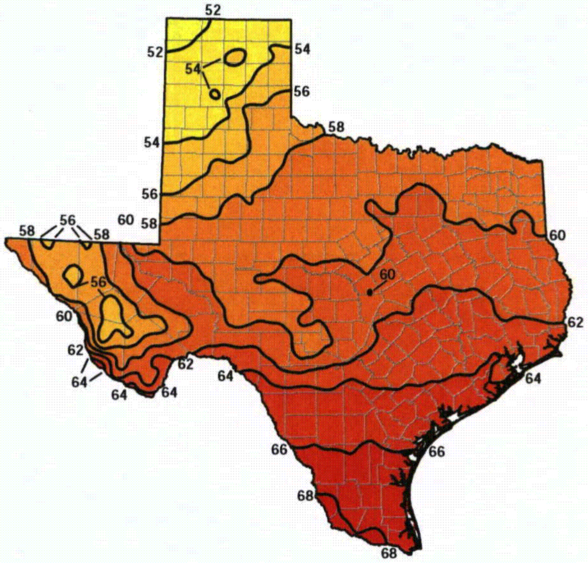


FIGURE 4.4. AVERAGE ANNUAL PRECIPITATION FOR 1981 TO 2010 (INCHES) (SOURCE DATA FROM TWDB, 2005 AND PRISM CLIMATE GROUP, 2011).

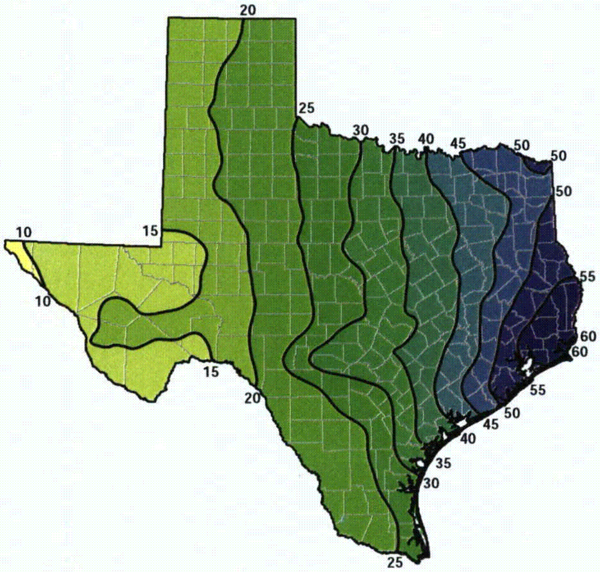


FIGURE 4.5. AVERAGE ANNUAL GROSS LAKE EVAPORATION FOR 1971 TO 2000 (INCHES) (SOURCE DATA FROM TWDB, 2005).

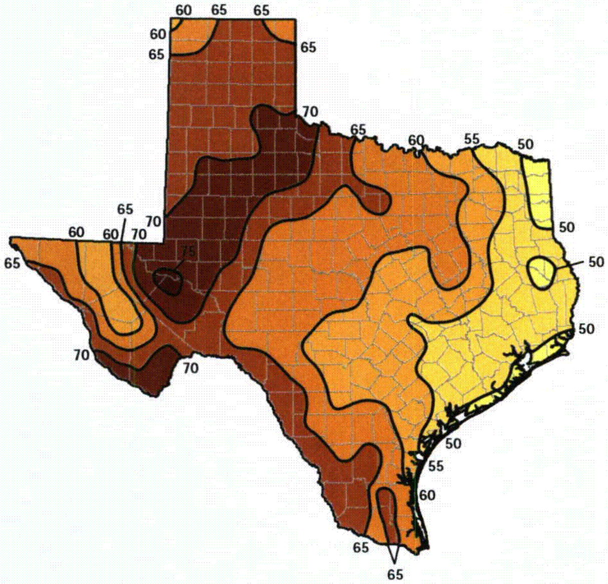


TABLE 4.1. RANKINGS OF PALMER DROUGHT SEVERITY INDICES BASED ON DROUGHT DURATION AND DROUGHT INTENSITY FOR CLIMATE DIVISIONS OF TEXAS

Climate Division	Duration Ranking			Intensity Ranking		
	1	2	3	1	2	3
1	1950 to 1956	1962 to 1967	1933 to 1936	1950 to 1956	1909 to 1911	1933 to 1936
2	1950 to 1956	1909 to 1913	1963 to 1967	1950 to 1956	1909 to 1913	1916 to 1918
3	1951 to 1956	1909 to 1913	1916 to 1918	1951 to 1956	1916 to 1918	2005 to 2006
4	1962 to 1967	1915 to 1918	1936 to 1939	1915 to 1918	1954 to 1956	1951 to 1952
5	1950 to 1957	1998 to 2003	1962 to 1967	1950 to 1957	1933 to 1937	1998 to 2003
6	1950 to 1956	1909 to 1913	1993 to 1996	1950 to 1956	1916 to 1918	1962 to 1964
7	1948 to 1956	1909 to 1912	1896 to 1899	1948 to 1956	1916 to 1918	1962 to 1964
8	1950 to 1956	1915 to 1918	1962 to 1965	1950 to 1956	1915 to 1918	1962 to 1965
9	1950 to 1956	1909 to 1913	1962 to 1965	1950 to 1956	1916 to 1918	1988 to 1990
10	1945 to 1957	1960 to 1965	1988 to 1991	1945 to 1957	1999 to 2002	1988 to 1991

and is responsible for long-term impacts on Texas precipitation, often leading to periods of moderate to severe drought. During a weak or negative oscillation, known as a La Niña phase, precipitation will generally be below average in Texas and some degree of drought will occur. (The State Climatologist and the National Atmospheric and Oceanic Administration both attribute drought conditions experienced in Texas in 2010 and 2011 to La Niña conditions in the Pacific.) During a strong positive oscillation or El Niño phase, Texas will usually experience above average precipitation.

The Pacific Decadal Oscillation affects sea surface temperatures in the northern Pacific Ocean, while the Atlantic Multidecadal Oscillation affects the sea surface temperature gradient from the equator poleward (Nielson-Gammon, 2011a). These two long-term oscillations can enhance or dampen the effects of the El Niño Southern Oscillation phases and therefore long-term patterns of wet and dry cycles of the climate. Generally, drought conditions are enhanced by cool sea surface temperatures of the Pacific Decadal Oscillation and also warm sea surface temperatures of the Atlantic Multidecadal Oscillation.

FIGURE 4.6. ANNUAL PRECIPITATION BASED ON POST OAK TREE RINGS FOR THE SAN ANTONIO AREA (DATA FROM CLEAVELAND, 2006).

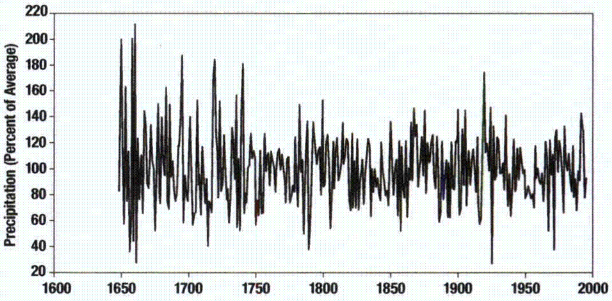
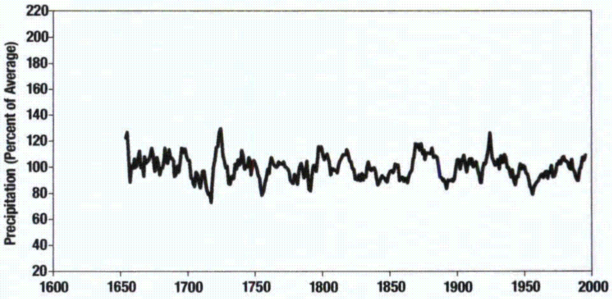


FIGURE 4.7. SEVEN-YEAR RUNNING AVERAGE OF PRECIPITATION BASED ON POST OAK TREE RINGS FOR THE SAN ANTONIO AREA (DATA FROM CLEAVELAND, 2006).



4.5 DROUGHT SEVERITY IN TEXAS

Droughts are periods of less than average precipitation over a period of time. The Palmer Drought Severity Index is often used to quantify long-term drought conditions and is commonly used by the U.S. Department of Agriculture to help make policy decisions such as when to grant emergency drought assistance. The severity of drought depends upon several factors, though duration and intensity are the two primary components. The drought of record during the 1950s ranks the highest in terms of both duration and intensity (Table 4.1). However, it should be noted that drought rankings can be misleading since a single year of above average rainfall can interrupt a prolonged drought, reducing its ranking. Nonetheless, on a statewide basis, the drought of the 1950s still remains the most severe drought the state has ever experienced based on recorded measurements of precipitation. Other significant droughts in Texas occurred in the late 1800s and the 1910s, 1930s, and 1960s. At the end of 2011, the 2011 drought may rank among the most intense one-year droughts on record in many climatic divisions.

4.6 CLIMATE VARIABILITY

The climate of Texas is, has been, and will continue to be variable. Since variability affects the availability of the state's water resources, it is recognized by the regional water planning groups when addressing needs for water during a repeat of the drought of record. More discussion on how planning groups address climate variability and other uncertainties can be found in Chapter 10, Challenges and Uncertainty.

Climate data are generally available in Texas from the late 19th century to the present, but this is a relatively short record that can limit our understanding of long-term climate variability. Besides the variability measured in the record, historic variability can be estimated through environmental proxies by the study of tree rings, while future variability can be projected through the analysis of global climate models. Annual tree growth, expressed in a tree growth ring, is strongly influenced by water availability. A dry year results in a thin growth ring, and a wet year results in a thick growth ring. By correlating tree growth ring thickness with precipitation measured during the period of record, scientists can extend the climatic record back hundreds of years.

In Texas, scientists have completed precipitation data reconstructions using post oak and bald cypress trees. In the San Antonio area (Cleaveland, 2006), reconstruction of precipitation using post oak trees from 1648 to 1995 (Figure 4.6) indicates that the highest annual precipitation was in 1660 (about 212 percent of average) and the lowest annual precipitation was in 1925 (about 27 percent of average).

Drought periods in this dataset can also be evaluated with seven-year running averages (Figure 4.7). The drought of record that ended in 1956 can be seen in this reconstruction, with the seven-year precipitation during this period about 79 percent of average. This record shows two seven-year periods that were drier than the drought of record: the seven-year period that ended in 1717 had precipitation of about 73 percent of average, and the seven-year period that ended in 1755 had a seven-year average precipitation of about 78 percent. There have been about 15 seven-year periods where precipitation was below 90 percent of average, indicating an extended drought.

4.7 FUTURE VARIABILITY

Climate scientists have developed models to project what the Earth's climate may be like in the future under certain assumptions, including the composition of the atmosphere. In simple terms, the models simulate incoming solar energy and the outgoing energy in the form of long-wave radiation. The models also simulate interactions between the atmosphere, oceans, land, and ice using well-established physical principles. The models are capable of estimating future climate based on assumed changes in the atmosphere that change the balance between incoming and outgoing energy. These models can provide quantitative estimates of future climate variability, particularly at continental and larger scales (IPCC, 2007). Confidence in these estimates is higher for some climate variables, such as temperature, than for others, such as precipitation.

While the climate models provide a framework for understanding future changes on a global or continental scale, scientists have noted that local temperature changes, even over decades to centuries, may also be strongly influenced by changes in regional climate patterns and sea surface temperature variations, making such changes inherently more complex. According to John W. Nielsen-Gammon, "If temperatures rise and precipitation decreases as projected by climate models, droughts as severe as those in the beginning or middle of the 20th Century would become increasingly likely" (2011b). However, the temperature increase began during a period of unusually cold temperatures. It is only during the last 10 to 15 years that temperatures have become as warm as during earlier parts of the 20th century, such as the Dust Bowl of the 1930s and the drought of the 1950s.

Climate scientists have also reported results of model projections specific to Texas, with the projected temperature trends computed relative to a simulated 1980 to 1999 average. The projections indicate an increase of about 1°F for the 2000 to 2019 period, 2°F for the 2020 to 2039 period, and close to 4°F for the 2040 to 2059 period (Nielsen-Gammon, 2011c).

Precipitation trends over the 20th century are not always consistent with climate model projections. The model results for precipitation indicate a decline in precipitation toward the middle of the 21st century. However, the median rate of decline (about 10 percent per century) is smaller than the observed rate of increase over the past century. Furthermore, there is considerable disagreement among models whether there will be an increase or a decrease in precipitation prior to the middle of the 21st century. While the climate models tend to agree on the overall global patterns of precipitation changes, they produce a wide range of precipitation patterns on the scale of Texas itself, so that there is no portion of the state that is more susceptible to declining precipitation in the model projections than any other.

Climate scientists have reported that drought is expected to increase in general worldwide because of the increase of temperatures and the trend toward concentration of rainfall into events of shorter duration (Nielsen-Gammon, 2011c). In Texas, temperatures are likely to rise; however, future precipitation trends are difficult to project. If temperatures rise and precipitation decreases, as projected by climate models, Texas would begin seeing droughts in the middle of the 21st century that are as bad or worse as those in the beginning or middle of the 20th century.

While the study of climate models can certainly be informative during the regional water planning process, there is a considerable degree of uncertainty associated with use of the results at a local or regional scale. The large-scale spatial resolution of most climate models (typically at a resolution of 100 to

200 miles by 100 to 200 miles) are of limited use for planning regions since most hydrological applications require information at a 30-mile scale or less. Recent research, including some funded by TWDB, has been focused in the area of "downscaling" climate models, or converting the global-scale output to regional-scale conditions. The process to produce a finer-scale climate model can be resource-intensive and can only be done one region at a time, thus making it difficult to incorporate the impacts of climate variability in local or region-specific water supply projections.

4.8 TWDB ONGOING RESEARCH

TWDB has undertaken several efforts to address potential impacts from climate variability to water resources in the state and how these impacts can be addressed in the water planning process. In response to state legislation, TWDB co-hosted a conference in El Paso on June 17, 2008, to address the possible impact of climate change on surface water supplies from the Rio Grande (Sidebar: The Far West Texas Climate Change Conference). The agency also hosted two Water Planning and Climate Change Workshops

THE FAR WEST TEXAS CLIMATE CHANGE CONFERENCE

As a result of legislation passed during the 80th Texas Legislative Session, TWDB, in coordination with the Far West Texas Regional Water Planning Group, conducted a study regarding the possible impact of climate change on surface water supplies from the portion of the Rio Grande in Texas subject to the Rio Grande Compact. In conducting the study, TWDB was directed to a convene a conference within the Far West Texas regional water planning area to review

- any analysis conducted by a state located west of Texas regarding the impact of climate change on surface water supplies in that state;
- any other current analysis of potential impacts of climate change on surface water resources; and
- recommendations for incorporating potential impacts of climate change into the Far West Texas Regional Water Plan, including potential impacts to the Rio Grande in Texas subject to the Rio Grande Compact, and identifying feasible water management strategies to offset any potential impacts.

The Far West Texas Climate Change Conference was held June 17, 2008, in El Paso. Over 100 participants attended, including members of the Far West Texas Regional Water Planning Group and representatives from state and federal agencies, environmental organizations, water providers, universities, and other entities. TWDB published a report on the results of the conference in December 2008. General policy recommendations from the conference included

- continuing a regional approach to considering climate change in regional water planning;
- establishing a consortium to provide a framework for further research and discussion;
- reconsidering the drought of record as the benchmark scenario for regional water planning; and
- providing more funding for research, data collection, and investments in water infrastructure.

in 2008 and 2009 to address the issue of climate on a state level. The workshops convened experts in the fields of climate variability and water resources planning to discuss possible approaches to estimating the impact of climate variability on water demand and availability and how to incorporate these approaches into regional water planning efforts.

In response to recommendations from these experts, TWDB initiated two research studies. The *Uncertainty and Risk in the Management of Water Resources* (INTERA Incorporated and others, 2010) study developed a generalized methodology that allows various sources of uncertainty to be incorporated into the regional water planning framework. Using estimates of the probability of specific events, planners will be able to use this model to analyze a range of scenarios and potential future outcomes. A second, on-going research study assessing global climate models for water resource planning applications is comparing global climate models to determine which are most suitable for use in Texas. The study is also comparing regionalization techniques used in downscaling of global climate models and will provide recommendations on the best methodology for a given region.

The agency also formed a staff workgroup that leads the agency's efforts to

- monitor the status of climate science, including studies for different regions of Texas;
- assess changes predicted by climate models;
- analyze and report data regarding natural climate variability; and
- evaluate how resilient water management strategies are in adapting to climate variability and how regional water planning groups might address the impacts.

Until better information is available to determine the impacts of climate variability on water supplies and water management strategies evaluated during the planning process, regional water planning groups can continue to use safe yield (the annual amount of water that can be withdrawn from a reservoir for a period of time longer than the drought of record) and to plan for more water than required to meet needs, as methods to address uncertainty and reduce risks. TWDB will continue to monitor climate policy and science and incorporate new developments into the cyclical planning process when appropriate. TWDB will also continue stakeholder and multi-disciplinary involvement on a regular basis to review and assess the progress of the agency's efforts.

REFERENCES

Cleaveland, M.K., 2006, Extended Chronology of Drought in the San Antonio Area: Tree Ring Laboratory, Geosciences Department, University of Arkansas.

INTERA Incorporated, Richard Hoffpauir Consulting, and Jackson, C.S., 2010, Analyzing Uncertainty and Risk in the Management of Water Resources for the State of Texas: Prepared for the Texas Water Development Board, http://www.twdb.state.tx.us/RWPG/rpgm_reports/0904830857_uncertainty_waterresourcemgmt.pdf.

IPCC (International Panel on Climate Change), 2007, Climate Change 2007: Synthesis Report: Cambridge University Press, http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm.

Larkin, T.J. and Bomar, G.W., 1983, Climatic Atlas of Texas: Texas Water Development Board Limited Publication 192, http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/LimitedPublications/LP192.pdf.

NCDC (National Climatic Data Center), 2011, Climate data: Asheville, NC, National Climatic Data Center, National Environmental Satellite Data and Information Services, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, ASCII tabular data files, http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#.

Nielsen-Gammon, J.W., 2011a, The Drought of Record was Made to Be Broken, Houston Chronical, http://blog.chron.com/climateabyss/2011/09/the-drought-of-record-was-made-to-be-broken/.

Nielsen-Gammon, J.W., 2011b, written communication: comments on the Draft 2012 State Water Plan.

Nielsen-Gammon, J.W., 2011c., The Changing Climate of Texas in Schmandt and others, eds., The Impact of Global Warming on Texas, Second Edition: University of Texas Press, http://www.texasclimate.org/Home/ImpactofGlobalWarmingonTexas/tabid/481/Default.aspx.

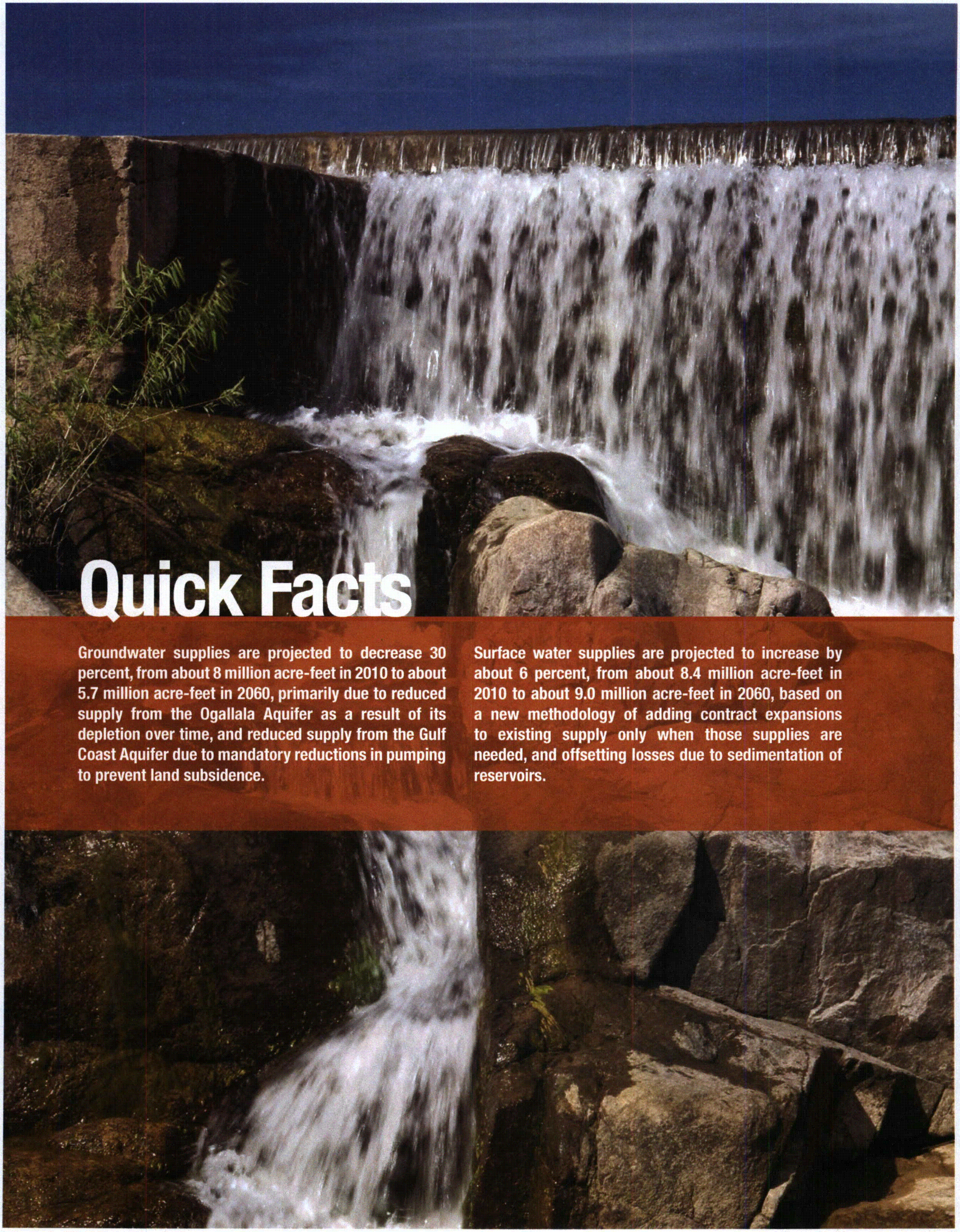
PRISM Climate Group, 2011, Annual high-resolution climate data sets for the conterminous United States (2.5-arc minute 2001–2010 mean annual grids for the conterminous United States): Corvallis, OR, PRISM Climate Group, Oregon State University, Arc/INFO ASCII raster grid files, http://www.prism.oregonstate.edu.

Slade, R.M., Jr. and Patton, J., 2003, Major and catastrophic storms and floods in Texas – 215 major and 41 catastrophic events from 1853 to September 1, 2002: U.S. Geological Survey Water Resources Division Open-File Report 03-193.

TWDB (Texas Water Development Board), 1967, The Climate and Physiography of Texas: Texas Water Development Board Report 53, http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/GWReports/R53/R53.pdf.

TWDB (Texas Water Development Board), 2005, Digital Climatic Atlas of Texas: Texas Water Development Board, Annual high-resolution climate data sets for the state of Texas (2.5-arc minute 1981–1990 and 1991–2000 10-year mean annual grids for Texas) raster grid files, http://www.twdb.state.tx.us/GAM/resources/Digital_Climate_Atlas_TX.zip.

USGS (U.S. Geological Survey), 2000, Hydro 1K digital elevation model (DEM) for North America: Sioux Falls, SD, Earth Resources Observation and Science Center, U.S. Geological Survey, U.S. Department of the Interior, DEM file, http://edc.usgs.gov/products/elevation/gtopo30/hydro/na_dem.html.



Quick Facts

Groundwater supplies are projected to decrease 30 percent, from about 8 million acre-feet in 2010 to about 5.7 million acre-feet in 2060, primarily due to reduced supply from the Ogallala Aquifer as a result of its depletion over time, and reduced supply from the Gulf Coast Aquifer due to mandatory reductions in pumping to prevent land subsidence.

Surface water supplies are projected to increase by about 6 percent, from about 8.4 million acre-feet in 2010 to about 9.0 million acre-feet in 2060, based on a new methodology of adding contract expansions to existing supply only when those supplies are needed, and offsetting losses due to sedimentation of reservoirs.

5 Water Supplies

Existing water supplies — the amount of water that can be produced with current permits, current contracts, and existing infrastructure during drought — are projected to decrease about 10 percent, from about 17.0 million acre-feet in 2010 to about 15.3 million acre-feet in 2060.

When planning to address water needs during a drought, it is important to know how much water is available now and how much water will be available in the future. Water supplies are traditionally from surface water and groundwater sources; however, water reuse and seawater desalination are expected to become a growing source of water over the next 50 years. Existing water supplies are those supplies that are physically and legally available now. In other words, existing supplies include water that providers have permits or contracts for now and are able to provide to water users with existing infrastructure such as reservoirs, pipelines, and well fields. Water availability, on the other hand, refers to how much water would be available if there were no legal or infrastructure limitations.

During their evaluation of existing water supplies, regional water planning groups determine how much water would be physically and legally available from existing sources under drought conditions with consideration of all existing permits, agreements, and infrastructure. To estimate existing water supplies, the planning groups use the state's surface water and groundwater availability models, when available. The state's existing water supplies—mainly from surface water, groundwater, and reuse water—are projected to decrease about 10 percent over the planning horizon, from about 17.0 million acre-feet in 2010 to about 15.3 million acre-feet in 2060 (Figure 5.1). Estimates of existing supplies compared to projected water demands are used by the planning groups to determine water supply needs or surpluses for individual water user groups.

FIGURE 5.1. PROJECTED EXISTING WATER SUPPLIES (ACRE-FEET PER YEAR).

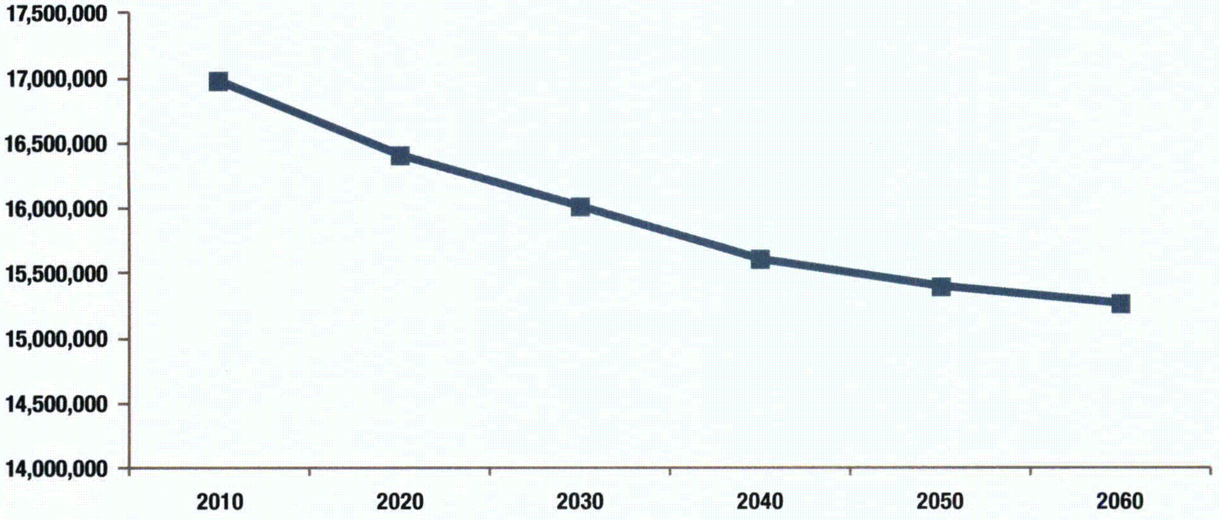
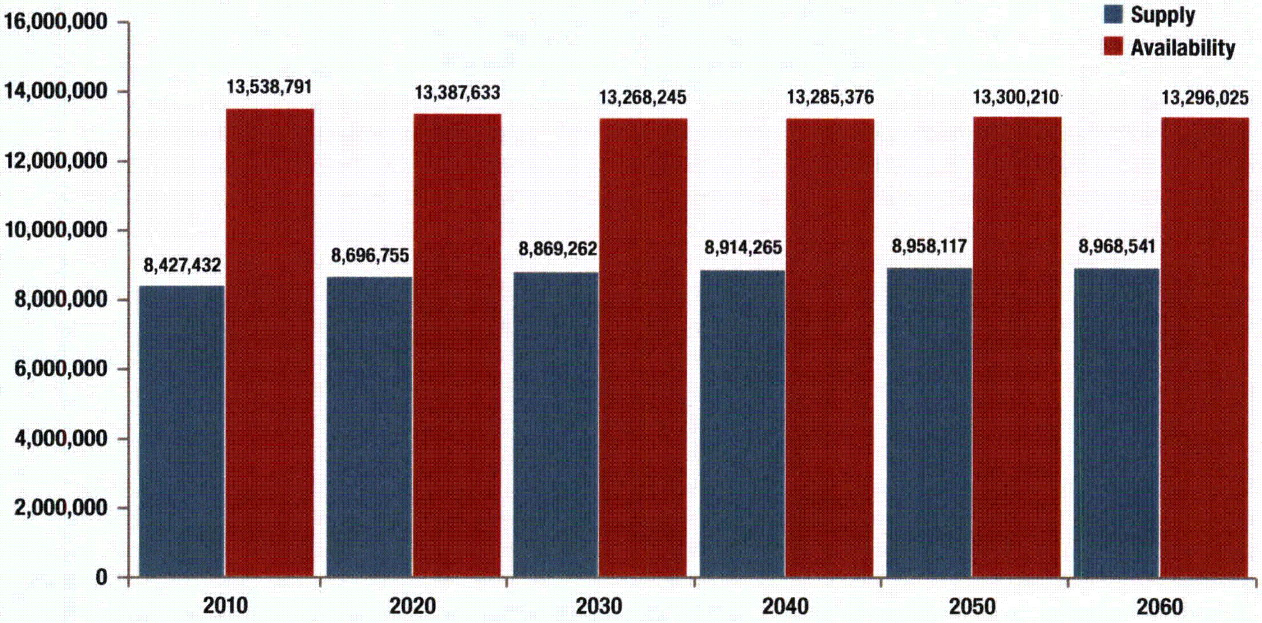


FIGURE 5.2. MAJOR RIVER BASINS OF TEXAS.

FIGURE 5.3. PROJECTED EXISTING SURFACE WATER SUPPLIES AND SURFACE WATER AVAILABILITY THROUGH 2060 (ACRE-FEET PER YEAR).



5.1 SURFACE WATER SUPPLIES

Surface water accounted for nearly 40 percent of the total 16.1 million acre-feet of water used in Texas in 2008, according to the latest TWDB Water Use Survey information available. The state has a vast array of surface waters, including rivers and streams, lakes and reservoirs, springs and wetlands, bays and estuaries, and the Gulf of Mexico. Texas' surface water resources include

- 15 major river basins and 8 coastal basins (Figure 5.2)
- 191,000 miles of streams and rivers
- 7 major and 5 minor estuaries

The 2007 State Water Plan included summaries of each of the 15 major river basins in Texas; these summaries are still current and are incorporated by reference in the 2012 State Water Plan. The river basin summaries included location maps; a description of the basin; and information on reservoir capacity and yield, surface water rights, and approximate surface water supply with implementation of water management strategies recommended in the 2007 State Water Plan.

Surface water is captured in 188 major water supply reservoirs (Appendix C)—those with a storage capacity of 5,000 acre-feet or more—and in over 2,000 smaller impoundments throughout the state. Nine of Texas' 16 planning regions rely primarily on surface water for their existing supplies and will continue to rely on this important resource through 2060. Surface water abundance generally matches precipitation patterns in Texas; annual yield from Texas' river basins, the average annual flow volume per unit of drainage area, varies from about 11.8 inches in the Sabine River Basin in east Texas to 0.1 inch in the Rio Grande Basin in west Texas.

5.1.1 EXISTING SURFACE WATER SUPPLIES

Existing surface water supplies represent the maximum amount of water legally and physically available from existing sources for use during drought

TABLE 5.1. EXISTING SURFACE WATER SUPPLIES BY RIVER BASIN (ACRE-FEET PER YEAR)

River Basin	2010	2020	2030	2040	2050	2060	Percent Change*
Brazos	1,273,273	1,271,586	1,275,209	1,277,160	1,277,876	1,278,589	0
Brazos-Colorado	21,433	21,485	21,536	21,591	21,654	21,662	1
Canadian	44,174	55,816	55,779	55,729	54,332	54,264	22
Colorado	994,305	989,650	990,151	991,147	992,524	991,281	-0
Colorado-Lavaca	4,298	4,298	4,298	4,298	4,298	4,298	0
Cypress	274,271	273,979	273,618	273,247	273,915	274,029	-0
Guadalupe	205,990	206,626	205,197	201,260	201,329	201,408	-2
Lavaca	79,354	79,354	79,354	79,354	79,354	79,354	0
Lavaca-Guadalupe	434	434	434	434	434	434	0
Neches	524,063	802,883	985,391	1,013,133	1,034,174	1,060,852	102
Neches-Trinity	79,066	79,066	79,066	79,066	79,066	79,067	0
Nueces	148,874	153,069	157,631	159,427	159,934	160,746	8
Nueces-Rio Grande	8,908	8,908	8,908	8,908	8,908	8,908	0
Red	342,559	328,060	323,901	319,524	314,769	309,339	-9
Rio Grande	1,150,631	1,144,214	1,138,329	1,132,278	1,125,801	1,119,901	-2
Sabine	691,243	670,275	650,091	649,761	649,841	648,341	-6
Sabine-Louisiana	235	235	235	235	235	235	0
San Antonio	61,259	61,259	61,258	61,258	61,257	61,256	0
San Antonio-Nueces	1,794	1,794	1,794	1,794	1,794	1,794	0
San Jacinto	202,592	202,952	203,117	203,113	203,126	203,133	0
San Jacinto-Brazos	27,450	27,434	27,501	27,545	27,597	27,645	0
Sulphur	308,788	311,559	316,552	321,336	325,577	333,513	8
Trinity	1,943,370	1,962,750	1,970,841	1,993,645	2,021,370	2,009,621	3
Trinity-San Jacinto	39,068	39,069	39,071	39,022	38,952	38,871	0
Total	**8,427,432**	**8,696,755**	**8,869,262**	**8,914,265**	**8,958,117**	**8,968,541**	**6**

*Percent represents the percent change from 2010 through 2060.

conditions. Most planning regions base their estimates of existing surface water supplies on firm yield, the maximum volume of water a reservoir can provide each year under a repeat of the drought of record. Some regions, however, base their plans and estimates of existing supply on safe yield, the annual amount of water that can be withdrawn from a reservoir for a period of time longer than the drought of record, often one to two years. Use of safe yield in planning allows a buffer to account for climate variability, including the possibility of a drought that might be worse than the drought of record.

Total existing surface water supplies in Texas were 8.4 million acre-feet in 2010; these supplies are projected to increase to 9.0 million acre-feet by 2060 (Figure 5.3). The amount of existing supplies was determined by the planning groups based on a combination of firm yields and safe yields.

Existing surface water supplies are greatest in the Trinity, Brazos, and Rio Grande river basins (Table 5.1). Existing supplies increase the most from 2010 to 2060 for the Neches River Basin as additional surface water is made available through existing contracts. The increase in contracted water through 2060 is greater than the loss of existing surface water supply that occurs due to reservoir sedimentation. Decreases in the amount of existing surface water supplies can occur due to loss of reservoir capacity to sedimentation. The 2007 State Water Plan also showed a decreasing trend in surface water supply due to sedimentation.

TABLE 5.2. SURFACE WATER AVAILABILITY BY RIVER BASIN (ACRE-FEET PER YEAR)

River Basin	2010	2020	2030	2040	2050	2060	Percent Change*
Brazos	1,641,169	1,653,791	1,594,374	1,586,831	1,579,328	1,571,832	-4
Brazos-Colorado	21,433	21,485	21,536	21,591	21,654	21,662	1
Canadian	48,136	68,105	68,064	68,024	67,984	67,947	41
Colorado	1,170,052	1,149,068	1,154,169	1,183,249	1,189,432	1,225,451	5
Colorado-Lavaca	4,298	4,298	4,298	4,298	4,298	4,298	0
Cypress	378,087	377,847	377,607	377,367	377,127	376,887	0
Guadalupe	273,961	273,890	273,820	273,749	273,678	273,607	0
Lavaca	79,374	79,374	79,374	79,374	79,374	79,374	0
Lavaca-Guadalupe	434	434	434	434	434	434	0
Neches	2,328,154	2,324,792	2,321,431	2,318,067	2,314,705	2,311,367	-1
Neches-Trinity	79,070	79,070	79,070	79,070	79,070	79,071	0
Nueces	185,920	184,902	183,884	182,866	181,851	180,843	-3
Nueces-Rio Grande	8,922	8,922	8,922	8,922	8,922	8,922	0
Red	578,732	574,363	569,966	565,463	560,798	556,427	-4
Rio Grande	1,184,415	1,176,889	1,169,864	1,162,838	1,155,812	1,149,286	-3
Sabine	1,837,834	1,834,362	1,830,796	1,827,234	1,823,675	1,820,110	-1
Sabine-Louisiana	235	235	235	235	235	235	0
San Antonio	61,259	61,259	61,258	61,258	61,257	61,256	0
San Antonio-Nueces	1,794	1,794	1,794	1,794	1,794	1,794	0
San Jacinto	324,110	320,570	316,835	312,931	309,044	305,151	-6
San Jacinto-Brazos	58,791	58,775	51,026	51,070	51,122	51,170	-13
Sulphur	524,561	522,307	519,889	517,755	515,332	513,224	-2
Trinity	2,708,894	2,571,944	2,540,440	2,561,796	2,604,123	2,596,498	-4
Trinity-San Jacinto	39,156	39,157	39,159	39,160	39,161	39,179	0
Total	**13,538,791**	**13,387,633**	**13,268,245**	**13,285,376**	**13,300,210**	**13,296,025**	**-2**

*Percent represents the percent change from 2010 through 2060.

5.1.2 SURFACE WATER AVAILABILITY

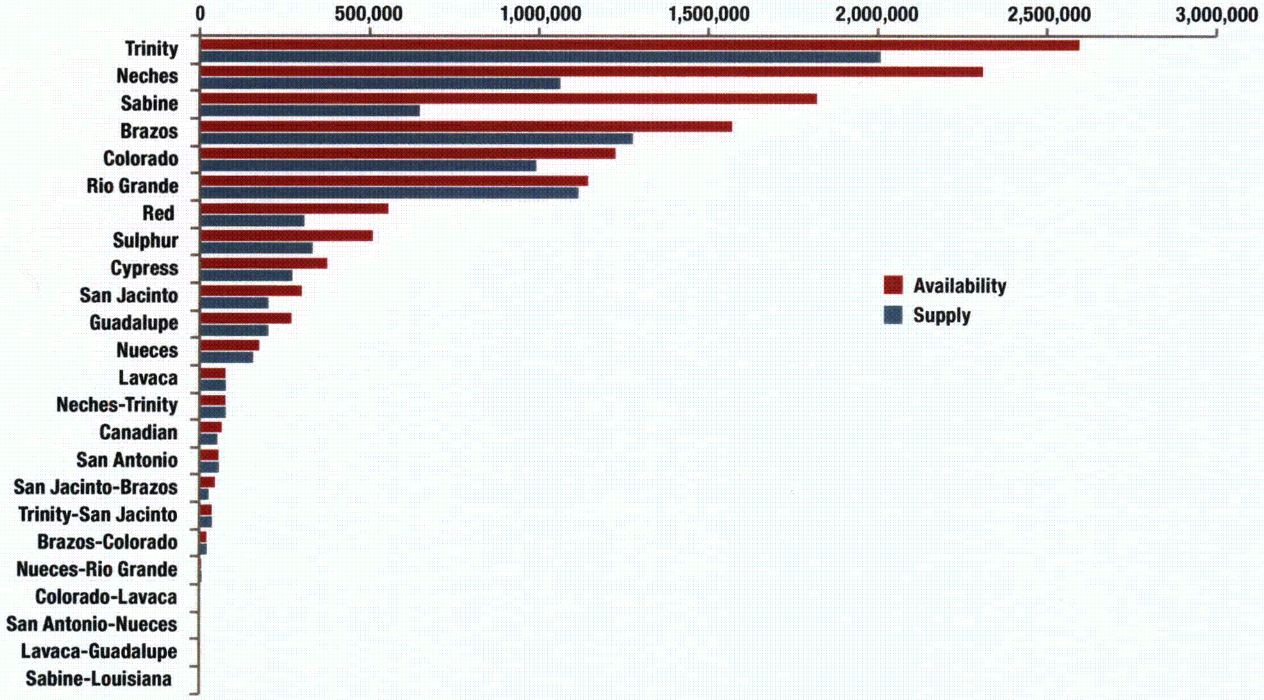
Surface water availability is derived from water availability models, computer-based simulations developed by the Texas Commission on Environmental Quality that predict the amount of water that would be available for diversion under a specified set of conditions. Surface water availability represents the maximum amount of water available each year during the drought of record regardless of legal or physical availability. Total surface water availability in Texas in 2010 is estimated at 13.5 million acre-feet per year and decreases to 13.3 million acre-feet per year (Figure 5.3) by 2060. Water availability is the greatest in the Trinity, Neches, and Sabine river basins for the 2010 to 2060 period (Table 5.2). Loss of some surface water availability is due to reservoir sedimentation.

Surface water availability projections equal or exceed existing supplies in all river basins in the state (Figure 5.4). The Neches and Sabine river basins, where availability exceeds supply by 2 million acre-feet in 2060, show the greatest potential to increase surface water supplies in the future.

5.1.3 FUTURE IMPACTS TO AVAILABILITY: ENVIRONMENTAL FLOWS

The concept of environmental flows refers to the water required to maintain healthy and productive rivers and estuaries—bays or inlets, often at the mouth of a river, in which large quantities of freshwater and seawater mix together. State law requires consideration of environmental flows in Texas' regional water planning and surface water permitting processes.

FIGURE 5.4. EXISTING SURFACE WATER SUPPLIES AND SURFACE WATER AVAILABILITY IN 2060 BY RIVER BASIN (ACRE-FEET PER YEAR).



Early studies of the effect of freshwater inflow upon the bays and estuaries of Texas led to a series of publications for all of Texas' major estuaries in the 1980s, with subsequent updates in the 1990s and 2000s. Instream flow needs—the amount of water needed in a stream to adequately provide for downstream uses occurring within the stream channel—were first developed for Texas' rivers using the "Lyon's method," and later the Consensus Criteria for Environmental Flow Needs for water supply planning. Senate Bill 2, passed by the 77th Texas Legislature in 2001, directed TWDB, the Texas Commission on Environmental Quality, and the Texas Parks and Wildlife Department to work together to maintain data collection programs and conduct studies to develop appropriate methodologies for determining environmental flows needed to protect rivers and streams.

Although methodologies had been established for developing environmental flow needs prior to 2007, there was a desire among stakeholders for more certainty in how the methodologies would be applied in the evaluation and permitting of new water supply projects. Senate Bill 3, passed by the 80th Texas Legislature in 2007, addressed these issues and led to a new approach in developing environmental flow needs for the state's major rivers and estuaries in an accelerated, science-based process with stakeholder input.

Environmental flow recommendations resulting from the Senate Bill 3 process are scheduled to be completed for the Sabine-Neches, Trinity-San Jacinto, Brazos, Colorado-Lavaca, Guadalupe-San Antonio, Nueces, and Rio Grande river basins and their associated bays by 2012. Standards and rules for these systems are scheduled to be set by the Texas Commission on Environmental Quality in 2013 and to be available for use in developing the 2017 State Water Plan. No schedule has been set for the remaining river basins in Texas.

Planning groups consider the impacts of recommended water management strategies on a number of resources, including instream flows and bay and estuary freshwater inflows. Senate Bill 3 rules for environmental flows for Texas' rivers and estuaries had not been adopted while the 2011 regional water plans were being developed; therefore, they were not considered in development of the 2012 State Water Plan. The regional water planning groups must meet all state laws when developing regional water plans and must therefore consider Senate Bill 3 environmental flow standards that are in place when developing future plans.

Beginning with the 2011 to 2016 planning cycle, regional water plans will consider environmental flow standards as they are developed and adopted by the Texas Commission on Environmental Quality as a result of the Senate Bill 3 environmental flow process. These new standards will be incorporated, as appropriate, within the surface water availability models that planning groups use to assess current surface water supplies and to evaluate and recommend water management strategies. In basins that do not have environmental flow standards in place, other site-specific studies or the Consensus Criteria for Environmental Flow Needs will continue to be considered, as in previous planning cycles.

5.2 GROUNDWATER SUPPLIES

Groundwater is and will continue to be an important source of water for Texas. Before 1940, groundwater provided less than 1 million acre-feet of water per year to Texans. Since the drought of record in the 1950s, groundwater production has been about 10 million acre-feet per year. In 2008, according to the latest TWDB Water Use Survey information available, groundwater provided 60 percent of the 16.1 million acre-feet of water used in the state. Farmers used about 80 percent of this groundwater to irrigate crops. Municipalities used about 15 percent of all the groundwater in 2008, meeting about 35 percent of their total water demands.

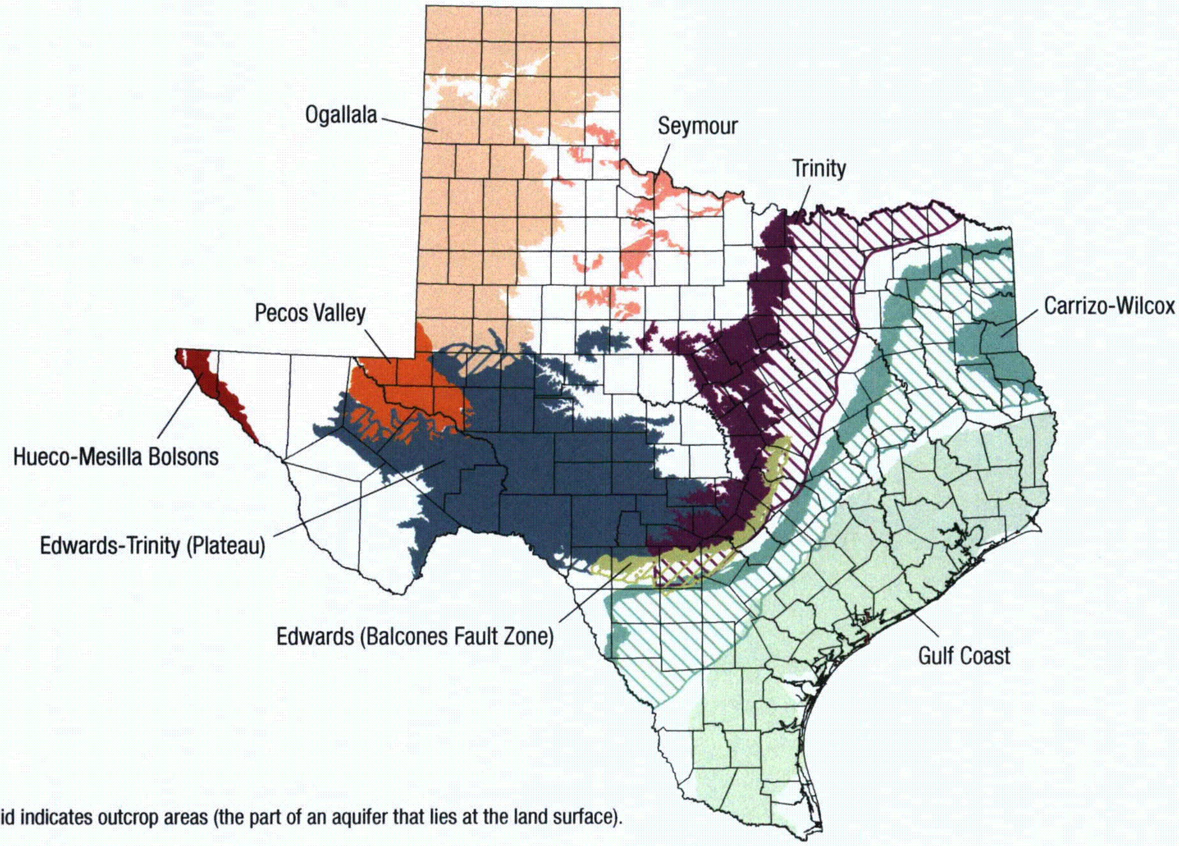
TWDB recognizes 30 major and minor aquifers, each with their own characteristics and ability to produce water. Along with a number of other local, state, and federal agencies, TWDB monitors the water quality and water levels of these aquifers. This information assists groundwater managers and regional water planning groups in estimating groundwater supplies and availability. It is also used in groundwater availability models, developed by TWDB to aid groundwater managers and water planners in better understanding and using this vital natural resource in Texas.

Texas has a number of aquifers that are capable of producing groundwater for municipal, industrial, and agricultural uses. TWDB recognizes 9 major aquifers that produce large amounts of water over large areas (Figure 5.5), and 21 minor aquifers that produce minor amounts of water over large areas or large amounts of water over small areas (Figure 5.6). The 2007 State Water Plan included summaries of each of the 30 major and minor aquifers in Texas; these summaries are still current and are incorporated by reference in the 2012 State Water Plan. The aquifer summaries include location maps; a discussion and list of aquifer properties and characteristics; and projections of groundwater supplies, including supplies to be obtained from implementing water management strategies from the 2007 State Water Plan.

5.2.1 EXISTING GROUNDWATER SUPPLIES

Existing groundwater supplies represent the amount of groundwater that can be produced with

FIGURE 5.5. THE MAJOR AQUIFERS OF TEXAS.



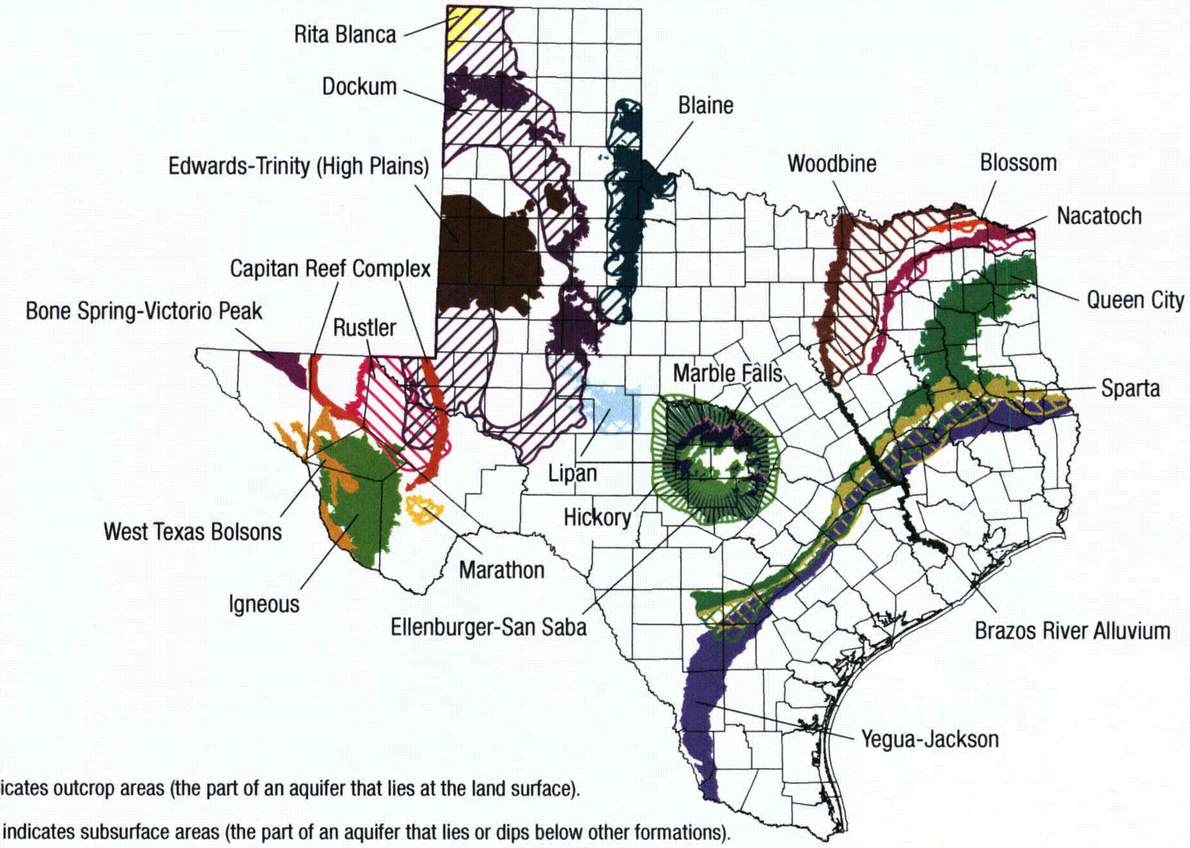
Solid indicates outcrop areas (the part of an aquifer that lies at the land surface).

Hatched indicates subsurface areas (the part of an aquifer that lies or dips below other formations).

current permits and existing infrastructure. Because permits and existing infrastructure limit how much groundwater can be produced, existing groundwater supply can be—and often is—less than the total amount that can be physically produced from an aquifer. A permit represents a legal limit on how much water can be produced. Therefore, even though a group of wells may be able to pump 2,000 acre-feet per year, the supply is limited to 1,000 acre-feet per year if the permit is for 1,000 acre-feet per year. On the other hand, if the permit is for 2,000 acre-feet per year but existing infrastructure—that is, current wells—can only pump 1,000 acre-feet per year, then the groundwater supply is 1,000 acre-feet per year. By calculating groundwater supply, water planners know how much groundwater can be used with current infrastructure and what needs to be done to meet needs in the future (for example, larger pumps, new wells, or pipelines).

Existing groundwater supplies were about 8.1 million acre-feet per year in 2010 and will decline 30 percent over the planning horizon, to about 5.7 million acre-feet per year by 2060 (Figure 5.7, Table 5.3). This decline is due primarily to reduced supplies from the Ogallala and Gulf Coast aquifers: annual Ogallala Aquifer supplies are projected to decline by about 2 million acre-feet per year by 2060 as a result of depletion, while annual Gulf Coast Aquifer supplies are projected to decline by about 210,000 acre-feet per year by 2060 due to mandatory reductions in pumping to prevent land surface subsidence (Figure 5.8). In most cases,

FIGURE 5.6. THE MINOR AQUIFERS OF TEXAS.



Solid indicates outcrop areas (the part of an aquifer that lies at the land surface).

Hatched indicates subsurface areas (the part of an aquifer that lies or dips below other formations).

The Edwards-Trinity (High Plains) and Rita Blanca aquifers are both entirely subsurface.

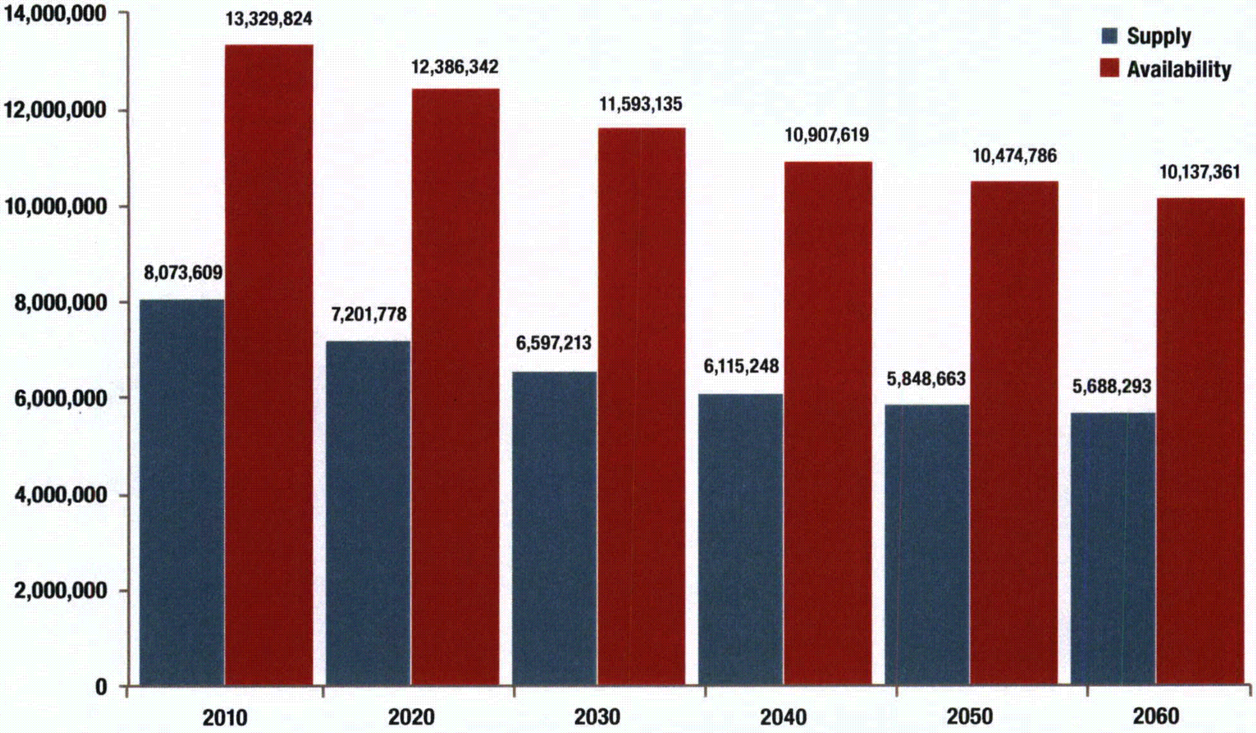
existing groundwater supplies either remain constant over the planning horizon or decrease by 2060.

5.2.2 GROUNDWATER AVAILABILITY

Groundwater availability is the amount of water from an aquifer that is available for use regardless of legal or physical availability. One might think that the amount of groundwater available for use is all of the water in the aquifer; however, that may not—and probably is not—the case. Groundwater availability is limited by existing infrastructure, as well as by law, groundwater management district goals, and state rules. For example, the Texas Legislature directed the subsidence districts in Fort Bend, Galveston, and Harris counties to decrease and limit groundwater production to prevent land subsidence, the sinking of the land's surface. Another example is the Edwards (Balcones Fault Zone) Aquifer, most of which is regulated by the Edwards Aquifer Authority, which was created by the Texas Legislature to manage and protect the aquifer system by limiting groundwater production.

To determine groundwater availability, planning groups used one of two policies: sustainability, in which an aquifer can be pumped indefinitely; or planned depletion, in which an aquifer is drained over a period of time. Total groundwater availability in 2010 is about 13.3 million acre-feet per year (Table 5.4). Because of projected declines in the Dockum, Edwards-Trinity (High Plains), Gulf Coast, Ogallala, Rita Blanca, and Seymour aquifers, availability decreases to 10.1 million acre-feet per year by 2060.

FIGURE 5.7. PROJECTED EXISTING GROUNDWATER SUPPLIES AND GROUNDWATER AVAILABILITY THOUGH 2060 (ACRE-FEET PER YEAR).



5.2.3 GROUNDWATER SUPPLY TRENDS

The groundwater availability numbers established by the regional water planning groups for the 2011 regional water plans vary from those established by the regional planning groups in the 2007 State Water Plan. In some counties, planning groups increased their estimates of groundwater availability, and in other counties, planning groups decreased their estimates of groundwater availability. Table 5.5 summarizes these changes in terms of volume (acre-feet per year) by decade, with "no significant change" defined as an increase or decrease of less than 1,000 acre-feet per year. Table 5.6 summarizes these changes in terms of percent change from the 2007 State Water Plan, with "no significant change" defined as an increase or decrease of less than 10 percent of the 2007 State Water Plan groundwater availability.

5.2.4 POTENTIAL FUTURE IMPACTS RELATING TO GROUNDWATER AVAILABILITY

Future regional water plans may be impacted by the amount of groundwater that will be considered as available to meet water demands as determined through the state's desired future conditions planning process. They may also be impacted by groundwater permitting processes that limit the term of the permit or allow for reductions in originally permitted amounts.

In 2005, the 79th Legislature passed House Bill 1763, which modified the Texas Water Code regarding how groundwater availability is determined in Texas. Among the changes, House Bill 1763 regionalized decisions on groundwater availability and required regional water planning groups to use groundwater availability figures from the groundwater conservation districts. In 2011, the 82nd Texas Legislature replaced

TABLE 5.3. EXISTING GROUNDWATER SUPPLIES FOR THE MAJOR AND MINOR AQUIFERS (ACRE-FEET PER YEAR)

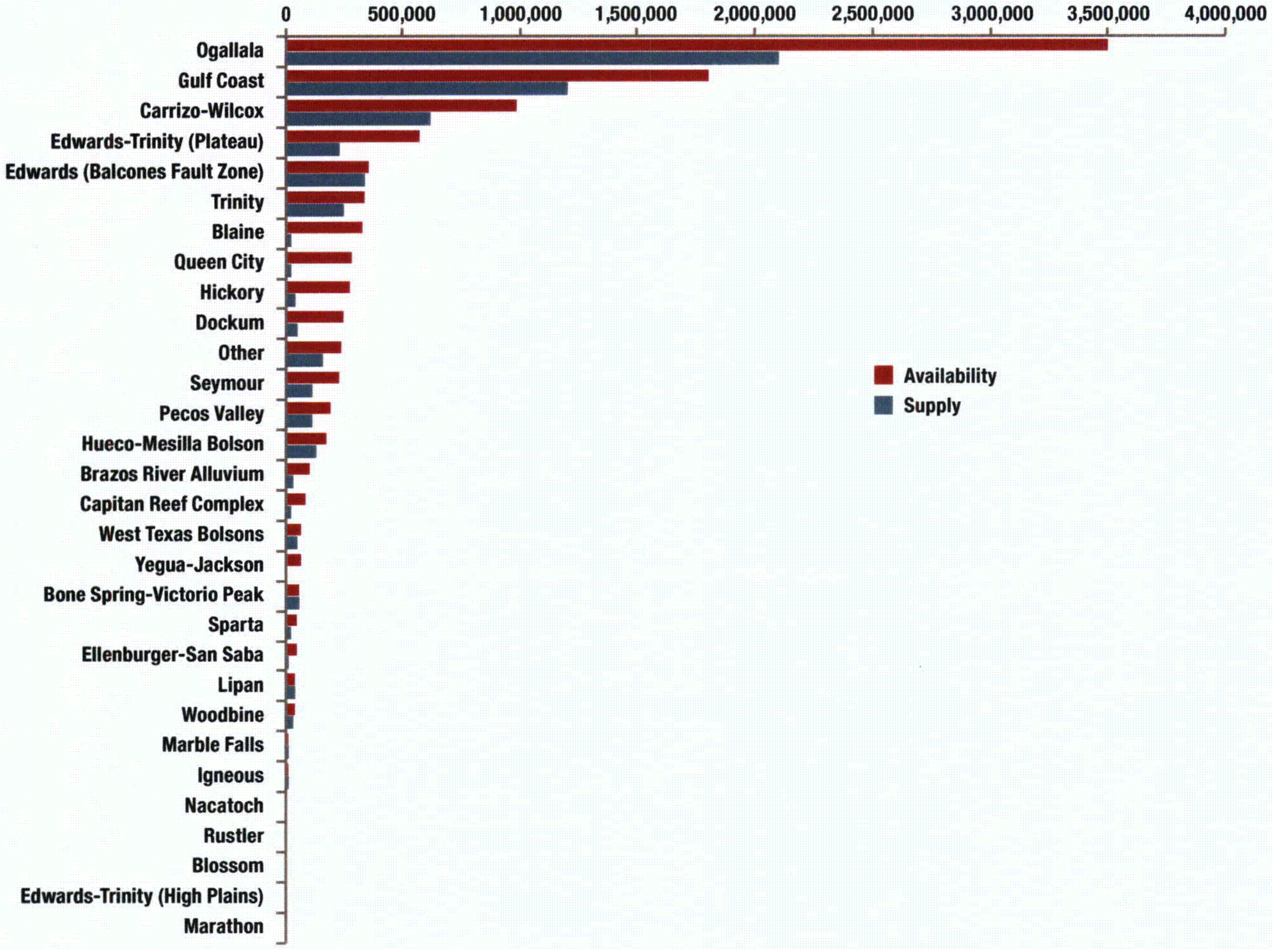
Aquifer	2010	2020	2030	2040	2050	2060	Percent Change*
Blaine	32,267	28,170	27,702	27,122	25,759	24,496	-24
Blossom	815	815	815	815	815	815	0
Bone Spring-Victorio Peak	63,000	63,000	63,000	63,000	63,000	63,000	0
Brazos River Alluvium	39,198	38,991	38,783	38,783	38,783	38,783	-1
Capitan Reef Complex	23,144	24,669	25,743	26,522	27,017	27,327	18
Carrizo-Wilcox	622,443	627,813	628,534	619,586	614,425	616,855	-1
Dockum	55,585	55,423	61,510	59,837	58,429	57,086	3
Edwards (Balcones Fault Zone)	338,778	338,702	338,828	338,794	338,775	338,763	0
Edwards-Trinity (High Plains)	4,160	3,580	2,802	2,335	2,065	2,065	-50
Edwards-Trinity (Plateau)	225,409	225,450	225,468	225,467	225,467	225,472	0
Ellenburger-San Saba	21,786	21,778	21,776	21,776	21,831	21,886	0
Gulf Coast	1,378,663	1,242,949	1,191,798	1,186,142	1,176,918	1,166,310	-15
Hickory	49,037	49,126	49,205	49,279	49,344	49,443	1
Hueco-Mesilla Bolson	131,826	131,826	131,826	131,826	131,826	131,826	0
Igneous	13,946	13,946	13,946	13,946	13,946	13,946	0
Lipan	42,523	42,523	42,523	42,523	42,523	42,523	0
Marathon	148	148	148	148	148	148	0
Marble Falls	13,498	13,498	13,498	13,498	13,498	13,522	0
Nacatoch	3,733	3,822	3,854	3,847	3,808	3,776	1
Ogallala and Rita Blanca	4,187,892	3,468,454	2,911,789	2,448,437	2,202,499	2,055,245	-51
Other	159,688	159,789	159,820	159,822	159,827	159,896	0
Pecos Valley	120,029	114,937	114,991	115,025	115,071	115,125	-4
Queen City	26,441	26,507	26,574	26,438	26,507	26,556	0
Rustler	2,469	2,469	2,469	2,469	2,469	2,469	0
Seymour	142,021	132,045	128,882	127,530	124,863	122,205	-14
Sparta	25,395	25,373	25,359	24,919	24,924	24,933	-2
Trinity	254,384	250,837	250,544	250,392	249,291	249,040	-2
West Texas Bolsons	52,804	52,804	52,804	52,804	52,804	52,804	0
Woodbine	34,173	34,036	33,932	33,876	33,741	33,688	-1
Yegua-Jackson	8,354	8,298	8,290	8,290	8,290	8,290	-1
Total	**8,073,609**	**7,201,778**	**6,597,213**	**6,115,248**	**5,848,663**	**5,688,293**	**-30**

*Percent represents the percent change from 2010 through 2060.

the term "managed available groundwater" with "modeled available groundwater," effective September 1, 2011. Modeled available groundwater represents the total amount of groundwater, including both permitted and exempt uses, that can be produced from the aquifer in an average year, that achieves a "desired future condition," a description of how the aquifer will look in the future. Managed available groundwater was the amount of groundwater production not including uses that were exempt from permitting that would achieve the desired future condition. From a regional water planning and state water planning perspective, the use of modeled available groundwater considers all uses—those permitted by groundwater conservation districts as well as those uses that are exempt from permitting.

Before House Bill 1763, each groundwater conservation district defined groundwater availability for its jurisdiction and included it in their groundwater management plans under the name "total usable amount of groundwater." As a result of the passage of House Bill 1763, districts are now working together in each designated groundwater management area (Figure 5.9) to develop and adopt desired future conditions for their groundwater resources. The districts then submit these desired future conditions to TWDB. TWDB, in turn, provides estimates of

FIGURE 5.8. GROUNDWATER SUPPLY AND GROUNDWATER AVAILABILITY IN 2060 BY AQUIFER (ACRE-FEET PER YEAR).



"modeled available groundwater"—the new term in statute for groundwater availability—to the districts for inclusion in their groundwater management plans and to the regional water planning groups for inclusion in their regional water plans.

Statute required that groundwater conservation districts in groundwater management areas submit their desired future conditions to TWDB by September 1, 2010. However, for the regional water planning groups to be required to include managed available groundwater values in their 2011 regional water plans, desired future conditions had to be submitted to TWDB before January 1, 2008, allowing TWDB to estimate managed available groundwater values. The inclusion of managed available groundwater values in the regional water plans for desired future conditions submitted to TWDB after that date was at the discretion of the regional water planning groups.

Because most of the desired future conditions were adopted after 2008, regional water planning groups generally had to use their own estimates of groundwater availability to meet their statutory deadlines for adoption of their regional water plans. The groundwater conservation districts in groundwater management areas 8 and 9 were the only ones to submit desired future conditions for

TABLE 5.4. GROUNDWATER AVAILABILITY FOR THE MAJOR AND MINOR AQUIFERS (ACRE-FEET PER YEAR)

Aquifer	2010	2020	2030	2040	2050	2060	Percent Change*
Blaine	326,950	325,700	325,700	325,700	325,700	325,700	0
Blossom	2,273	2,273	2,273	2,273	2,273	2,273	0
Bone Spring-Victorio Peak	63,000	63,000	63,000	63,000	63,000	63,000	0
Brazos River Alluvium	108,183	108,183	108,183	108,183	108,183	108,183	0
Capitan Reef Complex	86,150	86,150	86,150	86,150	86,150	86,150	0
Carrizo-Wilcox	1,002,648	1,002,073	994,513	994,391	994,367	994,367	-1
Dockum	382,188	342,266	337,070	305,244	277,270	252,570	-34
Edwards (Balcones Fault Zone)	350,682	350,932	353,432	353,532	356,182	357,782	2
Edwards-Trinity (High Plains)	4,160	3,580	2,802	2,335	2,065	2,065	-50
Edwards-Trinity (Plateau)	572,598	572,598	572,598	572,598	572,598	572,598	0
Ellenburger-San Saba	50,339	50,339	50,339	50,339	50,339	50,339	0
Gulf Coast	1,898,091	1,816,285	1,776,213	1,775,997	1,776,384	1,775,991	-6
Hickory	275,089	275,089	275,089	275,089	275,089	275,089	0
Hueco-Mesilla Bolson	178,000	178,000	178,000	178,000	178,000	178,000	0
Igneous	15,100	15,100	15,100	15,100	15,100	15,100	0
Lipan	48,535	48,535	48,535	48,535	48,535	48,535	0
Marathon	200	200	200	200	200	200	0
Marble Falls	17,679	17,679	17,679	17,679	17,679	17,679	0
Nacatoch	10,494	10,494	10,494	10,494	10,494	10,494	0
Ogallala and Rita Blanca	6,379,999	5,561,382	4,832,936	4,179,979	3,773,018	3,459,076	-46
Other	238,192	238,209	238,202	238,174	238,144	238,154	0
Pecos Valley	200,451	200,451	200,451	200,451	200,451	200,451	0
Queen City	291,336	291,336	291,336	291,336	291,336	291,336	0
Rustler	2,492	2,492	2,492	2,492	2,492	2,492	0
Seymour	243,173	242,173	228,527	228,527	228,527	228,527	-6
Sparta	54,747	54,747	54,747	54,747	54,747	54,747	0
Trinity	342,192	342,193	342,191	342,191	341,580	341,580	0
West Texas Bolsons	70,746	70,746	70,746	70,746	70,746	70,746	0
Woodbine	44,905	44,905	44,905	44,905	44,905	44,905	0
Yegua-Jackson	69,232	69,232	69,232	69,232	69,232	69,232	0
Total	**13,329,824**	**12,386,342**	**11,593,135**	**10,907,619**	**10,474,786**	**10,137,361**	**-24**

*Percent represents the percent change from 2010 through 2060.

some of its aquifers by that deadline (Table 5.7). By the fourth round of regional water planning (2011 to 2016), managed available groundwater numbers that are based on the districts' desired future conditions will be available for use in all regional water plans.

In the next round of regional water planning (2011 to 2016), planning groups will be required to use modeled available groundwater volumes to determine water supply needs in their regions. As a result, there will be some groundwater availability estimates that are lower than the regional water planning group's groundwater availability estimates in prior regional plans. This situation may impact the amount of water supply needs and strategies in the plan. If needs are greater or strategies cannot be implemented due to unavailable supplies, regional water planning groups and those looking to implement water management strategies will have to consider other sources of water. It is also important to note that despite what is shown in this plan for groundwater availability, the managed available groundwater and a groundwater conservation district's associated permitting process will ultimately dictate whether or not a particular strategy can be implemented.

Groundwater permitting processes that provide for limited term-permits or that allow for reductions in a permit holder's allocations over a short period of time could also impact the certainty and feasibility

TABLE 5.5. NUMBER OF COUNTIES WHERE THERE IS A DECREASE, NO SIGNIFICANT CHANGE, OR INCREASE IN GROUNDWATER AVAILABILITY BETWEEN 2007 STATE WATER PLAN AND 2011 REGIONAL WATER PLANS (ACRE-FEET PER YEAR)

Decade	Decrease of more than 1,000 acre-feet per year	Decrease of less than 1,000 acre-feet per year or increase of less than 1,000 acre-feet per year	Increase of more than 1,000 acre-feet per year
2010	20	170	64
2020	22	169	63
2030	22	169	63
2040	23	170	61
2050	26	169	59
2060	29	170	55

of water management strategies and may require looking at strategies that use other sources of water than groundwater.

5.3 REUSE SUPPLIES

Reuse refers to the use of groundwater or surface water that has already been beneficially used. The terms "reclaimed water," "reused water," and "recycled water" are used interchangeably in the water industry. As defined in the Texas Water Code, reclaimed water is domestic or municipal wastewater that has been treated to a quality suitable for beneficial use. Reuse or reclaimed water is not the same as graywater, that is, untreated household water from sinks, showers, and baths.

There are two types of water reuse: direct reuse and indirect reuse. Direct reuse refers to the introduction of reclaimed water via pipelines, storage tanks, and other necessary infrastructure directly from a water reclamation plant to a distribution system. For example, treating wastewater and then piping it to an industrial center or a golf course would be considered direct reuse. Indirect reuse is the use of water, usually treated effluent, which is placed back into a water supply source such as a lake, river, or aquifer, and then retrieved to be used again. Indirect reuse projects that involve a watercourse require a "bed and banks" permit from the state, which authorizes the permit holder to convey and subsequently divert water in a watercourse or stream. Both direct and indirect reuse can be applied for potable—suitable for drinking—and non-potable—suitable for uses other than drinking—purposes.

Water reuse has been growing steadily in Texas over the past two decades. A recent survey of Texas water producers revealed that in 2010 approximately 62,000 acre-feet per year of water was used as direct reuse and 76,000 acre-feet per year of water was used as bed and banks permitted indirect reuse. The number of entities receiving permits from the Texas Commission on Environmental Quality for direct non-potable water reuse rose from 1 in 1990 to 187 by June 2010. Evidence of the increasing interest and application of indirect reuse is also illustrated by several large and successful projects that have been implemented by the Tarrant Regional Water District and the Trinity River Authority in the Dallas-Fort Worth area.

Like surface water and groundwater, the amount of existing water reuse supplies is based on the amount of water that can be produced with current permits and existing infrastructure. The planning groups estimated that the existing supplies in 2010 were approximately 482,000 acre-feet per year. Reuse supplies will increase to about 614,000 acre-feet per year by 2060 (Figure 5.10, Table 5.8). Existing water supplies from direct and indirect reuse by 2060 for 16 regional water planning areas are shown in Figure 5.11 and Figure 5.12. The amount of existing supply from direct reuse was about 279,000 acre-feet per year in 2010, and indirect reuse was approximately 203,000 acre-feet per year in 2012. Compared to the 2007 State Water Plan, this represents an increase of about 242,000 acre-feet per year of available supply by the year 2060.

TABLE 5.6. NUMBER OF COUNTIES WHERE THERE IS A DECREASE, NO SIGNIFICANT CHANGE, OR INCREASE IN GROUNDWATER AVAILABILITY BETWEEN 2007 STATE WATER PLAN AND 2011 REGIONAL WATER PLANS (EXPRESSED AS A PERCENT)

Decade	Decrease of more than 10 percent	Decrease of less than 10 percent or increase of less than 10 percent	Increase of more than 10 percent
2010	19	183	52
2020	19	182	51
2030	18	183	53
2040	20	182	52
2050	21	182	51
2060	22	182	50

TABLE 5.7. SUMMARY OF MANAGED AVAILABLE GROUNDWATER VALUES INCLUDED IN THE 2011 REGIONAL WATER PLANS

Regional water planning area	Groundwater management area	Aquifer
B	8	Trinity (Montague County)
C	8	Trinity, Woodbine
D	8	Woodbine
F	8	Trinity (Brown County)
G	8	Brazos River Alluvium, Woodbine, and Edwards (Balcones Fault Zone)
K	8	Edwards (Balcones Fault Zone), Hickory, Ellenburger-San Saba, Marble Falls
L	9	Edwards Group of the Edwards-Trinity (Plateau)

TABLE 5.8. PROJECTED EXISTING SUPPLY OF WATER FROM WATER REUSE (ACRE-FEET PER YEAR)

Region	Reuse type	2010	2020	2030	2040	2050	2060
A	Direct reuse	25,129	28,928	30,620	32,528	34,598	37,577
C	Direct reuse	34,552	33,887	32,413	31,465	30,731	30,340
C	Indirect reuse	148,134	197,929	240,590	261,827	269,412	276,789
D	Direct reuse	83,642	78,247	72,821	67,505	68,761	77,635
E	Direct reuse	6,000	6,000	6,000	6,000	6,000	6,000
E	Indirect reuse	38,031	38,031	38,031	38,031	38,031	38,031
F	Direct reuse	19,015	19,309	19,459	19,609	19,759	19,909
G	Direct reuse	17,344	17,344	17,344	17,344	17,344	17,344
H	Indirect reuse	0	0	438	14,799	14,840	14,866
I	Direct reuse	1,518	1,533	1,546	1,559	1,570	1,584
I	Indirect reuse	16,559	13,687	13,687	13,687	13,687	13,687
L	Direct reuse	16,049	16,049	16,049	16,049	16,049	16,049
M	Direct reuse	24,677	24,677	24,677	24,677	24,677	24,677
O	Direct reuse	51,514	35,071	35,822	36,737	37,853	39,213
	Total direct	**279,440**	**261,045**	**256,751**	**253,473**	**257,342**	**270,328**
	Total indirect	**202,724**	**249,647**	**292,746**	**328,344**	**335,970**	**343,373**
	Total reuse	**482,164**	**510,692**	**549,497**	**581,817**	**593,312**	**613,701**

FIGURE 5.9. GROUNDWATER MANAGEMENT AREAS IN TEXAS.

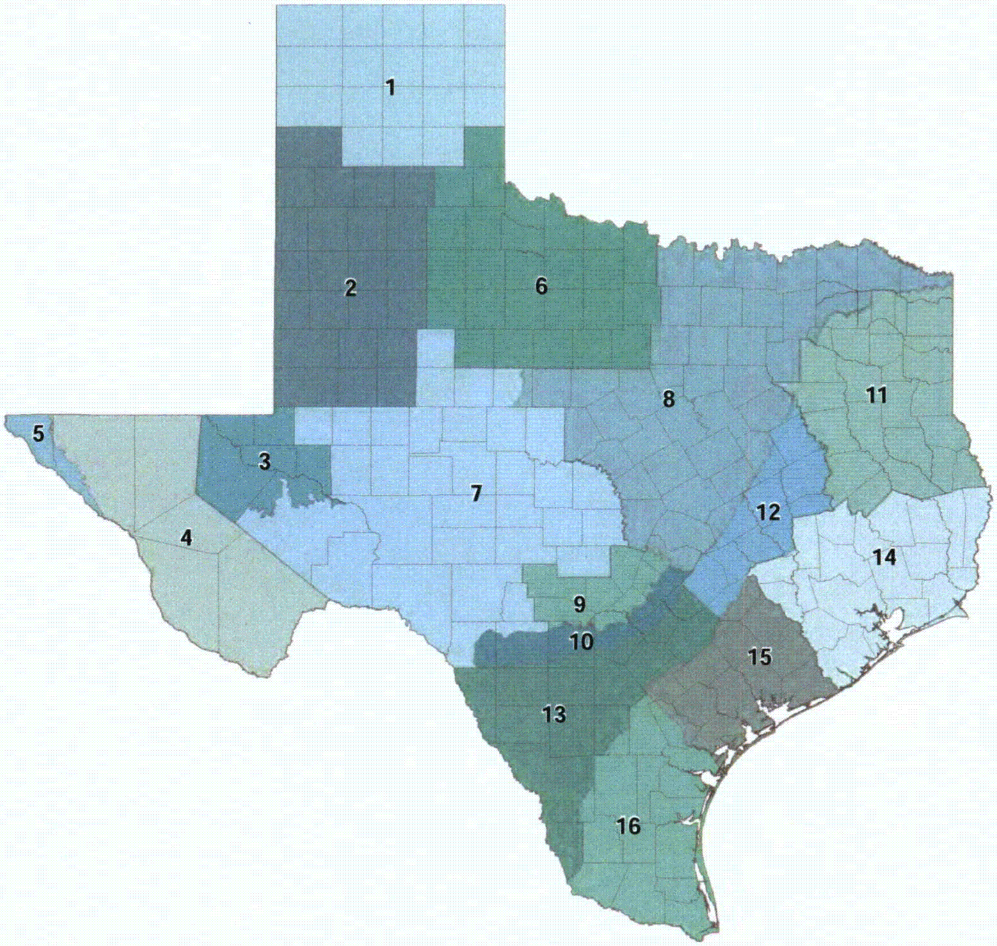


FIGURE 5.10. PROJECTED EXISTING WATER REUSE SUPPLIES THROUGH 2060 (ACRE-FEET PER YEAR).

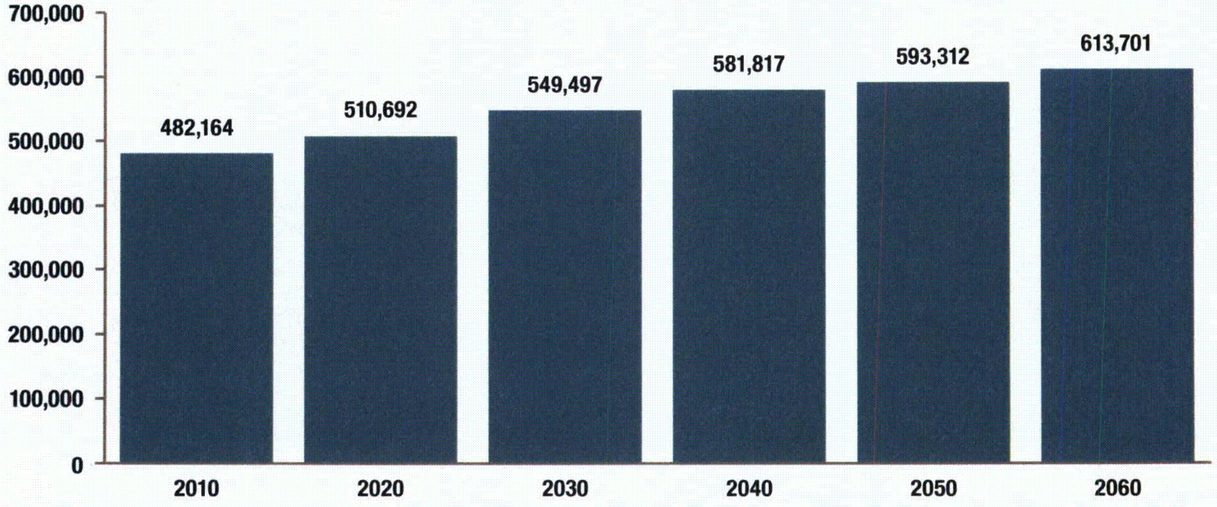


FIGURE 5.11. EXISTING INDIRECT REUSE SUPPLIES THROUGH 2060 BY REGION (ACRE-FEET PER YEAR).

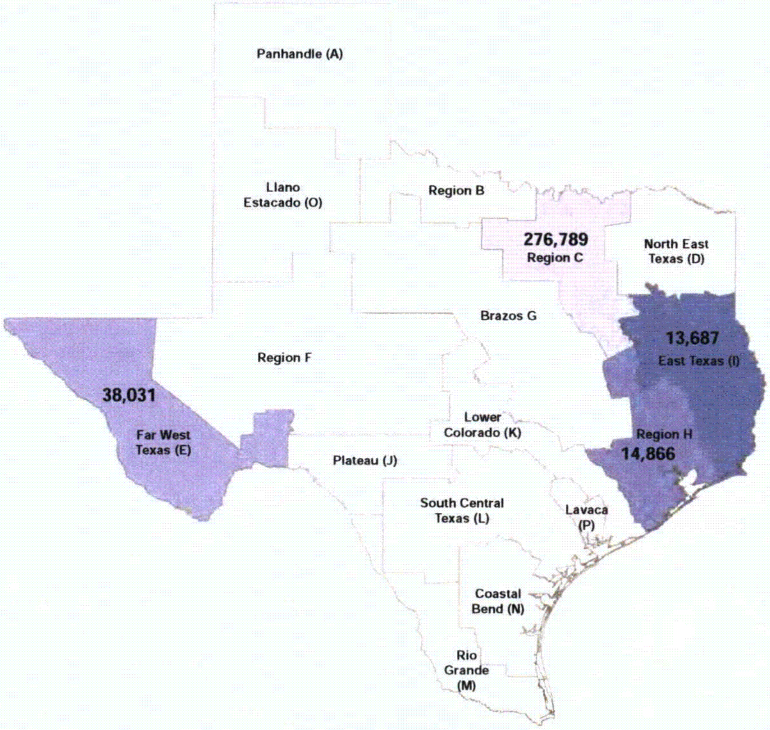
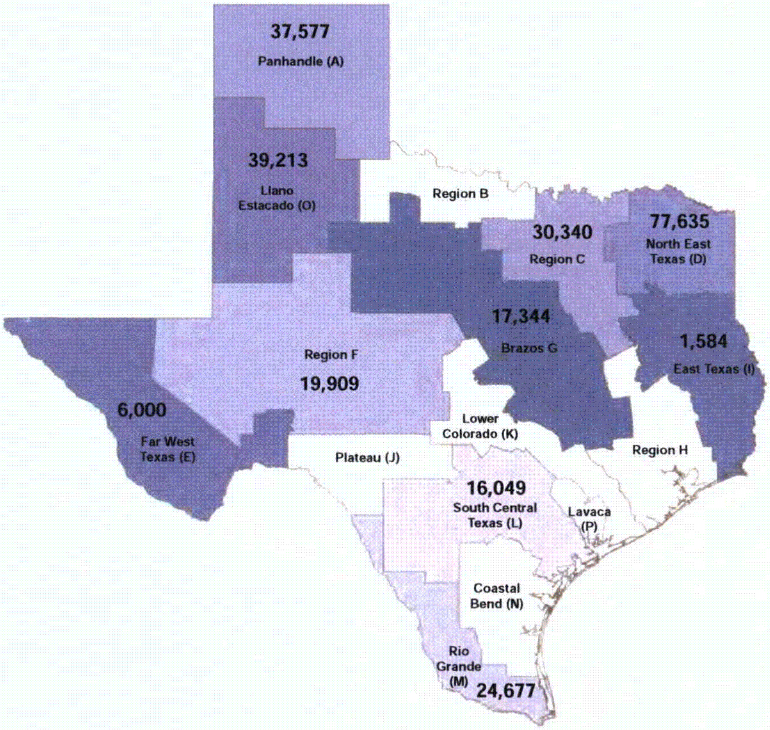
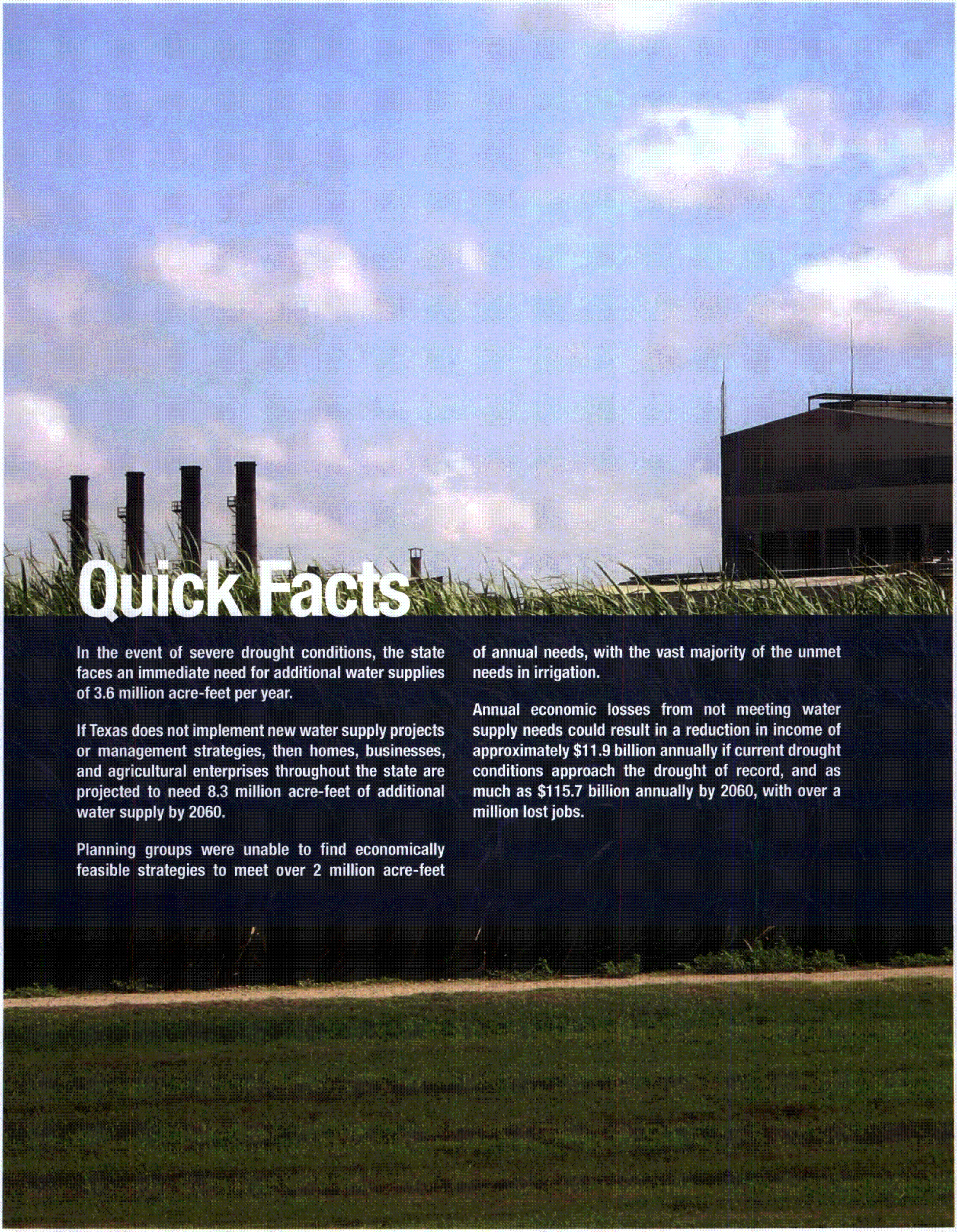


FIGURE 5.12. EXISTING DIRECT REUSE SUPPLIES THROUGH 2060 BY REGION (ACRE-FEET PER YEAR).





Quick Facts

In the event of severe drought conditions, the state faces an immediate need for additional water supplies of 3.6 million acre-feet per year.

If Texas does not implement new water supply projects or management strategies, then homes, businesses, and agricultural enterprises throughout the state are projected to need 8.3 million acre-feet of additional water supply by 2060.

Planning groups were unable to find economically feasible strategies to meet over 2 million acre-feet of annual needs, with the vast majority of the unmet needs in irrigation.

Annual economic losses from not meeting water supply needs could result in a reduction in income of approximately $11.9 billion annually if current drought conditions approach the drought of record, and as much as $115.7 billion annually by 2060, with over a million lost jobs.

6 Water Supply Needs

Needs are projected water demands in excess of existing supplies that would be legally and physically available during a drought of record.

Growing at a rate of approximately 1,100 people per day over the last decade, Texas is one of the fastest growing states in the nation. By 2060, the population of the state is projected to increase to over 46 million people. Rapid growth, combined with Texas' robust economy and susceptibility to drought, makes water supply a crucial issue. If water infrastructure and water management strategies are not implemented, Texas could face serious social, economic, and environmental consequences in both the large metropolitan areas as well as the vast rural areas of the state.

Unreliable water supplies could have overwhelming negative implications for Texas. For example, water shortages brought on by drought conditions would more than likely curtail economic activity in industries heavily reliant on water, which could result in not only job loss but a monetary loss to local economies as well as the state economy. Also, a lack of reliable water supply may bias corporate decision-makers against expanding or locating their businesses in Texas.

TABLE 6.1. WATER NEEDS BY REGION (ACRE-FEET PER YEAR)

Region	2010	2020	2030	2040	2050	2060
A	454,876	454,118	487,316	501,830	462,230	418,414
B	23,559	28,347	34,074	35,802	37,485	40,397
C	69,087	399,917	686,836	953,949	1,244,618	1,588,236
D	10,252	14,724	18,696	31,954	60,005	96,142
E	209,591	213,091	215,624	210,794	216,113	226,569
F	191,057	200,868	204,186	211,018	214,792	219,995
G	131,489	196,761	228,978	272,584	334,773	390,732
H	290,890	524,137	698,776	833,518	1,004,872	1,236,335
I	28,856	83,032	83,153	106,900	141,866	182,145
J	1,494	1,878	2,044	2,057	2,275	2,389
K	255,709	303,240	294,534	309,813	340,898	367,671
L	174,235	265,567	308,444	350,063	390,297	436,751
M	435,922	401,858	362,249	434,329	519,622	609,906
N	3,404	14,084	27,102	41,949	57,994	75,744
O	1,275,057	1,750,409	2,107,876	2,364,996	2,405,010	2,366,036
P	67,739	67,739	67,739	67,739	67,739	67,739
Total	**3,623,217**	**4,919,770**	**5,827,627**	**6,729,295**	**7,500,589**	**8,325,201**

For all these reasons as well as others, it is important to identify potential future water supply needs to analyze and understand how the needs for water could affect communities throughout the state during a severe drought and to plan for meeting those needs. When developing regional water plans, regional water planning groups compare existing water supplies with current and projected water demands to identify when and where additional water supplies are needed for each identified water user group and wholesale water provider. TWDB provides assistance in conducting this task by performing a socioeconomic impact analysis for each region at their request.

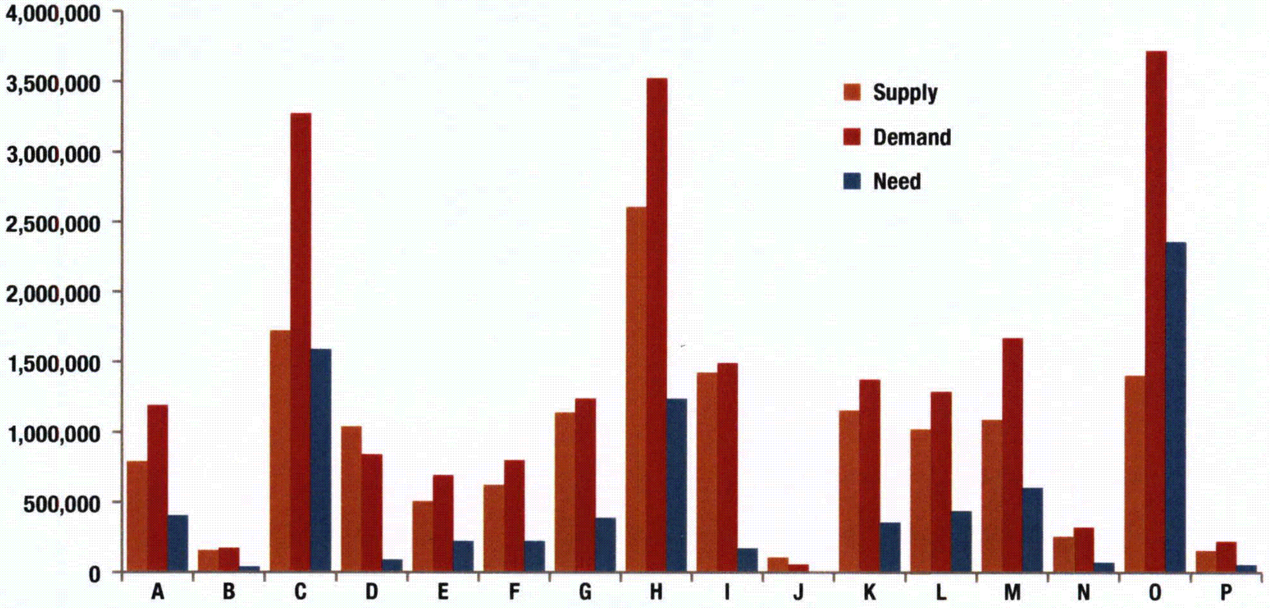
6.1 IDENTIFICATION OF NEEDS

When existing water supplies available to a specific water user group are less than projected demands, there is a need for water. In other words, once there is an identified water demand projection for a given water user group, this estimate is then deducted from identified existing supplies for that water user group, resulting in either a water supply surplus or a need. Planning groups have identified a statewide water supply need of 3.6 million acre-feet in 2010 and 8.3 million acre-feet by 2060, which is a slight reduction from the 2007 State Water Plan in which planning groups identified estimated needs of 3.7 million acre-feet in 2010 and 8.9 million acre-feet in 2060. Table 6.1 shows the total water supply needs identified for each region by the regional water planning groups for the current planning cycle.

Although in some regions it appears that there are sufficient existing water supplies region-wide to meet demands under drought conditions in the early planning decades, local existing water supplies are not always available to all users throughout the region. Therefore, water needs were identified as a result of this geographic "mismatch" of existing supplies and anticipated shortages (Figure 6.1).

The regional water planning groups were tasked with identifying needs for water user groups—municipal, county-other, manufacturing, steam-electric, livestock,

FIGURE 6.1. EXISTING WATER SUPPLIES, PROJECTED DEMANDS, AND NEEDS BY REGION IN 2060 (ACRE-FEET PER YEAR).



irrigation, and mining—and wholesale water providers. Water uses for the following categories were estimated at the county level: county-other, manufacturing, mining, steam-electric, livestock, and irrigation.

The planning groups identified 982 total non-municipal water user groups; 174 (18 percent) of these would currently have inadequate water supply in drought of record conditions, with that number increasing to 260 (26 percent) by 2060. The planning groups also identified 1,587 total municipal water user groups and 173 total wholesale water providers. Of the municipal water user groups, 470 (30 percent) would currently have water supply needs if the state were facing drought conditions, increasing to 825 (52 percent of the total) in 2060. Of the wholesale water providers, the planning groups identified 83 (48 percent) that would currently face shortages; those with needs are projected to increase to 109 (63 percent) by 2060 (Table 6.2). If no action is taken to implement water management strategies, over 50 percent of the state's population in 2060 would face a water need of at least 45 percent of their projected demand during a repeat of drought conditions.

6.1.1 MUNICIPAL NEEDS

Municipal water use accounts for about 9 percent of total identified needs or roughly 315,000 acre-feet in 2010, increasing to 41 percent or 3.4 million acre-feet by 2060. These estimates are down from projections in the 2007 State Water Plan, where municipal water supply needs were projected to be about 610,000 and 3.8 million acre-feet in 2010 and 2060, respectively. This reduction is a result of implementing projects from the past plan.

If the state were to experience drought conditions like those in the 1950s, Region L would currently experience the largest identified municipal needs at

TABLE 6.2. NUMBER OF WATER USER GROUPS WITH NEEDS BY REGION

Region	2010	2020	2030	2040	2050	2060
A	8	14	20	22	22	23
B	7	8	8	8	7	7
C	172	246	262	267	269	270
D	17	20	28	32	36	39
E	2	10	10	11	12	12
F	53	54	50	52	54	54
G	66	72	84	89	96	97
H	132	229	234	237	237	241
I	31	41	45	51	56	60
J	2	2	2	2	2	2
K	36	46	53	59	63	67
L	47	58	65	69	72	77
M	35	44	50	54	63	64
N	8	12	14	15	16	16
O	26	37	45	48	53	54
P	2	2	2	2	2	2
Total water user groups with needs	**644**	**895**	**972**	**1,018**	**1,060**	**1,085**
Total water user groups	**2,569**	**2,569**	**2,569**	**2,569**	**2,569**	**2,569**
Percent of water user groups with needs	**25**	**35**	**38**	**40**	**41**	**42**

about 96,000 acre-feet. However, by 2060, Regions C, H, and M account for the majority of these needs, with the Dallas-Fort Worth area responsible for a large portion of those needs. In fact, with the exception of Region P, every region in the state would be affected by future municipal water shortages.

6.1.2 WHOLESALE WATER PROVIDERS

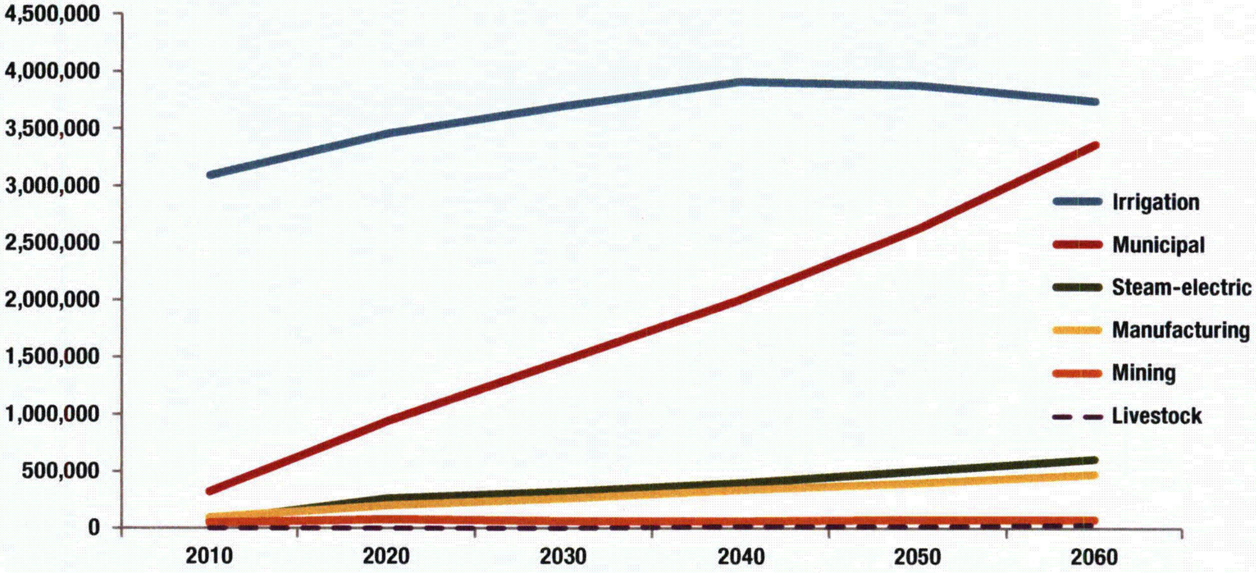
Wholesale water providers—entities such as some river authorities, municipal utility districts, and water supply corporations—deliver and sell large amounts of raw (untreated) or treated water for municipal and manufacturing use on a wholesale or retail basis. In many instances, the burden of their water needs is shared by both the water user group facing the projected shortage and the entity that provides water to them, since the needs for wholesale water providers are not additional to those of water user groups but made up of needs from several of those entities.

Wholesale water providers are projected to have total water supply needs under drought conditions of about 835,000 acre-feet in 2010 and 4.4 million acre-feet in 2060. Tarrant Regional Water District, the City of Dallas, North Texas Municipal Water District, and the City of Fort Worth are the wholesale water providers with the largest projected needs by 2060.

6.1.3 NON-MUNICIPAL NEEDS

Irrigation: Irrigation accounts for the largest share of the state's total current water demand, roughly 60 percent. It is projected to remain the state's largest water use category through 2050, although by 2060, TWDB projects its share of the total demand will decline to approximately 38 percent of total water demand. As expected, irrigation also accounts for the largest percentage of projected water supply needs under drought conditions at 3.1 million acre-feet, or 86 percent of the total in 2010; irrigation needs are projected to increase to 3.8 million acre-feet by 2060. However, this will only account for about 45 percent of the state's total water needs in 2060, due to the large increase in volume of municipal needs from 2010 to

FIGURE 6.2. PROJECTED WATER NEEDS BY USE CATEGORY (ACRE-FEET PER YEAR).



2060 (Figure 6.2). The vast majority of irrigation needs occur in the most heavily irrigated parts of the state.

Irrigation needs represent an increase from those projected in the 2007 State Water Plan, which were 2.8 million acre-feet in 2010 and 3.7 million acre-feet by 2060. This increase is largely due to the transfer of water rights from irrigation to municipal and groundwater depletion in the more heavily irrigated parts of the state.

Livestock: Although livestock water use is quite small in comparison to other water uses, the inability to meet demands could prove costly for some parts of the state. Under drought conditions, Region I would account for almost all of the projected livestock needs for 2010, which are slightly over 1,000 acre-feet. By 2060, the state total is projected to increase to approximately 30,000 acre-feet, with Region O accounting for the majority of the total needs followed by Region I. This represents a decline from the projected livestock needs of about 11,000 acre-feet in 2010 and 39,000 acre-feet in 2060, identified in the 2007 State Water Plan. Region A accounted for a large percentage of livestock needs during the last round of planning; however, based on reduced livestock water use demands that resulted from a detailed study performed for this round of planning, no projected needs for livestock have been identified in Region A in the 2012 State Water Plan.

Mining: Planning groups identified 47,000 acre-feet of water needs for the mining industry statewide under drought conditions for 2010, with that total increasing to almost 85,000 acre-feet by 2060. This is an increase from needs identified in the 2007 State Water Plan, which were approximately 38,000 and 79,000 acre-feet in 2010 and 2060, respectively. In 2010, Regions I and K will have the largest percentage of mining needs, whereas by 2060 Regions C and H have the largest portion of identified mining needs. However, these projections were developed before the boom in natural gas extraction extended to some eastern and southern areas of the state late in the last decade.

TABLE 6.3. PROJECTED WATER NEEDS BY USE CATEGORY BY REGION (ACRE-FEET PER YEAR)

Region	Category	2010	2020	2030	2040	2050	2060
A	Irrigation	454,628	452,144	477,338	482,226	433,155	381,180
	Manufacturing	173	800	1,317	2,845	4,212	5,866
	Municipal	0	1,075	8,544	16,631	24,727	31,214
	Steam-electric	75	99	117	128	136	154
B	Irrigation	22,945	23,926	24,909	25,893	26,876	29,058
	Mining	177	153	145	149	162	162
	Municipal	437	468	491	502	460	462
	Steam-electric	0	3,800	8,529	9,258	9,987	10,715
C	Irrigation	510	2,588	3,412	4,007	4,492	4,913
	Manufacturing	557	11,946	21,151	30,369	39,640	48,894
	Mining	414	4,909	10,036	14,782	19,445	23,779
	Municipal	67,606	367,257	622,541	869,956	1,140,044	1,459,327
	Steam-electric	0	13,217	29,696	34,835	40,997	51,323
D	Irrigation	56	0	14	115	238	388
	Municipal	1,557	2,358	3,245	4,443	8,938	18,285
	Steam-electric	8,639	12,366	15,437	27,396	50,829	77,469
E	Irrigation	209,591	201,491	195,833	183,734	176,377	169,156
	Manufacturing	0	813	1,511	2,186	2,760	3,674
	Municipal	0	6,981	13,300	18,464	28,823	43,460
	Steam-electric	0	3,806	4,980	6,410	8,153	10,279
F	Irrigation	157,884	154,955	152,930	149,472	146,995	144,276
	Manufacturing	3,537	4,138	3,747	4,403	4,707	5,152
	Mining	503	660	29	143	232	375
	Municipal	22,038	31,275	36,100	43,706	46,511	49,619
	Steam-electric	7,095	9,840	11,380	13,294	16,347	20,573
G	Irrigation	59,571	56,961	54,422	51,942	49,527	47,181
	Manufacturing	2,762	3,441	4,108	4,783	5,393	6,054
	Mining	9,670	10,544	10,963	11,301	11,704	12,158
	Municipal	20,944	54,332	76,594	110,959	150,533	192,467
	Steam-electric	38,542	71,483	82,891	93,599	117,616	132,872
H	Irrigation	151,366	141,232	137,995	137,113	140,733	144,802
	Manufacturing	75,164	131,531	168,597	202,219	231,118	255,604
	Mining	5,992	10,595	13,850	16,278	18,736	20,984
	Municipal	55,151	228,106	360,236	453,142	579,269	758,934
	Steam-electric	3,203	12,609	18,058	24,726	34,976	55,972
	Livestock	14	64	40	40	40	39
I	Irrigation	1,675	1,805	2,156	2,536	2,955	3,416
	Manufacturing	3,392	16,014	24,580	33,256	40,999	49,588
	Mining	14,812	29,744	9,395	10,075	10,748	11,276
	Municipal	4,412	7,351	9,314	11,633	15,366	20,509
	Steam-electric	3,588	25,922	33,615	43,053	62,778	85,212
	Livestock	977	2,196	4,093	6,347	9,020	12,144
J	Municipal	1,494	1,878	2,044	2,057	2,275	2,389
K	Irrigation	234,738	217,011	198,717	181,070	164,084	135,822
	Manufacturing	146	298	452	605	741	934
	Mining	13,550	13,146	12,366	6,972	5,574	5,794
	Municipal	6,894	19,592	29,636	44,548	88,381	135,891
	Steam-electric	193	53,005	53,175	76,430	81,930	89,042
	Livestock	188	188	188	188	188	188
L	Irrigation	68,465	62,376	56,519	50,894	45,502	41,782
	Manufacturing	6,539	13,888	20,946	27,911	34,068	43,072
	Mining	521	726	1,771	1,992	2,293	2,493
	Municipal	96,653	137,614	178,217	218,245	256,777	297,386
	Steam-electric	2,054	50,962	50,991	51,021	51,657	52,018
	Livestock	3	1	0	0	0	0
M	Irrigation	407,522	333,246	239,408	245,896	252,386	258,375
	Manufacturing	1,921	2,355	2,748	3,137	3,729	4,524
	Municipal	26,479	64,277	115,719	178,005	252,293	330,625
	Steam-electric	0	1,980	4,374	7,291	11,214	16,382
N	Irrigation	627	569	1,264	2,316	3,784	5,677
	Manufacturing	409	7,980	15,859	25,181	34,686	46,905
	Mining	1,802	2,996	4,471	6,166	6,897	7,584
	Municipal	566	557	753	827	2,440	2,395
	Steam-electric	0	1,982	4,755	7,459	10,187	13,183
O	Irrigation	1,264,707	1,735,399	2,084,569	2,331,719	2,361,813	2,318,004
	Municipal	10,349	14,247	20,116	23,771	28,489	30,458
	Livestock	1	763	3,191	9,506	14,708	17,574
P	Irrigation	67,739	67,739	67,739	67,739	67,739	67,739

TABLE 6.4. UNMET NEEDS 2010–2060 (ACRE-FEET PER YEAR)

Region	Category	2010	2020	2030	2040	2050	2060
A	Irrigation	454,628	254,900	127,413	97,003	60,375	30,307
B	Irrigation	9,911	0	0	0	0	0
C	Irrigation	87	0	0	0	0	0
D	Irrigation	56	0	14	115	238	388
E	Irrigation	209,591	168,904	163,246	158,209	159,914	161,775
F	Irrigation	153,159	125,967	100,485	97,453	96,177	94,108
F	Steam-electric	1,219	3,969	5,512	7,441	10,608	14,935
G	Irrigation	49,973	45,234	40,664	38,358	36,113	33,932
G	Mining	1,800	2,001	2,116	2,281	2,446	2,567
G	Municipal	2,196	0	0	0	0	0
G	Steam-electric	36,086	0	0	0	0	0
I	Mining	7,772	8,620	9,191	9,760	10,333	10,772
I	Steam-electric	2,588	0	0	0	0	0
L	Irrigation	48,378	44,815	42,090	39,473	36,959	34,544
M	Irrigation	394,896	285,316	149,547	107,676	59,571	4,739
N	Mining	1,591	2,448	3,023	3,374	3,660	3,876
O	Irrigation	862,586	1,348,515	1,728,725	2,000,555	2,057,677	2,043,247
O	Livestock	1	763	3,191	9,506	14,708	17,574
Total		**2,236,518**	**2,291,452**	**2,375,217**	**2,571,204**	**2,548,779**	**2,452,764**

Steam-electric: Planning groups identified 63,000 acre-feet of potential water shortages for the steam-electric category in 2010, increasing dramatically to over 615,000 acre-feet by 2060. Region G accounts for the largest share of these needs for both 2010 and 2060.

Regions K, I, and D, however, are also projected to have significant water supply needs by 2060 under drought conditions. This is a reduction from the steam-electric needs identified in the 2007 State Water Plan, which were approximately 76,000 acre-feet in 2010 and 675,000 acre-feet in 2060, statewide.

Manufacturing: Planning groups identified a potential shortage of 95,000 acre-feet for the manufacturing water use category in 2010, increasing to about 470,000 acre-feet by 2060. This represents a decline from those needs identified in the last round of planning, where planning groups estimated projected needs of 132,000 and 500,000 acre-feet in 2010 and 2060, respectively. The decline is due to a reduction in Region H's water supply needs in 2010 and reductions for Regions A, C, and K in 2060, which was a result of an increase in allocated supplies in these regions. The majority of potential manufacturing needs in the 2012 State Water Plan occur in Region H, most notably in Brazoria and Harris counties, in both 2010 and 2060.

6.2 UNMET NEEDS

During the current round of planning, planning groups identified some water needs that could not be met because no feasible water management strategy could be implemented in the identified decades of needs. The majority of unmet needs fall under the irrigation water use category, especially in Regions A, E, F, M, and O. For irrigation water needs, it is likely that under drought conditions, the return on the investment is not sufficient to support implementation of costly water management strategies.

The remainder of unmet needs are relatively small, with many of them occurring only in the 2010 decade when timing issues precluded strategy implementation. In the remaining decades, there are unmet steam-electric needs in Region F, unmet mining needs in Regions G, I, and N, and unmet livestock needs in Region O. Identified unmet needs can be seen in Table 6.4.

6.3 SOCIOECONOMIC IMPACT OF NOT MEETING WATER NEEDS

As part of the regional planning process, planning groups are tasked with evaluating the social and economic impacts of not meeting identified water supply needs. TWDB provided assistance in conducting this task by performing a socioeconomic impact analysis for each region at their request. The impact analysis is based on the assumption of a physical shortage of raw surface or groundwater due to drought conditions. Under this scenario, impacts are estimates for a single year (2010, 2020, 2030, 2040, 2050, and 2060), and shortages are assumed to be temporary events resulting from drought conditions.

There are two major components to TWDB's socioeconomic analysis: (1) an economic impact component and (2) a social impact component. The economic component analyzes the impacts of water shortages on residential water consumers and losses to regional economies from reduced economic output in agriculture, industry, and commerce. The social component focuses on demographic effects, including changes in population and school enrollment, by incorporating results from the economic impact element and assessing how changes in a region's economy due to water shortages could affect patterns of migration.

Variables impacted by projected water shortages identified in this analysis include the following:

- **Regional income:** Total payroll costs, including wages and salaries plus benefits paid by industries; corporate income; rental income; and interest payments to corporations and individuals in a given region.
- **State and local business taxes:** Sales, excise, fees, licenses, and other taxes paid during normal operation of an industry.
- **Number of full- and part-time jobs:** Number of full and part-time jobs including self-employment.
- **Population losses:** Unrecognized gains in population due to water shortages.
- **Declines in school enrollment:** Potential losses to future enrollment due to population losses.

There are a variety of tools available for use in estimating economic impacts; however, the most widely used methods are input-output models combined with social accounting matrices. Impacts in this study were estimated using proprietary software known as IMPLAN PRO™. IMPLAN is a modeling system originally developed by the U.S. Forest Service in the late 1970s. Today, MIG Inc. (formerly Minnesota IMPLAN Group Inc.) owns the copyright and distributes data and software. IMPLAN is also utilized by the U.S. Army Corps of Engineers as well as many other federal and state agencies.

Once potential output reductions due to water shortages were estimated, direct impacts to total sales, employment, regional income, and business taxes were derived using regional level economic multipliers. Secondary impacts were derived using a similar methodology; however, indirect multiplier coefficients are used.

As with any attempt to measure human social activities, assumptions are necessary. Assumptions are needed to maintain a level of generality and simplicity so that models can be applied on several geographic levels and across different economic sectors. Some of the assumptions made in this analysis include the following:

- Water supply needs as reported by regional planning groups are the starting point for socioeconomic analysis.
- Since plans are developed for drought conditions on a decadal basis, estimated socioeconomic impacts are point estimates for years in which water needs are reported (2010, 2020, 2030, 2040, 2050, and 2060). Given that the resulting impacts are not cumulative in nature, it is inappropriate to sum these impacts over the planning horizon; doing so would imply that the drought conditions will occur every 10 years in the future.
- Indirect impacts measure only linkages to supporting industries (those who sell inputs to an affected sector), not the impacts on businesses that purchase the sector's final product. Thus, the measured impacts of a given water shortage likely represent an underestimate of the losses to a region's economy.
- The analysis assumes the general structure of the economy remains the same over the planning horizon.
- Monetary figures are reported in constant year 2006 U.S. dollars.

6.3.1 SOCIOECONOMIC ANALYSIS RESULTS

Assuming drought conditions were experienced statewide and water management strategies identified in the 2012 State Water Plan were not implemented, planning areas could suffer significant economic losses (Table 6.5). Models show that Texas businesses and workers could lose approximately $11.9 billion in income in 2010, with that total increasing to an estimated $115.7 billion by 2060. Losses to state and local business taxes associated with commerce could reach $1.1 billion in 2010 and escalate to roughly $9.8 billion in 2060. If water management strategies identified in the 2012 State Water Plan are not implemented to meet these needs, Texans could face an estimated 115,000 lost jobs in 2010 and 1.1 million in 2060. The state could also fail to meet its true growth potential, losing an estimated 1.4 million in potential population growth and 403,000 fewer students by 2060. The 1950s drought of record was estimated to cost the Texas economy about $3.5 billion (adjusted to 2008 dollars) annually (TBWE, 1959).

In short, TWDB estimates of socioeconomic impacts show if the state were to experience drought conditions in any year in the planning horizon and strategies were not put in place, there would be severe social and economic consequences. Furthermore, if drought conditions were to recur, the duration would likely exceed a single year and possibly cause actual impacts to the state that would exceed the estimates included in the 2012 State Water Plan.

REFERENCES

TBWE (Texas Board of Water Engineers), 1959, A Study of Droughts in Texas: Texas Board of Water Engineers Bulletin 5914, 76 p.

TABLE 6.5. ANNUAL ECONOMIC LOSSES FROM NOT MEETING WATER SUPPLY NEEDS FOR 2010–2060 (MILLIONS OF 2006 DOLLARS)

Region	Category	2010	2020	2030	2040	2050	2060
A	Regional income ($)	183	309	472	509	538	906
	State and local business taxes ($)	11	30	53	57	62	116
	Number of full- and part-time jobs	2,970	3,417	4,067	4,459	4,806	4,879
	Population losses	3,693	4,234	4,670	5,548	6,338	6,864
	Declines in school enrollment	1,042	1,201	1,237	1,025	1,171	1,270
B	Regional income ($)	5	5	5	5	5	6
	State and local business taxes ($)	0.3	0.3	0.3	0.3	0.3	0.4
	Number of full- and part-time jobs	85	88	92	96	100	108
	Population losses	13	522	1,156	1,254	1,354	1,451
	Declines in school enrollment	4	148	328	356	384	412
C	Regional income ($)	2,336	5,176	12,883	19,246	24,741	49,721
	State and local business taxes ($)	130	341	848	1,288	1,672	3,060
	Number of full- and part-time jobs	23,808	52,165	131,257	206,836	270,935	546,676
	Population losses	33,019	74,375	190,664	301,075	394,560	796,606
	Declines in school enrollment	10,348	24,340	64,415	102,345	134,283	271,468
D	Regional income ($)	357	515	620	871	1,341	1,960
	State and local business taxes ($)	51	73	88	123	189	267
	Number of full- and part-time jobs	1,224	1,780	2,150	2,998	4,639	6,784
	Population losses	1,472	2,144	2,590	3,611	5,588	8,171
	Declines in school enrollment	415	608	735	1,024	1,585	2,318
E	Regional income ($)	41	749	1,212	1,690	2,144	2,810
	State and local business taxes ($)	2	51	78	107	137	179
	Number of full- and part-time jobs	340	2,447	3,944	5,669	7,380	9,843
	Population losses	409	2,947	4,745	6,787	8,814	11,750
	Declines in school enrollment	115	836	1,257	1,254	1,628	2,173
F	Regional income ($)	1,444	1,715	2,195	2,729	3,061	3,470
	State and local business taxes ($)	145	176	236	288	330	380
	Number of full- and part-time jobs	19,225	21,784	26,293	34,853	37,661	40,877
	Population losses	25,050	26,239	31,670	41,980	45,362	49,236
	Declines in school enrollment	7,065	7,444	8,389	7,759	8,378	9,106
G	Regional income ($)	1,890	4,375	5,621	6,297	7,183	8,204
	State and local business taxes ($)	214	530	693	778	893	1,027
	Number of full- and part-time jobs	14,699	33,660	39,733	48,896	58,432	73,117
	Population losses	15,801	35,645	41,465	51,910	61,309	71,604
	Declines in school enrollment	4,457	10,112	11,764	14,727	17,393	20,314
H	Regional income ($)	3,195	5,189	10,012	12,910	15,759	18,637
	State and local business taxes ($)	326	536	1,024	1,375	1,689	2,036
	Number of full- and part-time jobs	20,176	37,849	82,478	100,622	126,412	149,380
	Population losses	24,433	45,514	99,071	122,686	152,028	175,839
	Declines in school enrollment	6,891	12,913	26,242	22,674	28,078	32,522
I	Regional income ($)	1,264	3,279	2,087	3,609	5,027	5,957
	State and local business taxes ($)	116	334	213	358	528	627
	Number of full- and part-time jobs	8,739	20,661	11,018	16,886	24,091	28,872
	Population losses	10,511	24,754	13,269	20,337	29,015	34,773
	Declines in school enrollment	2,965	7,023	3,764	5,770	8,232	9,865

TABLE 6.5. ANNUAL ECONOMIC LOSSES FROM NOT MEETING WATER SUPPLY NEEDS FOR 2010–2060 (MILLIONS OF 2006 DOLLARS) - CONTINUED

Region	Category	2010	2020	2030	2040	2050	2060
J	Regional income ($)	2	2	2	2	2	2
	State and local business taxes ($)	0.3	0.3	0.2	0.2	0.2	0.2
	Number of full- and part-time jobs	63	63	61	59	60	61
	Population losses	80	80	80	80	80	80
	Declines in school enrollment	20	20	20	20	20	20
K	Regional income ($)	138	1,326	1,396	2,246	2,407	2,933
	State and local business taxes ($)	15	179	186	305	326	393
	Number of full- and part-time jobs	1,989	8,447	9,860	14,651	16,273	21,576
	Population losses	2,393	10,174	11,876	17,647	19,601	25,988
	Declines in school enrollment	675	2,886	3,146	3,261	3,620	4,807
L	Regional income ($)	299	5,279	5,943	7,034	8,192	8,944
	State and local business taxes ($)	39	564	668	775	885	965
	Number of full- and part-time jobs	10,128	19,948	39,716	53,848	67,085	78,736
	Population losses	12,886	43,823	58,402	74,857	86,896	54,411
	Declines in school enrollment	3,635	12,433	15,470	13,835	16,049	10,064
M	Regional income ($)	324	325	382	909	1,568	2,935
	State and local business taxes ($)	27	34	43	104	179	337
	Number of full- and part-time jobs	5,081	5,609	6,664	17,658	32,124	62,574
	Population losses	6,112	6,756	8,027	21,269	38,597	75,252
	Declines in school enrollment	1,724	1,917	2,277	6,034	10,950	21,349
N	Regional income ($)	56	427	1,612	2,484	5,999	7,796
	State and local business taxes ($)	3	22	74	123	274	352
	Number of full- and part-time jobs	430	3,125	11,275	16,375	42,420	55,025
	Population losses	520	3,770	13,590	19,730	51,100	66,280
	Declines in school enrollment	130	890	2,990	3,030	7,840	10,180
O	Regional income ($)	356	714	949	1,214	1,415	1,437
	State and local business taxes ($)	18	38	53	71	83	86
	Number of full- and part-time jobs	5,546	10,843	14,760	19,532	23,761	23,966
	Population losses	7,160	13,910	18,670	24,590	29,830	30,030
	Declines in school enrollment	1,680	3,270	4,380	5,770	7,000	7,040
P	Regional income ($)	16	16	16	16	16	16
	State and local business taxes ($)	2	2	2	2	2	2
	Number of full- and part-time jobs	215	215	215	215	215	215
	Population losses	258	259	259	259	259	259
	Declines in school enrollment	73	73	73	73	73	73
Total	**Regional income losses ($)**	**11,905**	**29,400**	**45,409**	**61,771**	**79,398**	**115,734**
	State and local business taxes losses ($)	**1,100**	**2,909**	**4,261**	**5,755**	**7,249**	**9,828**
	Number of full- and part-time jobs losses	**114,718**	**222,101**	**383,583**	**543,653**	**716,394**	**1,102,689**
	Population losses	**143,810**	**295,146**	**500,204**	**713,620**	**930,731**	**1,408,594**
	Declines in school enrollment	**41,239**	**86,114**	**146,487**	**188,957**	**246,684**	**402,981**