Chapter 12

Challenges and Uncertainties in Water Supply Planning

TEXAS WATER DEVELOPMENT BOARD

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The five-year cycle of adopting regional and state water plans allows the state to respond to challenges and uncertainties in water supply planning. In order to reduce risks associated with planning for and providing sufficient water supplies, every five years the state and planning groups evaluate changes in population, demand, and supply projections, new climate information, improvements in technologies, and policy and statutory changes.

The State of Texas has established a regional and state water planning process that is engineered to respond to new challenges, new realities, and uncertainties. By revisiting the regional water plans every five years, planning groups can respond and change their plans to address new information (such as population, water demand, and supply projections), technology advancements (such as desalination), and new policy directives. The purpose of this chapter is to introduce several areas of uncertainty and challenge affecting water planning in Texas and address how the planning groups and the state are responding to reduce the associated risks.

12.1 Understanding Risk and Uncertainty

People assess risk every day. That risk may be as simple as deciding whether or not to accelerate through a yellow light or as complex as deciding whether or not to build a water supply project. Both are responding to the probability of a negative outcome. In the case of the yellow light, the risk is running a red light and getting a ticket or, worse, getting into an accident. In the case of the water supply project, the risk is not having enough water at some point in the future. Implicit in any risk is uncertainty. Not only may an outcome be uncertain, but also the exact value of critical numbers and parameters may be unpredictable or even unknown. In the case of the yellow light, there may be uncertainty in how long the light remains yellow, whether or not a police officer or camera is watching the intersection, and how quickly someone may pull into the intersection after the light turns red. In the case of a water supply project, there is uncertainty in how many people there will be in the future, how much water they will need, what the climate will be, and even whether or not the project can be implemented.

A classic risk assessment responds to the questions: What might become a concern? How likely is that to occur? What are the results? For water planning, the risk is not having enough water for the population, economy, and environment. The

likelihood of water shortages depends on demand for water, which is related to population and water use, the reliability of our water supplies, and climate—especially drought. The results of not having enough water could be dire: residential shortages, failed crops, stalled factories, and stressed environments.

12.1.1 Addressing Risk in Water Supply Planning

Regional water planning is, in a way, a risk assessment of whether or not we will have enough water in the future and, if we do not, what we will do to remedy the shortage. Planning groups assess projections of population and water demand and also assess existing water supplies. Although these projections are based on sound, scientific methods, they are still only estimates of how many people will be living in Texas through 2060 and how much water they will need. One way of addressing the risk in water planning is to plan for water supplies during a drought of record because the risk of not meeting water demand is higher during droughts than during normal or above-normal rainfall conditions. The water supply projections are then coupled with the population and demand projections to determine whether or not there are enough existing water supplies to meet current or future demand. In other words, the planning groups and TWDB assess whether or not there is a risk of a water shortage during a repeat of the drought of record.

12.1.2 Addressing Uncertainty in Regional Water Planning

A number of uncertainties are inherent in the regional water planning process. One of those is the projections on which population and water demand are based. For example, the population projections become more uncertain the further out into the future they go because they are based on assumptions of birth, death, and migration rates that are true today but may not be true in the future. More recent projections based on new migration rates suggest that the population of Texas could be much greater than projected in this plan. (See Section 12.2.1 for more discussion of population projections.) Water demand projections are also uncertain, not only because they are based in part on population projections, but also because assumptions have to be made concerning how much water people, industry, and agriculture will use in the future. (See Sections 12.2.2 and 12.3.3 for more discussion of water demand projections.) Although this uncertainty is not quantified in regional water planning, the projections are revisited every five years to consider new information, trends, and decadal census counts to ensure that they are as accurate as possible.

Another uncertainty in regional water planning is the effect of climate, especially drought. Because what has occurred in the past may not occur in the future, it is difficult to predict how drought may affect future water supplies. Regional water planning is based on the drought of record in the 1950s, which is the worst drought in recorded history in most of Texas. Some have argued that it is too conservative to plan for the drought of record. Others have argued that it is prudent to plan for a drought greater than the drought of record. However, planning for the drought of record can address the uncertainty related to water supplies in the future. (See Section 12.3 for more discussion on uncertainty and drought.)

There is also uncertainty about which water management strategies are viable because there is a risk that a water management strategy may not, for a variety of reasons, be implemented. For example, a potential reservoir may not get a permit, or a policy change may lower groundwater availability, which, in turn, means that a recommended well field cannot be developed. Some planning groups recommended several water management strategies that, in total, could result in more water being produced than they need but which would account for the implied risks in each recommended strategy. Other planning groups planned for more water than they need to account for the uncertainty in population and demand projections. For example, one planning group recommended meeting projected water supply needs and a reasonable surplus of planned supplies over projected needs.

By revisiting the planning process every five years, planning groups can address many of the unavoidable risks and uncertainties. They can update population and demand projections and respond to changes in climate if a worse drought occurs. Periodically revisiting the plans also allows the planning groups to deal with uncertainties in technology, science, and policy. For example, since the 2002 State Water Plan was approved, desalination has become a much more viable water management strategy. As more studies and better models become available, surface water and groundwater supply and availability numbers can be more accurately determined. As policy changes at the federal, state, or local level, the planning groups can adjust accordingly.

12.2 Uncertainty in Projections

Determining future water needs in Texas and the strategies and costs for meeting those needs depends on the projected demand for water. Those projected demands, in turn, hinge on other sets of projections that are sensitive to uncertainties, such as population growth, per capita water use, and industrial and agricultural water use. One of the challenges in water planning is to choose the most likely set of projections based on the best available science but to do so with an understanding that even the best projections are not guarantees of what will happen.

12.2.1 Population Projections

There are many uncertainties in projecting population growth over time. Future population may vary based on a number of factors, but the most important factor is the rate of migration—the rate at which people move in and out of a region. A consensus process designed to gather local input on population projections for each county was used for regional water planning. Part of that process was examining whether it was appropriate to assume migration would continue to occur at the full rates experienced in the 1990s or would be reduced. In most cases, it was assumed that the high migration rates of the 1990s could not continue over the next 50 years. However, if migration rates change dramatically from these assumptions, they could have a significant impact on future populations and on the demand for municipal water.

In 2004, the Texas State Data Center released a new set of population projections for Texas counties. These projections assume that the migration rates from 2000–2002 will continue in the future, resulting in projections that differ from those used in the 2006 Regional Water Plans and this state water plan (Table 12.1). Some of the differences are large. For example, the population projection based on 2000–2002 migration rates is 53 percent greater (an additional 5.4 million people) in 2040 for Region C than the projections in the regional and state water plans. An additional 5.4 million people in this region results in an additional 1.25 million acre-feet per year of municipal water demand. For Region H, the projection based on 2000–2002 migration rates is 35 percent greater (an additional 3 million people) in 2040 than the projections in the regional and state water plans. This population increase results in an additional 483,000 acre-feet per year of municipal water demand in Region H.

The differences between the projections in the current regional and state water plans and the projections based on the 2000–2002 migration rates demonstrate that uncertainty can affect planning numbers. It is unclear whether or not the 2000–2002 migration rates can be maintained into the future. Nonetheless, these differences indicate the need to revisit and update regional and state water plans periodically and to plan for having more water than is needed according to current estimates.

12.2.2 Industrial Demand Projections

Projecting industrial demand also has uncertainties based, in part, on future economic growth and the price of energy—factors that are difficult to predict. Prior to developing the 2006 Regional Water Plans, TWDB contracted with private firms to research and develop draft water demand projections for the steam-electric, manufacturing, and mining sectors. A most likely series of projections for these sectors was agreed upon and used in the water supply planning process.

Table 12.1. Potential impact in 2040 of population growth using full migration rates of 2000–2002

	TWDB approved		Updated 2000-2002 migration rates[a]		Difference	
Region	Projected population	Municipal water demand (acre-feet)	Projected population	Municipal water demand (acre-feet)	Projected population	Municipal water demand (acre-feet)
A	484,954	94,683	447,771	87,561	-37,183	-7,122
B	224,165	39,664	196,373	34,761	-27,792	-4,903
C	10,246,795	2,294,491	15,663,875	3,544,466	5,417,080	1,249,975
D	978,298	145,404	1,020,641	152,631	42,343	7,227
E	1,283,725	217,668	1,115,009	189,296	-168,716	-28,372
F	700,806	153,206	621,725	135,904	-79,081	-17,302
G	2,739,717	491,312	3,535,228	635,253	795,511	143,941
H	8,653,377	1,391,710	11,646,438	1,875,073	2,993,061	483,363
I	1,294,976	208,193	1,287,651	215,831	-7,325	7,638
J	190,551	36,973	148,253	29,332	-42,298	-7,641
K	2,181,851	394,101	1,962,696	344,362	-219,155	-49,739
L	3,644,661	547,136	3,445,222	514,853	-199,439	-32,283
M	2,854,613	472,632	3,152,497	516,227	297,884	43,595
N	810,650	139,425	623,712	107,205	-186,938	-32,220
O	552,188	106,042	466,203	89,692	-85,985	-16,350
P	51,940	6,952	54,742	7,354	2,802	402
Texas	36,893,267	6,739,592	45,388,036	8,479,801	8,494,769	1,740,209

[a] Updated projections based on 2000–2002 migration rates were developed by the Texas State Data Center. The comparisons for future population are based on revised projections from the Texas State Data Center that are available only for the decades through 2040. Thus, to allow for consistency of comparisons, all of the sensitivity analyses use the year 2040 as the basis for comparison.

12.2.3 Irrigation Demand Projections

Agricultural irrigation has historically been the largest water use in the state. Therefore, even small variations in future projections can have large implications for water demand. Irrigation demand depends on the profitability of production; however, profitability largely depends on highly volatile energy and crop prices. As a result, making specific and accurate projections is difficult.

Although only a single projection was developed for irrigation, irrigation projections from past water plans can illustrate the uncertainty in these estimates. The 1984 State Water Plan used irrigation projections developed in the wake of expanding markets and increasing crop prices of the late 1970s. Because the 1984 plan was based on an extremely optimistic future, it projected irrigation in 2000 to be 16 million acre-feet, about 60 percent more than actually occurred because crop prices did not maintain their previous levels. In contrast, the 1990 State Water Plan, developed during a pessimistic economic climate, projected irrigation in 2000 at about 3 million acre-feet less than actually occurred and projected irrigation in 2040 about 30 percent less than the current projection.

Given this wide range of results in projecting irrigation water use, TWDB believes that it is more appropriate to base irrigation demand projections on the status quo rather on overly optimistic or pessimistic predictions concerning the profitability of production. If the global economy or the levels of price supports that result from the next farm bill in Congress require

substantial adjustments to irrigation demand projections, these adjustments can be made in the next five-year water planning cycle.

12.3 Drought

Drought poses one of the greatest challenges in water planning because its effects can be so profound and because it is generally unpredictable. Texas has experienced both long- and short-term statewide droughts as well as numerous regional droughts. A normal part of the hydrological cycle, drought, in simple terms, is a drier-than-normal period. The severity of a drought depends on both its duration and intensity. It has three phases that typically develop in this order:

1. meteorological drought, or a period of lower-than-normal precipitation
2. soil moisture/vegetative drought, which is a result of meteorological drought and affects plants, wildlife, and crops
3. hydrologic drought, which results in lower stream flows, lake levels, and water levels in aquifers

Droughts also terminate in a predictable order. First, it begins to rain; then soils once again become wet enough to support vegetation; and, finally, lakes, streams, and aquifers fill to normal levels. In Texas, many droughts have been ended by floods or hurricanes.

Although the Dust Bowl era of the 1930s was the greatest weather disaster in American history, it was not as intense or prolonged in Texas as the extreme drought of the 1950s. This historical drought of record affected every area of the state and lasted for about eight years. Lake levels dropped. Lake Dallas, for example, was at only 11 percent storage capacity. Water in some Texas streams disappeared entirely or flowed only in minute amounts, while aquifer levels were at record low levels.

More recently, the statewide drought of 1996 produced widespread crop failure and significant environmental stress, requiring many cities and utilities to implement some form of water demand management. Two cities had to obtain emergency water supplies from other entities. Most of these demand management measures were taken because utilities could not treat and distribute water as fast as it was being used. A number of utilities, especially in South Texas, had to ration water because of diminished supplies. As a result of the drought of 1996, agricultural losses were estimated to be about $5 billion.

Although the drought that followed two years later in 1998 was much shorter, agricultural losses were even greater than in 1996—estimated to be slightly more than $6 billion. The intensity and timing of the 1998 drought made it especially hard on crops planted in the spring. Extreme summer heat also led to 131 heat-related deaths, more than 14,000 farm workers out of jobs, and almost 500,000 acres burned by wildfires.

Texas has also experienced droughts, although less severe, in 2001, 2002, and 2003. In 2005, Brownsville, San Antonio, and Dallas-Fort Worth topped the list of cities with the least amount of normal precipitation. Brownsville received

51 percent of its normal precipitation; San Antonio received 50 percent of normal; and Dallas-Fort Worth received 55 percent of normal. Other locations, including Austin, Galveston, and Waco, received less than 70 percent of their normal rainfall totals. This drought has continued into 2006, affecting lake levels in North Texas and placing the San Antonio pool of the Edwards (Balcones Fault Zone) Aquifer into Stage I water restrictions for the first time since October 2000.

Water planning in Texas is focused on the drought of record; however, it is important to note that the period of record is a relatively short one. Precipitation in the state was not systematically measured until the late 1800s, which was the beginning of the period of record for the state. Based on the thickness of tree rings, which are thinner for dry years, scientists believe that Texas has had more severe droughts over the last thousand years than we have had since the late 1800s. It is only a matter of time before a drought of the proportions of the 1950s—or even worse—occurs. Although planning groups plan for water supply needs in the drought of record, many recommend water management strategies that, taken in whole, produce more water than the projected need. Given the uncertainty in drought and other planning factors, planning for more water than is "needed" is advisable in order to reduce risk. It is much better to have too much water in a time of drought than not enough.

Another way to deal with the risks associated with droughts is to implement drought contingency plans. In response to water shortages and system capacity problems as a result of the droughts in the 1990s, the 75th Legislature enacted Senate Bill 1 in 1997, which required wholesale and retail public water suppliers and irrigation districts to develop drought contingency plans. A drought contingency plan is a strategy or combination of strategies to manage responses to temporary and potentially recurring water supply shortages and other water supply emergencies. The underlying philosophy of drought contingency planning is that (1) short-term water shortages and other water supply emergencies can be anticipated; (2) the potential risks and impacts of drought or other emergency conditions can be considered and evaluated in advance of an actual event; and, most important, (3) response measures and best management practices can be identified in advance to avoid, minimize, or mitigate the risks and impacts of drought-related shortages and other emergencies.

12.4 Climate Change

Climate change refers to the variation in the global or regional climate over time and is caused by a variety of factors. Scientists believe that our planet may be experiencing a change in its climate. Research suggests that, over the 20th century, the global average surface temperature has increased by about 1°F (Houghton and others, 2001). Nine of the 10 hottest years on record have been in the past decade (New Scientist, 2005). In addition, many areas, including the Northern Hemisphere and the tropics, are experiencing increased precipitation (Houghton and others, 2001). These global trends, however, do not necessarily hold true for Texas. Average rainfall does not appear to have changed significantly this past century in Texas on either a regional or statewide basis (Figure 12.1). Temperature trends are just as important as rainfall in water resources planning because of their relationship to reservoir evaporation and irrigation demand. As was the case with precipitation, temperature has also not changed significantly in Texas (Figures 12.2 and 12.3).

So what might the future hold for Texas? Ruosteenoja and others (2003) describe and compare simulations from seven state-of-the-art, atmosphere-ocean global climate models. The models predict annual average precipitation in Texas to remain essentially the same in the future. However, they also predict an average temperature increase in all seasons of somewhere between 3° and 10°F by the year 2099 for Texas.

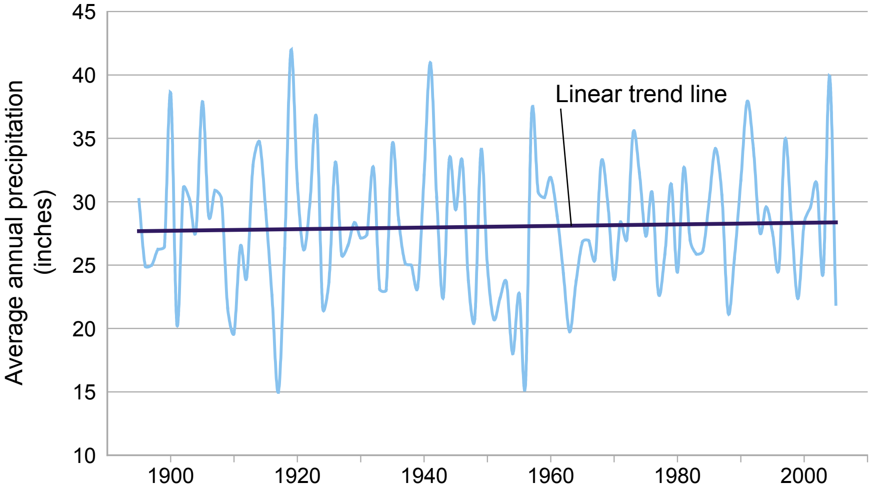


Figure 12.1. Statewide average annual precipitation (data from WRCC, 2005).

They also expect the frequency, and possibly the magnitude, of droughts in semiarid climates, such as Texas, to increase. However, there is a great deal of uncertainty in the models used to make these predictions, especially at regional levels.

Uncertainties in predicting climate change lead to even greater uncertainties in predicting the impacts of climate change, including water availability. Climate change, however, is only one of the uncertainties in the planning process. When considering the uncertainties of population and water demand projections, the effect of climate change on the state's water resources over the next 50 years is probably small enough that it is unnecessary to plan for it specifically. Furthermore, because the state plans on a five-year cycle, planning groups can closely monitor the latest science on climate change and react quickly to any changes that might affect the state's future water resources.

12.5 Natural Disasters and Terrorism

Natural disasters and terrorism also introduce uncertainty and challenges into water planning. Natural disasters include floods, hurricanes, tornados, and fires. (Drought is also considered a natural disaster but is addressed in 12.3.) In 1965, the federal government began to maintain records of events determined to be significant enough to warrant their designation as a major disaster by the President of the United States. Since that time, virtually every county in Texas has been subject to at least one Presidential Disaster Declaration. Through 2002, there were approximately 70 Presidential Disaster Declarations in Texas. The areas included in the disaster declarations have ranged from relatively small regions with one or two counties to larger areas of several counties. Harris County holds the record for most disaster declarations with 16.

Natural disasters in Texas have thus far generally not had long-term effects on water resources. However, Hurricane Katrina, which heavily damaged New Orleans, has flooded Texas with displaced residents from Louisiana, many of whom will stay in Texas and create greater demand for water. Natural disasters can, however, have a number of short-term effects on water resources. These impacts are generally associated with effects on water quality or the ability to distribute water to satisfy demands immediately following a disaster. To minimize the short-term effects of disasters, the State of Texas has a State Emergency Management Plan prepared and implemented by the Governor's Division of Emergency Management. This plan provides for an integrated, functional approach to disasters, including general coordination of responsibilities and/or actions required during all phases of emergency management, whether they are natural or man-made hazards. The state and local Emergency Management Plans provide guidance for response and recovery

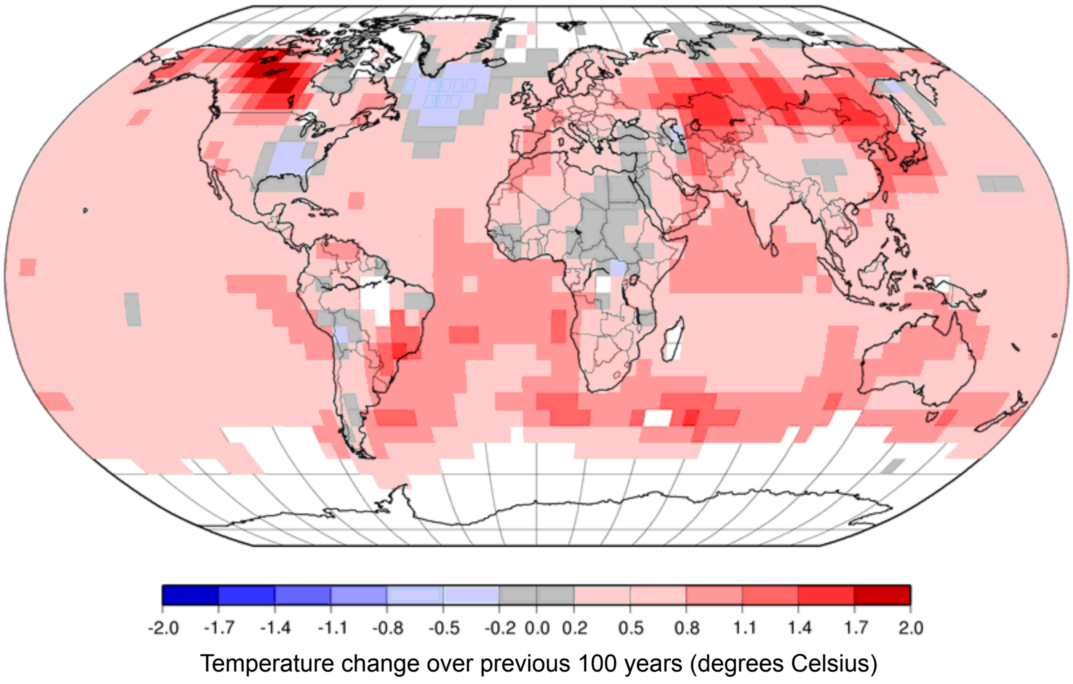


Figure 12.2. Global trend in average temperature for 1901–2003 (Viner, 2005).

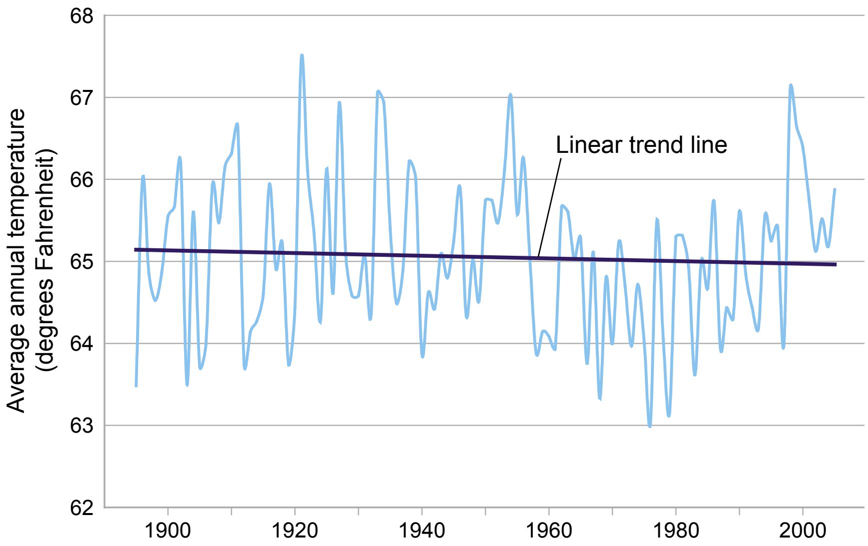


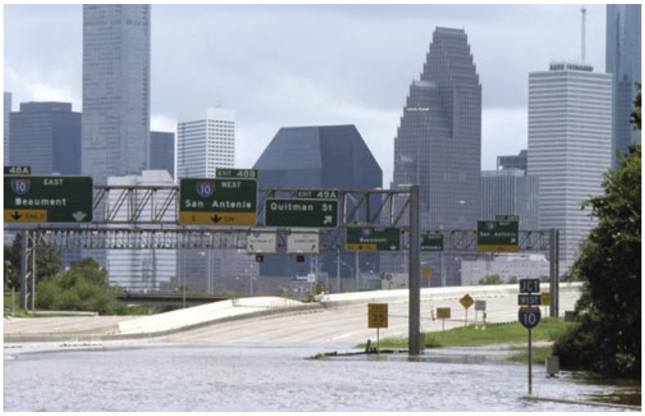
Figure 12.3. Statewide average annual temperature (data from WRCC, 2005).

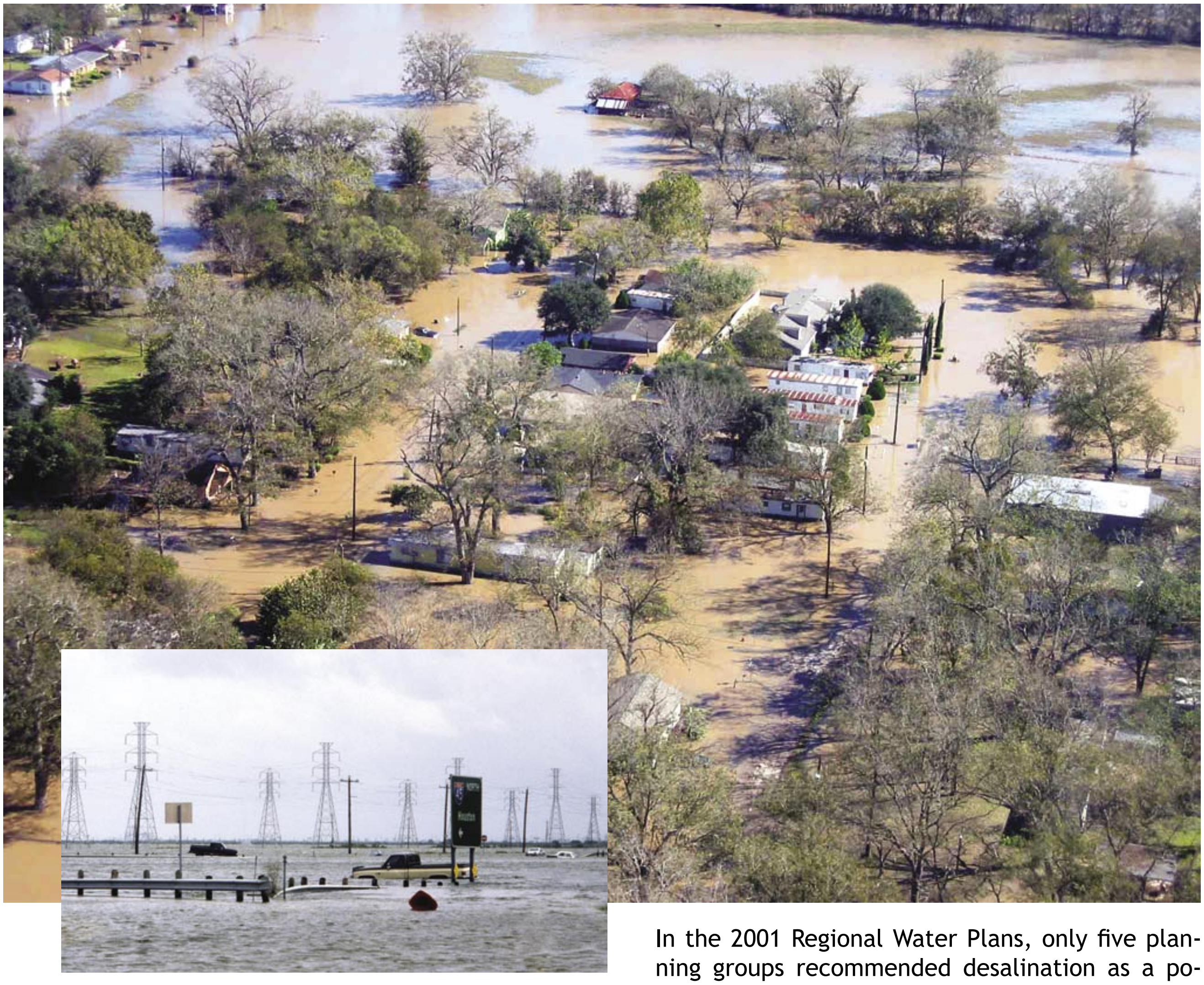
for all disasters, including actions to be taken by state agencies and local personnel.

Terrorism also adds a great deal of uncertainty to water planning. When and where terrorism may affect water resources is difficult to predict, but it is easy to imagine how it might occur: poisoned water supplies, sabotaged dams, or disrupted service. The Federal Bureau of Investigation has noted that water systems are on the target lists of domestic and foreign terrorists (Schattenberg, 2005). Therefore, it is important for local, state, and federal entities to evaluate risks and prepare appropriately for terrorist acts.

The Texas Legislature created the Homeland Security Council to advise the governor on developing and coordinating a statewide strategy to

protect critical infrastructures. The council also advises the governor on implementing the homeland security strategy. This group is composed of the governor and representatives of various agencies, including the Texas Water Development Board, the Texas Commission on Environmental Quality, the Texas Department of Public Safety, the Railroad Commission of Texas, and the Texas Public Utility Commission, among others. Governor Perry has noted the vulnerability of Texas' water resources and infrastructure to terrorism and has asked the Texas Parks and Wildlife Department to police water intake structures and dams on park property and multijurisdictional task forces to protect Texas ports and Gulf Coast waterways as part of their mission (Perry, 2002). The U.S. Army Corps of Engineers, river authorities, U.S. Bureau of Reclamation, and other entities have increased surveillance at and reduced access to key areas of dams and water and wastewater plants they control. Congress has provided money for security at water infrastructure facilities and passed a bill requiring drinking water utilities to conduct security vulnerability assessments (Copeland and Cody, 2006). In addition, the U.S. Department of Homeland Security collects information on critical water infrastructure across the nation, including Texas. There are tools available for water suppliers and wastewater facility operators to evaluate their vulnerability to natural disasters and terrorism (for example, ASDWA and NRWA, 2002; and the Vulnerability Self Assessment Tool for Water & Wastewater Utilities [www.vsatusers.net]). As was demonstrated by the natural disaster of Hurricane Katrina, careful coordination between local, state, and federal emergency response teams is critical for a meaningful response.





12.6 New Technologies

The pace at which new technologies are emerging for the water industry presents another challenge in water planning, but a welcome challenge. What seemed too expensive or even improbable a few years ago can be a viable solution for solving today's water supply issues. For example, there have been advances that increase the effectiveness of water conservation strategies and improve the performance and reliability of water treatment methods for water reuse. Reverse-osmosis desalination also illustrates the impact technology plays in developing new water supplies or enhancing access to existing ones. Today's reverse-osmosis desalination can produce more than 27 times the amount of water than could be produced in 1980 for about the same cost (Pankratz, 2004). This pace of improvement is one of the reasons why desalination has gained acceptance in the water supply industry not only for long-term planning of new supplies, but also as a tool to meet immediate needs.

In the 2001 Regional Water Plans, only five planning groups recommended desalination as a potential water management strategy. Five years later, in the 2006 Regional Water Plans, nine planning groups recommended desalination as a water management strategy to meet needs. In addition, over the course of these two planning cycles, reverse-osmosis desalination has become a more common component of water systems around the state. A prominent example of this trend is the 27.5 million gallons per day El Paso-Fort Bliss Brackish Groundwater Desalination Treatment Plant that is under construction. It will be the largest inland facility of its type in the world. Another example is the 7.5 million gallons per day Southmost Regional Water Authority Brackish Groundwater Treatment Plant in Cameron County. This plant has been in operation since April 2004 and supplies more than 40 percent of the annual water supply needs of the Brownsville Public Utilities Board, City of Los Fresnos, Valley Municipal Utility District #2, Town of Indian Lake, and Brownsville Navigation District.

The proximity of large water demand centers to the Gulf of Mexico and the abundance of brackish groundwater throughout the state points to

the continued interest in water desalination for the foreseeable future. In the case of seawater desalination, this interest will be tempered by the energy costs associated with desalting water with higher salt concentrations. For inland facilities that will desalt brackish groundwater, a potential deterrent is the safe and cost-effective disposal of the concentrate. However, basic and applied research continues to improve desalination technologies, and new products are being developed that will increase the efficiency of water desalination by lowering its energy requirements and reducing the volumes of concentrate.

For water providers, however, the challenge of successfully incorporating these emerging technologies is ongoing. The use of technology demonstration projects, such as the large-scale demonstration seawater desalination initiative and the brackish groundwater desalination initiative, are valuable and practical tools for transferring technology. They provide tangible examples for water providers to become more familiar with new products. The large-scale demonstration seawater desalination initiative started in April 2002 when Governor Perry directed TWDB to pursue the development of drought-proof water supplies from seawater desalination. Governor Perry's initiative called for implementing the state's first large-scale demonstration seawater desalination project. Since then, three promising sites proposed by Brownsville, Corpus Christi, and Freeport have been evaluated, and currently a pilot plant study is underway for the Brownsville proposal. When this study is completed, the project sponsor, Brownsville Public Utilities Board, will decide whether or not to proceed with a full-scale project within the 2008-2009 biennium.

The focus of the brackish groundwater desalination initiative is to continue facilitating the development of brackish groundwater desalination supplies by creating replicable models of projects that can be transferred to other communities. These projects can be used by other communities as engineering facility roadmaps to characterize source waters, implement desalination technologies, and manage desalination concentrate.

12.7 Sustainability of Water Resources in Texas

Another challenge in water planning is managing water resources in a sustainable manner where possible and, when managing a water resource in a sustainable way, agreeing on the appropriate balance of water for humans and the environment. Different people define sustainability differently. However, there is generally one constant—that something managed in a sustainable manner will

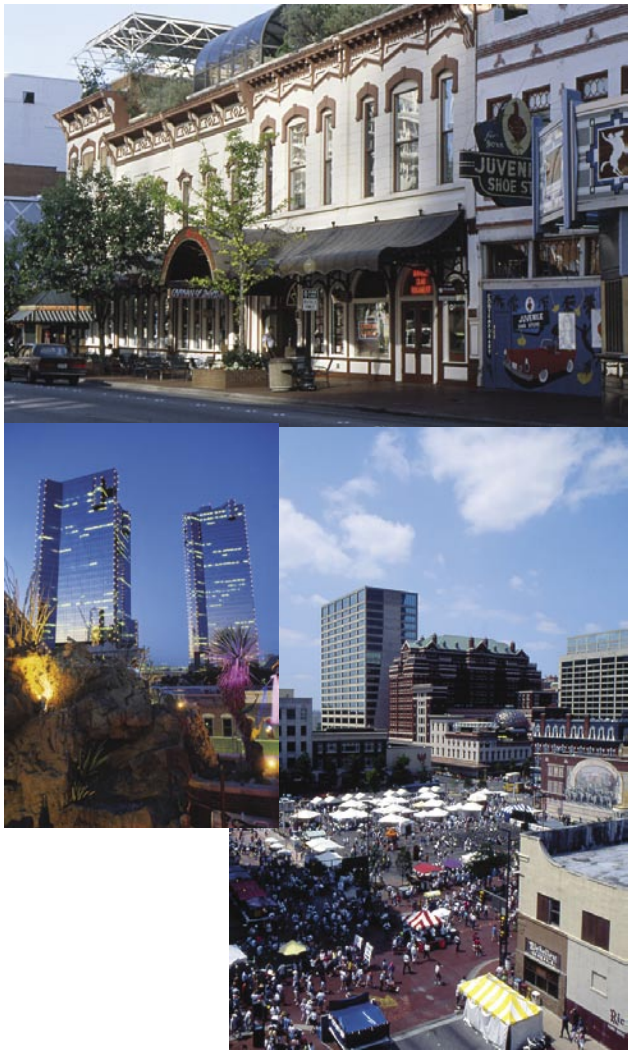
be available today and in the future. In the case of water resources, this means managing surface water and groundwater in such a way that they can be relied upon as water supplies to meet or help meet current and future demands. For example, if the rate that people are pumping water from an aquifer is no greater than the rate that water is recharging the aquifer, then that aquifer is likely being pumped in a sustainable manner. If a water resource is not managed in a sustainable manner, then current rates of water use cannot be maintained indefinitely. For example, the amount pumped from the Ogallala Aquifer was about 6.3 million acre-feet per year in 2003, while the recharge to the aquifer—the amount of water from rainfall and irrigation return flow replenishing the aquifer—was about 1.4 million acre-feet per year. In other words, groundwater is being pumped from the Ogallala Aquifer more than four times faster than water is seeping back into it—a situation that the resource cannot sustain indefinitely. In fact, groundwater supply and availability numbers used by the planning groups for the Ogallala Aquifer decrease with time because the aquifer is already being pumped at too great a rate to maintain it into the future.

Water resource sustainability is the development of water in such a manner that it is maintained for an indefinite time without causing unacceptable social, economic, and environmental consequences. (This is a definition similar to that of Alley and others, 1999.) Social concerns may include the fair distribution of water supplies among all users and the effects of water supplies on public health. Economic concerns may include both the cost of water and access to it to support the economy. Environmental concerns cover a wide range of issues, including the need to maintain instream flows in our rivers and streams, freshwater inflows to our bays and estuaries, minimum water quality standards, and spring flows. In many cases, the amount of water that can be produced in a sustainable manner is not a set amount and represents some balance that addresses all these concerns. Note that the definition refers to "unacceptable" social, economic, and environmental consequences. The acceptability of these consequences is a difficult policy decision that has to be made by local, regional, state, or federal policy makers—and is something that can change with time.

The sustainable management of surface water and groundwater resources is different for each resource type. In the case of surface water resources, the sustainability of the resource depends on the climate. In times of drought, especially long droughts, surface water may not be available. In addition, reservoirs are affected by sedimentation, which results in a gradual decrease in their storage capacity over time. In order to maintain a reservoir's storage capacity, engineers need to either remove the sediment from existing reservoirs to restore or maintain their storage capacity or build new reservoirs. Sustaining the yield

of a river basin involves very complex and detailed planning to maximize the effectiveness and efficiency of water-related infrastructure while ensuring that water is not overdrawn to the detriment of the environment and economy.

To manage surface water resources and supply effectively, planners need to determine reservoir firm yield. The firm yield is the maximum volume of water a reservoir can provide each year under a repeat of the drought of record. The Texas Commission on Environmental Quality's water availability models are used for water supply planning in Texas. These models generally use between 50 and 60 years of naturalized flow to determine the firm yield. Naturalized flow is what the flow in the river would be without human influence, for example, without reservoirs, direct diversions of water, and land use changes. Using the firm yield assumes that a water supply reservoir will run completely dry at the end of the drought of record after meeting all demands. Some planning groups considered planning to have a firm yield water supply to be unacceptable for social, economic, or environmental reasons, so they planned for having a safe yield supply instead. The safe yield is the firm yield in addition to an amount of water supply for an additional period of time (usually one year or less). The use of safe yield effectively builds in a safety factor to reduce the risk associated with a drought worse than the drought of record.



The sustainable development of groundwater resources is easier to manage than that of surface water because aquifers are, in general, less responsive to ephemeral changes in climate and tend to hold a much larger volume of water compared to the water that seeps in as recharge. These characteristics allow groundwater resources to be more dependable during droughts, especially when surface water resources become temporarily unreliable. One exception to this is the Edwards (Balcones Fault Zone) Aquifer, an aquifer that responds quickly to rainfall events. Because of a policy decision to maintain spring flows and because of the aquifer's responsiveness to drought, the Edwards (Balcones Fault Zone) Aquifer is not reliable during severe droughts.

Conjunctive use—the combined use of groundwater and surface water sources that optimizes the beneficial characteristics of each source—is a way to leverage the positive traits of surface water and groundwater to assist in sustaining all supplies. For example, using surface water as a supply during wet periods and groundwater during droughts is a simple form of conjunctive use.

With respect to the sustainability of water resources, the planning groups focused primarily on groundwater. This is probably because the sustainable management of surface water resources is well regulated and already considered in reservoir management. Surface water management is governed by the prior appropriation doctrine; therefore, the sustainability of any supply from surface water resources is predicated on the firmness of their water right. The need to maintain instream flows and inflows to bays and estuaries and the amount of these flows continues to be a challenging policy debate. Groundwater, on the other hand, is less regulated (parts of the state

have no regulation), and sustainability is not required by state law. In many cases, the planning groups noted that estimates of sustainable groundwater availability resulting from the sustainable groundwater management policies are based on available information. The quality and effectiveness of the resulting recommendations depend on good and improving information. This adaptive management—changing estimates of water availability to reflect current conditions and information—is an appropriate way of dealing with the uncertainty of quantifying water resources.

In most cases, sustainability is intended to maintain groundwater availability at current levels through perpetuity. As determined by the planning groups, all of the state's aquifers except five—the Dockum, Edwards-Trinity (High Plains), Gulf Coast, Ogallala, and Seymour—have sustainable values of groundwater availability—values that stay the same or change very little with time. Three of these aquifers—the Edwards-Trinity (High Plains), Gulf Coast, and Seymour—have sustainable groundwater availabilities by the end of 2060. Even though pumping of the Ogallala Aquifer is currently at a nonsustainable rate, the planning groups in Region A and Region O discussed the need to extend the current use of the aquifer as far into the future as possible. The Region A Planning Group recommended using no more than 1.25 percent of the annual saturated thickness for long-term, sustainable management of the aquifers within their planning area to meet local demands.

Although most of the planning groups adopted a policy of sustainability for their aquifers, several planning groups—Region A, Region C, Region G, Region I, Region K, and Region P—recommended temporarily overdrafting their aquifers, in other words, pumping more than the groundwater availability from an aquifer to meet demand during a drought of record. However, the overdrafting in the plans for Region G, Region I, and Region K is less than 500 acre-feet per year in any given year.

12.8 Policy and Legislative Changes

Like water planning, policy and legislation in Texas changes and evolves through time. New laws reflect changing times and perspectives and sometimes result from crises and varying opinions of stakeholders. Thus, water policy adds another dimension of uncertainty to the planning process and to the water supply we have to meet demands. Two areas of current legislation that have had unexpected effects and have created an atmosphere of uncertainty with respect to state and regional water planning involve transfers of surface water and groundwater management.

Senate Bill 1, the omnibus water bill of the 75th Texas Legislature that redefined state water planning in 1997, contained provisions regulating interbasin transfers of surface water. The impetus of the law was to ensure that the water needs of a contributing river basin are not ignored in

favor of a receiving basin. To do this, Senate Bill 1 placed a series of conditions on interbasin transfers, including the so-called "junior rights provision." In 2004, the Texas Senate Select Committee on Water Policy studied various water issues, including interbasin transfers, as part of an effort to review water policy in the state. The committee and others noted that current laws regarding interbasin transfers may contribute to an overreliance on other strategies, including those that rely on increasingly stressed groundwater resources in some parts of Texas. One of the recommendations of the committee was that the legislature reconsider the policies affecting interbasin transfers to ensure that communities can implement critical water supply projects.

Another piece of legislation creating uncertainty in water planning was enacted by the 79th Legislature in 2005, House Bill 1763. This bill requires joint planning among groundwater conservation districts within groundwater management areas. Before House Bill 1763, planning groups only had to consider the districts' management plans or other information, including information on groundwater availability, for inclusion in their regional water plans. In the future, planning groups will be required to use the numbers that result from the joint planning process among groundwater conservation districts. This requirement will result in changes in groundwater availability, with some areas having less groundwater available for use.

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