Efficient Water Use for Texas: Policies, Tools, and Management Strategies

Prepared for Environmental Defense
by
Texas Agricultural Experiment Station
Texas A&M University
College Station, Texas

September 2002

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Acknowledgments

The authors would like to express their appreciation to the following internal and external reviewers: Carole Baker, The Harris–Galveston Coastal Subsidence District; Janie Harris, Texas Cooperative Extension; Hari Krishna and John Sutton, Texas Water Development Board; Dana Porter, The Texas A&M University System Agriculture Program; and Elaine Smith, Environmental Defense, Austin.

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A Survey of Efficient Water Use Strategies for Texas

Texas faces a formidable challenge in meeting the water needs of its citizens as its population doubles over the next fifty years. To meet this challenge and to provide necessary flows of water for the environment, Texas will need to rely upon water conservation and alternative water management strategies.

But first, policy makers and interested citizens need to be made aware of the available options to meet these challenges. This paper will present some alternative conservation and water management strategy options, the challenges of implementing them, and their overall costs and benefits.

The State's current dependable water supply will meet only about 70 percent of projected demand by the year 2050. New water supply projects such as reservoirs are expensive, may take decades to build, and can have detrimental impacts on the environment. Water conservation—making more efficient use of existing water resources—can be a less expensive and less disruptive way of meeting water needs.

Already baseline water conservation assumptions for Texas are projected to result in a 22-gallon per capita per day (gpcd) savings in 2050 over current rates of municipal water use. This projection translates into an avoided supply requirement of 976,000 acre-feet/year by 2050, according to the Water for Texas 2002 State Water Plan.[1] This equates to about 12.4 percent of Texas' water needs. An additional 6.0 percent of needs will be met through water reuse.

But most of the projected water savings called for in the State Water Plan result from the implementation of existing regulations that call for more efficient plumbing fixtures. This report will discuss a wide range of additional water conservation and efficiency measures that are available. If implemented aggressively, these measures can make a significant impact on meeting Texas' future water needs.

Water-Use Sectors

When discussing water-use efficiency, it is customary to divide water users into three sectors—domestic; industrial, commercial and institutional; and agricultural—each with its own possibilities for improved water-use efficiency. Although agriculture now accounts for more than 60 percent of water use in Texas, this percentage is projected to decline to about 43 percent in the 50-year planning window.[1]

With the Texas population shifting from rural to urban areas, and with the migration of people from other states to Texas cities, urban demands will increasingly compete with agricultural interests for the same water (figure 1). For instance, in the Lower Rio Grande Valley, irrigation districts deliver water to both farmers and cities, but in the event of a shortage, the municipal users have precedence. Competition for shared water may become contentious, as the population of the Lower Rio Grande Valley is projected to increase 70 percent within the next 50 years.

Tools to Promote Water-Use Efficiency

Within each sector there are many individual practices to increase the efficiency of water use. For all sectors, three tools can help encourage the respective populations to use water efficiently. First and foremost is an effective outreach and education effort. In fact, the first step towards the success of any demand management or water conservation program is achieving support of the affected consumers.

An effective outreach campaign can involve utility bill stuffers, media outlets, public events, and speaking engagements. In addition to creating knowledge of water efficiency practices among citizens, an outreach campaign can facilitate public acceptance of the two other tools: financial incentives and regulatory programs.

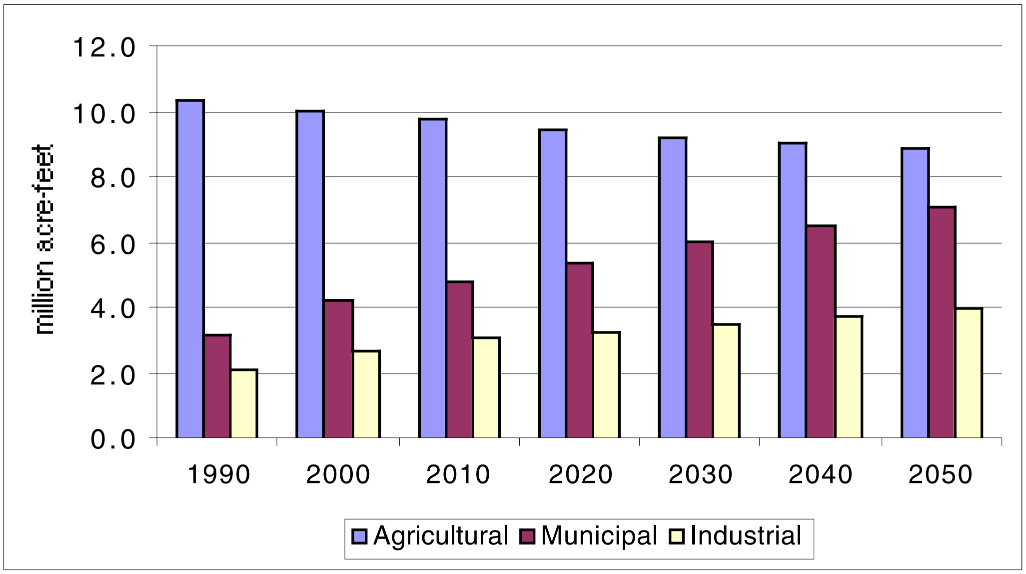

Figure 1. Texas projected water use by sector.

Financial incentives can reward efficient water users with rebates or send a warning in the form of a price signal to water-wasters. The most common disincentive implemented by water utilities is an increasing block structure, in which high-volume water users pay a higher per-unit price for water use above set threshold levels.

Finally, regulatory tools, including plumbing fixture rules and landscaping ordinances, may be an appropriate way of producing water savings.

Water Efficiency and Drought Management

At this point, it is worth drawing the distinction between water-use efficiency and drought management. Water-use efficiency refers to a permanent behavioral change or application of technology that changes the baseline level of water use. Drought management practices are enacted in response to an emergency in either water supply or water capacity. Water supply is the volume of raw water available to a population. Capacity refers to a water utility's treatment and distribution capability. Focusing on drought after it arrives forces water managers to react to immediate needs with costly remedies to balance competing interests in a charged atmosphere.

It has been the experience of many Texas cities that water use increases as soon as drought management restrictions are lifted, causing what is known as the "hydro-illogical" cycle. The hydro-illogical cycle refers to the phenomenon in which drought management measures may induce a feeling of denial among citizens, who return with relief to wasteful water consumption once restrictions are lifted.

On the other hand, wise water use practices are a win-win situation: reducing demand on a natural resource, reducing water bills, and avoiding the capital costs of building more water utility capacity.

Domestic and municipal water-use efficiency

Municipal water use will increase from 25 percent of the state total in 2000 to 35 percent by 2050.[1]

Indoor and outdoor domestic water use follows somewhat predictable cycles throughout the year, with a sharp peak in the summer months attributable to landscape irrigation.

Outdoor landscape irrigation is responsible for the peak demand which often strains a utility's capacity and infrastructure. It follows that irrigating in the most efficient, science-based manner would benefit both homeowners and the utilities serving them.

Indoor domestic water use

Average indoor water use in a single-family residence in the United States is 69.3 gallons per capita per day, as broken down in figure 2.[2]

Although most indoor domestic use is nondiscretionary—cooking, cleaning—there exist behavioral and technological methods to reduce indoor water use. Hardware measures, once installed, easily achieve long-term water savings since they enable passive savings: they reduce the amount of water use to accomplish the same function with no ongoing effort. Behavioral changes, such as those listed in the box on page 7, cost consumers nothing but can also result in substantial water savings. Common low-volume appliances include the 1.6-gallon-per-flush toilets, 2.2-gallon-per-minute faucet aerators, 2.5-gallon-per-minute showerheads, and horizontal-axis washing machines.

In 1991, Texas adopted the Water Saving Performance Standards for Plumbing Fixtures Act, which established low-flow performance standards for plumbing fixtures sold in Texas—toilets, urinals, showerheads, and faucet aerators. The Energy Policy Act of 1992 mandated plumbing efficiency standards nationally, including the 1.6 gallon-per-flush ultra low flush toilet.

This legislation has produced dramatic water savings. For example, replacing a conventional 3.5-gallon-per-flush (gpf) toilet saves 1.9 gpf or 54 percent. Some older toilets use as much as 5 to 7 gallons per flush.

Studies by the Metropolitan Water District of Southern California revealed water savings of 29 gallons per day for replacement of one toilet in a single-family residence and a second retrofit saved an additional 17 gallons per day.[3]

A study by the Texas Water Development Board estimated an amortized cost of $400 (including program and staff costs) per acre-foot of water saved by a utility-sponsored program of single-family home toilet retrofits.[4]

If these savings held true in Texas, installing ultra-low flush toilets in new construction and replacing conventional fixtures in existing homes would save 840,000 acre-feet per year, enough to serve the needs of 8,300 persons.

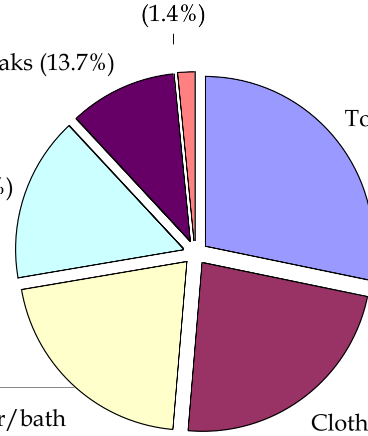

Figure 2. Mean per capita residential indoor water use, 69.3 gpcd . Adapted from Residential End Uses of Water, *AWWARF, 1999*[2].

Outdoor Domestic Water Use

Outdoor landscape irrigation accounts for as much as 60 to 70 percent of a typical residential customer's water use in the summer, and is responsible for peak summer demand. Water utilities and their customers can save money by reducing the peak, which allows the utility to defer or avoid building excess capacity to meet demand that occurs only a few days or weeks within the year. The capacity built at great expense to meet peak demand often sits idle most of the year.

With careful attention to plant need-based irrigation practices and irrigation system maintenance, landscape irrigation can be cut dramatically while maintaining a healthy landscape.

Water Use-Efficiency Practices

Texas' water suppliers rely upon a creative array of conservation-promoting practices to achieve demand reduction among their residential customer base, including—

- high-volume price disincentives,
- system water audits; leak detection and repair,
- ultra-low flush toilets, showerhead, and faucet aerator retrofit programs,
- horizontal-axis high-efficiency clothes washer rebates,
- landscape irrigation audits,
- water waste ordinances and enforcement,
- public information programs,
- school educational programs,
- residential water surveys,
- landscape rebates and educational programs,
- rainwater harvesting incentives,
- submetering,
- graywater reuse.

Figure 3. Public education campaigns can use bill stuffers, the print and broadcast media, billboards, booths at public events, and even unconventional —yet practical—media, such as this bench in Corpus Christi.

Education and Outreach

The success of every demand management effort, even incentives and regulatory measures, is dependent upon a conscientious public relations effort via the media, bill stuffers, public events and fairs, speeches to civic organizations, and public informational meetings to ensure citizen support (figure 3).

In response to droughts in four of the past five years, almost every water utility in the state engaged in some type of public information campaign. San Antonio Water System (SAWS), for instance, has achieved a relatively low per capita usage through a multipronged media approach that involved television and radio advertisements; bill stuffers; booths at public gatherings; such as the Stock Show and Rodeo; a speaker's bureau; and a turfgrass evapotranspiration project.

Bill stuffers are a cost-effective means to reach every ratepayer. The cost of public events varies; for instance the Texas Trail Tent at the San Antonio Stock Show and Rodeo cost a total of $40,000, or about $0.30 per contact for the more than 130,000 spectators.[5]

The City of Houston's conservation plan expects public education to provide 47 percent of water savings over the next 50 years, exclusive of unaccounted-for water. Elements of the city's public information campaign include advertisements in the mass media, education programs such as *Major Rivers* and *Learning to be Water Wise & Energy Efficient*, home water audit kits, presentations to civic and environmental associations, and a T-shirt design contest. In the cost-benefit analysis, cost categories are labor, expenses, incentives, and one-time setup costs. Benefits from conservation include current savings in operations and maintenance and savings from deferral or cancellation of capital projects.[6]

A 1999 Water Conservation Program National Benchmarking Survey conducted by the City of Austin Planning Environmental and Conservation Services Department, found that public education programs were almost universal across the 34 large utilities in the United States and Canada: 94 percent of respondents reported community education efforts to raise public awareness of water conserving techniques.

Water conservation professionals have learned that it is important to present a unified message to the public. Conflicting and confusing watering schedules, for instance, have the effect of overwhelming ratepayers. Also, drought management stages between overlapping jurisdictions (such as the Edwards Aquifer Authority and San Antonio Water System) and adjacent jurisdictions (such as the smaller communities surrounding a major metropolitan area) should be coordinated.

Outreach and education (nonprice) programs appear to be more effective if the water utility achieves a "critical mass" of programs. In a study published by the American Water Works Research Foundation, an increase in the number of nonprice conservation programs from five to ten options is estimated to reduce demand by 13 percent. Nonprice programs also achieve the desired objectives without the political consequences of a rate increase.[8]

Demand management

Many water utilities are making a fundamental shift from conventional supply enhancement to demand management. In other words, instead of casting the net farther for new water supplies, water suppliers are trying to induce customers to use existing supplies more wisely. As noted earlier, lowering the summertime peak demand defers or avoids the expensive prospect of building new capacity to meet the high demands of relatively few days per year.

According to water conservation consultant Amy Vickers, "An important assumption associated with incentive strategies is that increased water efficiency is an equal substitute for water supply capacity and has equivalent value in the marketplace."[9]

At the disposal of water suppliers is an array of financial incentive and disincentive tools to effect demand management. These tools can be roughly divided into price disincentives and rebate or credit programs.

When it comes to encouraging customers to install water-saving appliances, there is no lack of creativity in the state as Texas water suppliers offer a virtual smorgasbord of rebates, discounts, and giveaways.

Plumbing fixtures. After the Energy Policy Act of 1992 mandated that only water-conserving

Water: It's Worth Using Wisely

Indoors

- Fix leaks; a slow, steady drip can waste 350 gallons per month.
- Install low-flow faucet aerators and showerheads.
- Insulate hot water pipes to avoid long delays waiting for the water to "run hot."

Bathroom—

- Install low-flow showerheads.
- Install low-flush toilets, or displace water in tank with toilet dam.
- Install early-closure flapper.
- Take shorter showers.
- Turn off water while brushing teeth or while soaping up in the shower.
- Capture"warm-up" water for houseplants.

Kitchen—

- Wash only full loads in the dishwasher.
- Rinse vegetables in a pan rather than under a stream of running water.
- Keep a pitcher of water in the refrigerator.

Laundry—

- Wash only full loads.
- Consider replacing clothes washer with a front-loading machine.

Outdoors

- Irrigate lawn deeply and infrequently.
- Mulch gardens.
- When cleaning walkways and driveways, don't use water from a hose in place of a broom.
- Install rainbarrels or a rainwater harvesting system for outdoor irrigation
- Replace turf with water-efficient landscapes.

Figure 4. Many cities and utilities offer financial assistance or rebates for customers "trading up" from a conventional toilet to a 1.6-gallon-per-flush toilet. The porcelain is often crushed for road-bed material.

toilets, faucet aerators, and showerheads could be sold in the United States, larger Texas water suppliers took up the charge to encourage the retrofit of existing appliances.

The City of Austin Water and Wastewater, San Antonio Water System, and El Paso Water Utilities created programs involving free ultra-low flush toilets to low-income households and rebates for purchase of the fixtures to other customers (figure 4). El Paso Water Utilities conducts large city-wide low-flow showerhead distributions. The City of Houston replaced leaking older toilets with ULFTs in a 60-unit low-income housing development, netting a 72- percent decrease in total water use.

In a unique symbiotic partnership in California, a private corporation administers the toilet exchange project by paying nonprofit groups to perform the actual replacement.

Figure 5. Front-loading horizontal-axis clothes washers conserve water by tumbling laundry through a small volume of water rather than by filling a tub. Many Texas cities offer rebates on purchases of these appliances.

eClothes washers. Horizontal-axis clothes washers (figure 5), use about 40 percent less water per load than conventional vertical-axis appliances. Although standards adopted in 2000 by the US Department of Energy address energy use rather than water use, more water-efficient machines achieve some of their energy savings by using less hot water. The retail purchase price of these appliances, however, is generally higher than that of conventional clothes washers. To partially offset this difference and to boost the market for such machines, a few Texas urban utilities—the City of Austin, SAWS, Bexar Metropolitan Water System, and El Paso Water Utilities—offer rebates on the purchase price. Under an initiative funded by the US Department of Energy, the City of Austin was able to not only arrange to sell these appliances at a discount through participating retailers, but also to offer two rebates: one from the water utility and an energy rebate through the electric or gas utility. SAWS implemented a similar dual-rebate program: SAWS offered $100 per washer and the city's electric utility offered $100 for each machine purchased. SAWS estimates the washer rebate program saved 271 acre-feet of water, at a cost of about $600 per acre-foot.[10]

Rebates for rainwater harvesting. The City of Austin offers rebates up to $500 for a rainwater harvesting installation to encourage the use of collected rainwater for landscape irrigation. In Hays County, zoning density rules are loosened for homes with rainwater harvesting equipment.

Rebates for waterwise landscaping and irrigation audits. El Paso Water Utilities, SAWS, and the City of Austin offer rebates for replacing turf with water-efficient landscapes that incorporate low-water-use plants and common-sense horticultural practices to save water (figure 6).

The SAWS Watersaver Landscape program offered rebates of $0.10 per square foot for installation of an approved waterwise landscape. In 2001, the program saved an estimated 314 acre-feet at a cost of $253 per acre-foot.[10]

Utilities in larger municipalities offer free irrigation audits to residential and/or business customers to determine efficient water schedules, (figure 7). The City of Austin offers credits to high-volume users who submit to an irrigation audit. Austin also provides discounted rainbarrels.

Graywater reuse. Wastewater from a household is divided into graywater and blackwater components. In general, graywater is wastewater drained from washing machines, showers, bathtubs, and bathroom sinks. Black water is usually wastewater from the toilet and the kitchen sink, due to higher pathogen, nutrient, and solids content.

The Texas Water Development Board estimated that Texans generate between 30 and 50 gallons of graywater per person per day. By 2050, graywater volume in the state will amount to 1.3 billion gallons. Graywater recycling involves filtering, treating, storing and using nonpotable water generated by a household or business for local reuse. Within a residence, graywater is often used for outdoor irrigation. Dyed graywater is sometimes used for toilet flushing in small businesses, such as those in a strip shopping center.

For outdoor irrigation, the Texas Commission on Environmental Quality rules allow discharge of laundry graywater directly on to the ground providing that the graywater does not pond, the disposal area has vegetative cover and limited access, use of detergents with phosphorus are avoided, and a lint trap is installed at the end of the discharge line. Laundry graywater that has been in contact with human or animal waste must be routed to a sewer or treated by an approved on-site septic system.

The Texas State Board of Plumbing Examiners and the Texas Commission on Environmental Quality are continuing to evaluate options for reuse of separated graywater streams, as well as treatment of the entire wastewater stream to a quality suitable for outdoor irrigation. Installation of a domestic graywater reuse system that stores and routes shower and lavatory wastewater for toilet flushing costs between $1,500 and $2,000. In many cases, more graywater is collected than can be used for toilet flushing, requiring rerouting to other wastewater disposal.

Submetering. Apartment complex owners can recoup the cost of water used by tenants in three ways: by submetering each unit; by allocation—using an approved formula (usually square footage of the apartment)—to proportionately divide master meter bill; or by embedding an amount for water in the base rent.

In the allocated and nonallocated schemes, the tenants have no financial incentive to conserve, and no quantitative feedback if they try to conserve. The apartment owner simply passes on the bill to the tenants.

Many water conservation professionals feel that submetering offers a more equitable means of charging tenants for water, as well as a more direct way to effect conservation. With submetering, each tenant is charged for the water used by that tenant.

A study by a San Antonio Water System conservation specialist revealed that when low-flow plumbing fixtures are in place, per capita consumption appears to decline with the introduction of some type of system for charging tenants for water consumption. The study also revealed that the presence of low-flow toilets and fixtures is more important in reducing consumption than the method of billing.[11]

Other. The Plumbers to People program of SAWS provides plumbing services free of charge to fix leaking plumbing in the homes of low-income, elderly, disabled or handicapped customers.

El Paso Water Utilities has conducted several mass distributions of free low-flow showerheads throughout the city.

Figure 6. Water-wise gardening, following seven common-sense principles, yields an attractive, low-maintenance landscape. The landscape shown here is at the Texas A&M Research and Extension Center in El Paso.

The *Learning to be Water Wise & Energy Efficient* program combines distribution of low-flow showerheads and faucet aerators with a grade school curriculum focused on water. Already the kits distributed in Texas from the Panhandle to the Lower Rio Grande Valley have saved enough water to fill the Astrodome several times over.

Other appliances. Tankless hot water heaters eliminate the "warm-up" water that is normally wasted waiting for hot water to travel the distance from the tank to the end use. Energy Star dishwashers use less hot water in the wash cycle. As with horizontal-axis clothes washers, these appliances are more expensive than conventional appliances.

photo courtesy David Smith, Texas Water Audits

Figure 7. Water audits accurately determine sprinkler system precipitation and efficiency. By analyzing sprinkler performance, soil type, plant type, and evapotranspiration, the auditor can provide the customer with an irrigation schedule geared to the needs of the plant.

Regulatory Oversight and Implementation

Drought contingency plans. The droughts of 1990s convinced Texans that drought contingency planning is critical for the sustainability of the state's water resources. All water suppliers were required by Senate Bill 1 to submit drought contingency plans to the Texas Commission on Environmental Quality. Almost all municipal plans call for some type of outdoor watering restrictions.

Drought contingency plans typically specify increasingly stringent measures in response to predetermined trigger conditions such as groundwater levels or daily pumping rates. For instance, Stage 1 conditions may limit outdoor irrigation to early morning and evening hours, Stage 2 might restrict irrigation to certain days of the week, and Stage 3 may prohibit outdoor irrigation altogether.

Although outdoor watering schedules are usually enacted as part of a drought management plan, as opposed to a water efficiency effort, several points are worth noting here.

Cities within a geographic area should make every effort to coordinate irrigation schedules, thereby sending a unified message to customers. For instance, starting during the drought of 1996, a coalition of 20 Travis and Williamson county mayors agreed to a coordinated regional watering schedule. In previous years, conflicting schedules in neighboring cities confused citizens.

Care must be taken in mandating watering schedules as evidenced by the experience with the odd-even strategy, in which citizens water on a prescribed day determined by the last number of the address. Although no scientific studies have been performed to determine the effectiveness of the odd-even regime, empirical evidence from several Texas cities, including Houston, indicates that odd-even actually has the effect of increasing water use. Some citizens even misconstrued the message, thinking that they were required to water on their day. In other persons, the mandatory days induces a "siege mentality" in which citizens overwater their landscapes on their prescribed day.

Water waste ordinances. During the droughts of 1996 through 2000, Texas municipalities first relied on public appeals to encourage adherence to drought stage restrictions, but ultimately resorted

Figure 8. Concrete and ashphalt will never grow. Overshooting turf areas is wasteful. Several cities have banned sprinkler irrigation on narrow turf strips.

to issuing Class 3 misdemeanor summons when voluntary conservation did not achieve adequate savings. El Paso, with only 8 inches of rainfall annually, prohibits washing a vehicle without a positive shut-off nozzle, allowing irrigation runoff to run into the street, and outdoor watering on other than the assigned days. Watering on the wrong day nets the violator a $137 fine plus court costs. Citizens caught watering at the wrong time or allowing water to run into the right-of-way (figure 8) are fined $112 fine plus court costs. Failure to repair leaks is a $245 fine.

Landscaping ordinances. In light of the expected population increases and population shift from rural to urban areas, some Texas cities have begun to consider regulating the types of plants in municipal landscapes. The water requirements of turfgrass species vary widely, from water-thrifty Buffalograss to St. Augustine, which is water-thirsty in the sun and lacks drought tolerance. The City of Schertz, located northeast of San Antonio, adopted an ordinance in 1996 requiring that all new landscape turf be both low-water-use and drought-tolerant.

In the next 50 years, most Texas municipalities and other water providers will consider year-round water use-efficiency ordinances focused primarily on outdoor landscape irrigation. Selected water-conserving practices are compared in Table 1 on page 12. Public perception and the political process form the dual municipal hurdles to passage of any such ordinance. As with any other water conservation measure, success depends on the public information effort. For instance, in response to the drought of 1996, SAWS recruited a Community Conservation Committee to extend the range of programs deeper into the community and across a broader cross-section of water users. The committee, composed of representatives of business and neighborhood associations, school districts, civic groups, and environmental groups provides a clearinghouse for conservation ideas, evaluates and recommends programs to the SAWS board, and helps insure that conservation measures are implemented in all areas of the community.

A water provider's first job is to convince the public of the importance of using water more efficiently. Since water has largely been a relatively inexpensive resource the public perception is that water resources are inexhaustible. In addition, citizens feel that unlimited use of water to maintain their landscaping is a right they have so long as they are willing to pay for it.

Another requirement for efficient municipal water use is the establishment of an administration to manage utility programs. The SAWS conservation program is funded with fees on high-volume water use customers. SAWS actively measures the value of the saved water and the cost of the program, including staff costs. For instance, the cost per acre-foot of saved water has ranged from $13 for public education efforts of the Critical Period [drought] management effort of 2000 to $133 for a landscape irrigation system analysis program to $199 for the Plumbers to People program.[9]

Similarly, the City of Houston's water conservation plan considered two financial benefits from conservation: savings in operations and maintenance expenses and savings from delaying or canceling of capital projects. The conservation plan considered 200 conservation measures before settling on 20 with benefit-cost ratios greater than 1. The total cost of water saved was $1.41 per 1000 gallons.[6]

Groundwater districts. Under Texas law, groundwater pumpage is governed by the rule of capture; that is, a landowner can pump as much water as can be put to beneficial use. Groundwater conservation districts, however, are state-chartered entities that may regulate well spacing, monitor well construction standards, set guidelines on water withdrawal, and issue permits. About 80 percent of the groundwater pumped in the state is located in areas served by 63 water districts.

Special groundwater districts. Senate Bill 1477 created the Edwards Aquifer Authority in 1993, in response to a suit filed by environmental groups and the Guadalupe-Blanco River Authority charging that the US Fish and Wildlife Service was not effectively protecting endangered species that relied on stream flows arising from the Edwards Aquifer. The EAA water conservation requirements include reduction in overall pumpage of Edwards Aquifer water from 450,000 to 400,000 per year by 2008. This translates to a reduction of approximately 28,000 acre-feet per year by municipal and industrial users.

The Harris-Galveston Subsidence District, created by legislative decree in 1975, provides for the regulation of groundwater withdrawals to stem land subsidence. Land subsidence caused by groundwater pumping flooded and forced the abandonment of entire neighborhoods in southeastern Harris county. For similar reasons, the Fort Bend Subsidence District was created in 1989.

Table 1. Potential Water savings from selected municipal practices

Conservation practice	Target savings (%)	Potential water savings (acre-feet/year)[1]	Persons served by saved water[2]
Reduction of unaccounted-for water[3]	10-20	423,000 to 846,000	3.7 to 7.5 million
1.6 gallon/flush toilet retrofit[4]	54	840,000	7.4 million
Water budgeting and efficient pricing[5]	10-15	423,000 to 634,500	3.7 million to 5.6 million
Science-based landscape irrigation[6]	20-25	338,400 to 423,000	2.9 million to 3.7 million

[1] Savings based on *Water for Texas 2002*, municipal demand of 4.23 million acre-feet per year in 2000.

[2] Based upon domestic per capita demand of 101 gallon per capita per day (gpcd), Vickers, Amy, *Handbook of Water Use and Conservation*, 2001.

[3] Adapted from Beecher Janice A. and John E. Flowers, "Water Accounting for Management and Conservation," *Opflow*, American Water Works Association, May 1999, and personal communication, Pat Truesdale, Water Conservation Direct, City of Houston Public Works and Engineering, April 2002.

[4] Texas Section, American Water Works Association.

[5] Adapted from Ash, Tom, "Developing the Irvine Ranch Water District Water Budget and Incentive Rate Structure," presented at the 1999 Texas Water Conservation in Landscape Irrigation Conference.

[6] Assumes outdoor landscape demand of 40% of total domestic demand.

The supply side: unaccounted-for water

Most water-conservation strategies focus on demand management—reducing customer water use. Supply-side conservation, however, can be particularly effective, since the water distribution system is under a utility's direct control. Also, water savings can be achieved without affecting revenues—water saved translates directly to cost savings. Utilities can effect water supply conservation with programs to rein in unaccounted-for water, which includes leaks and water theft.

Utilities typically use the term "unaccounted-for water" or "unmetered water" to describe water that is not billed. While some unmetered water may go toward an authorized use, such as flushing of lines and fire suppression, leaks and water theft can have a serious effect on a utility's water supply.

The American Water Works Association, the trade organization of the drinking water industry, recommends a goal of 10 percent for unaccounted-for water.[1]

The City of Houston Public Works and Engineering, for instance, battled the burden of unaccounted-for water as high as 30 percent in April 2001. By April 2002, however, the city had succeeded in reducing the loss to 12.3 percent.[2]

Leak detection is usually undertaken in response to a problem. A water system survey is a preventive measure taken to measure components of unaccounted-for water, authorized or not. Leak detection is achieved by several techniques: cameras in water pipes, noise loggers, water-sound sensors, and transducers.

[1] Personal Communication, Staff members, City of Houston Public Works and Engineering, Water Conservation Department.

[2] Beecher, Janice A. and John E. Flowers, "Water Accounting for Management and Conservation," *Opflow*, American Water Works Association, May 1999.

SAWS water conservation: the sum of many parts

The San Antonio Water System has one of the most extensive and varied water conservation programs in the state, with a residential conservation effort that combines indoor and outdoor domestic programs.

Passage of SB 1477 in 1993 creating the Edwards Aquifer Authority had a profound effect on water resources planning by the San Antonio region. The Authority was obliged to reduce draws on the Edwards Aquifer from 450,000 to 400,000 acre-feet by 2008. As a result, the San Antonio Water System created a diverse, far-reaching water conservation effort, encompassing retrofits, price incentives, appliance volume purchases and rebates, and public information programs under its residential water conservation umbrella.

Indoor domestic programs

Two of the most successful programs involve toilet retrofits—replacement of leaky, high-water-volume commodes with 1.6-gallon per flush units—and the repair of residential plumbing leaks.

Plumbers to People, offered to San Antonio homeowners who meet low-income eligibility requirements, provides for the utility to hire a plumber to fix leaking faucets and broken pipes in the homes of eligible persons. Conventional toilets are replaced with new ULFT models. In 2001, 885 households were visited by a SAWS-contracted plumber, resulting in an estimated water savings of between 600 and 800 acre-feet annually, at a cost of $328 per acre-foot.

Kick the Can offers SAWS customers a $75 rebate for swapping toilets which use 3.5 to 7 gallons per flush with ULFTs. SAWS conservation specialists estimate a savings of more than 7,800 acre-feet over the next 10 years, at an estimated cost of about $300 per acre-foot.

A complementary program, the **Residential Toilet Distribution**, buys toilets in bulk and gives them away to SAWS residential customer homeowners. The estimated water savings from this program is about 85 acre-feet at a cost of $421 per acre-foot.

To boost the market for high-efficiency horizontal-axis clothes washers, SAWS made volume purchases of these appliances, which were then sold by retail dealers, under the aegis of the **Wash Right** program. After purchase, SAWS customers would be eligible for two rebates: $100 from the SAWS and $100 from the electrical utility. The appliances save between 8,000 and 10,000 gallons per year per family.

Outdoor domestic programs

San Antonio Water System formed a partnership with Bexar Master Gardeners and Texas Cooperative Extension to determine the feasibility of a **Potential Evapotranspiration (PET)-Based Watering Program for Turfgrass**.

Potential evapotranspiration is an approximation of the water used by a plant through evaporation from soil and transpiration from the leaf surface, taking into consideration plant species, temperature, humidity, wind, and rain. Results of the study revealed that some turf species performed well at less than 100 percent ET replacement, and considerably less than the 1 inch per week then recommended by Texas Cooperative Extension.

The advantage of a PET-based irrigation system is better water-use efficiency. Turf—and ornamentals—can be watered according to their actual water needs, avoiding water waste and runoff.

The popular **Watersaver Landscape** program offers a rebate of $.10 per square foot for a minimum 1,000- and maximum 5,000-square foot conversion of conventional landscapes to a more water-thrifty landscape with appropriate turf areas, proper soil preparation and mulching, and hardscapes that allow infiltration of rainwater. In 2001, Watersaver Landscapes saved 192 acre-feet of water at a cost of $253 per acre-foot.

SAWS also offers a **Landscape Irrigation System Analysis** to flag leaking, broken or misaligned sprinkler heads and making run-time adjustments. The program saved 508 acre-feet of water at a cost of $85 per acre-foot.

Taken together, these programs and aggressive leak detection and repair lowered San Antonio's per capita water use from 212 gallons per capital per day in 1984 to 147 gallons per capita per day in 2000.[1]

[1] Strassman, Neil, *Fort Worth Star-Telegram*, July 15, 2001.

Financial Incentives

Financial incentives can reward efficient water users with rebates or send a warning in the form of a price signal to water-wasters. For instance, the most common disincentive implemented by water utilities is an increasing block structure, in which high-volume water users pay a higher per-unit price for water at set threshold levels. At the disposal of water suppliers is an array of financial incentive and disincentive tools to promote demand management. These tools can be roughly divided into price incentives and rebate or credit programs.

First, though, a word about municipal water rates in general. Municipal water rates are expected to be efficient, revenue neutral, and equitable.[1]

- **Efficiency**. Efficient in the economic sense means that utility supplies water only so long as customers are willing to pay more per unit than production costs. Similarly, customers use or conserve water depending upon whether the cost of that water exceeds or falls short of those units' value to other customers, according to economics professor Robert A. Collinge at the University of Texas at San Antonio. Too often water prices send an incorrect signal about the true cost of new water supplies because water utilities average the high cost of new water supplies with the lower cost of existing resources. This prevents customers from realizing the the true economic value of conservation.
- **Revenue neutrality**. Ideally, utilities adjust rates such that excessive revenues are avoided. In other words, total water revenues should more or less equal total water supply expenses.
- **Equity.** No consumer group should bear a heavier burden than another.

Inclining (or inverted) block rate structure. The most direct signal a utility can use to modify customer behavior, of course, is a price signal in the water bill. Twenty years ago, most water utilities billed water at a flat rate, or even a decreasing block rate structure, which rewarded high-volume users with discounted rates. Now the increasing block structure, sometimes with a large jump between tiers, is implemented to send a price signal to large-volume water consumers.

Many utilities, such as San Antonio Water System (SAWS), earmark revenues generated from the highest tier of water rates to support the water conservation education programs.

Consumers, though, are not always readily responsive to higher water rates. One study performed for the American Water Works Research Foundation found that consumers are more cognizant of their average water price than the price of the last gallon used, which probably accounts for the short-term inelasticity of water demand.[2] Since consumers are unaware of the cost of the gallon of water being used, large price increases that only affect the last block of water consumption effect only small demand reductions. In contrast to gasoline, which is sold at a single, well-advertised retail price for a single purpose, water is a commodity with a myriad of end uses which is billed in sometimes difficult-to-understanc¯units.[3]

Water Budgets and Incentive Rate Structure

One controversial but progressive approach to water pricing is to allocate water to residences on the basis of a calculated water budget. The budget is the sum of per capita indoor water demand plus outdoor water demand. Outdoor water demand is calculated by a formula using the variables of landscape area, evapotranspiration, plant coefficient, precipitation, and irrigation system efficiency. According to Tom Ash, conservation coordinator for Irvine Ranch Water District in California, in addition to efficiency, revenue neutrality, and equity, the hallmarks of an incentive rate structure should achieve—

- Revenue Stability: The rate structure must be set to avoid the decrease in revenue that traditionally accompanies conservation actions.
- Credibility: The rate structure must have a logical and simple basis.
- Building of a conservation ethic: Flexibility to deal with drought should be inherent in the system.

• Flexibility. The structure should be adaptable and should address the needs of a variety of customers.

To ensure revenue stability, the Irvine Ranch Water District separates the fixed costs of delivering water from the commodity costs. A stable revenue stream is ensured by recovering fixed costs through water and sewer charges. Charges for the commodity of the water itself are directly related to consumption.

Low-volume water users actually pay a fraction of the base rate, while customers using excessive amounts over their calculated water budget are charged a higher rate. All customers groups have similar structures.

A further benefit is that charges for high-volume users also provide a funding mechanism for conservation plans.

Feebates

A variation on this incentive rate design proposed by economist Collinge are "feebates," a tool that would provide rebates to frugal users with the higher rates charged to wasteful customers. In this scenario, the utility determines an allocation, or water budget. It then sets a revenue-neutral flat rate. Feebates apply when customers' use varies from their allocation, with frugal customers rewarded with a rebate, paid for by the higher rate charged to high-volume users. Revenue neutrality is achieved because the fees pay for the rebates. Water goes to those who place the highest value on it, and low-volume users are rewarded for conservation.

Both the Irvine Ranch Water District model and the feebate model provide a mechanism for rewarding conservation by the most efficient users, a feature lacking in the standard inclining block rate structure.

The most contentious part of an allocation/ incentive rate structure is determination of the water budget. Water budgeting would represent a "rationing" of water that of necessity would represent a generalization of optimal water use.

Two major barriers to implementation exist: political and technical.

The political challenges largely involve public perception. The challenge of convincing customers that the water budget is an equitable solution has deterred at least one Texas utility from adopting water budgets after a year-long study. Communities in other states have abandoned the plan when elected officials shied away from supporting establishment of water budgets.

The technical challenges involve scientifically calculating the landscape water-use equation and determining lot size.

A water provider setting allocations must determine the equation from which the budget is derived using weather, landscaped area, a predetermined evapotranspiration rate, rainfall, and an estimated irrigation system efficiency factor. Landscaped area is probably the most difficult variable to determine. Remotely-sensed data or county property records offer two methods of obtaining such data, but incorporating data from a nonhomogeneous service area would prove difficult in some cases.

A utility must determine the most equitable manner of treating different classes of customers; for instance, setting multifamily dwelling allotments in contrast to those of single-family residences.

Also, in the Irvine Ranch model, even labeling each higher consumer use necessitated a delicate public information campaign. For instance, the highest tier of water use was initially labeled "abusive," which was changed to "wasteful" in response to negative customer reaction.

Once in place, administration of the water budget or feebate system entails no significant change in the utility's day-to-day operations.

[1] Collinge, Robert A., "Conservation Feebates," *Journal of the American Water Works Association*, 88:1:70 (January 1996).

[2] Michelsen, Ari M., *Effectiveness of Residential Water Conservation Price and Nonprice Programs,* AWWA Research Foundation, 1998.

[3] Whitcomb, John, *Water Price Inelasticities for Single-Family Homes in Texas,* Stratus Consulting, 1999.

In a water budget or feebate structure, the "silent hand" of the marketplace efficiently conserves water without the need for regulation.

Managing municipal water supply risk

Economists look at water supply in terms of risks and benefits. Instead of building supply infrastructure to meet every need in times of highest demand, economists consider allowing consumer preferences to determine the best use of water in the face of water scarcity.

Water utilities have traditionally focused on water development, management, conservation, and water transfer, usually with the goal of assuring a risk-free municipal water supply. To keep lawns green, bathtubs full, and car washes running, water utilities typically size the water supply system for a worst-case scenario: severe droughts of low probability.

Because water consumers are risk-averse, and also because water utilities are able to pass on the cost of development to those consumers, the tendency to size the water supply system for the severe drought contingency remains the industry standard.

A survey of 72 Texas cities by the Texas Water Development Board revealed that peak demand in some affluent communities is four times the normal demand.[1]

A study by the Department of Agricultural Economics at Texas A&M University analyzed optimal water supply levels by modeling risk in seven Texas communities. The study broached the idea of an alternate approach to the building of supply infrastructure to meet any and all water requests. The rationale is that in the current climate of high water development costs, it may not be sensible to maintain idealistic water supplies necessary to meet peak demands during times of drought.

Such a strategy would require an assessment of consumer preferences on the reliability of water supply. In one simple example, consumers would make decisions between the aesthetics of year-round green lawns and the considerable costs of new supply development. In some cases, supply development is not an option, so meeting all reasonable needs must be accomplished with demand management.

Aside from the obvious costs of "playing it safe," there is the environmental impact. When municipal water users decrease the risk of water supply shortfalls, they usually shift risk to nonmunicipal users. Obviously, some water users must bear the shortfall during drought conditions. Traditionally, that risk is shifted to natural, aquatic and habitat systems. These systems are residual claimants, using only water left over after humans have diverted water for their purposes. Recent public policy, however, has placed emphasis on streamflow protection. One result of this policy may be redistribution of risk back to municipal users.

[1] Mjelde, James W. and Griffin, Ronald C., Valuing and Managing Water Supply Reliability, research report for the Texas Water Development Board, December 1997.

Industrial, Commercial, and Institutional Water Conservation

Industrial, commercial, and institutional (ICI) use of fresh water accounts for more than half of nonagricultural water use in Texas and is expected to increase 47 percent in the next 50 years.[1]

In Texas, five industrial sectors (chemical manufacturing, steam electric power, petroleum refining, pulp and paper, and primary metals) account for 81 percent of the 2.67 million acre-feet of industrial fresh water used in Texas.[1] (For purposes of this paper, steam electric power and mining are included in the ICI total.)

Texas is a national leader in chemical and petroleum processing. The Houston–Beaumont area boasts 50 percent of the nation's petrochemical production and 30 percent of its petroleum industry. The Coastal Bend area is home to the country's third largest refinery and petrochemical complex. But significant differences between regions exist. The newer refineries in the Coastal Bend and in West Texas use only half as much water per barrel of refined oil as those on the Upper Gulf Coast between Houston and Beaumont. With the water they do use, these refineries are water-efficient: it is not uncommon for petroleum refineries to reuse water up to 50 times before discharging.

Many factors drive water-use efficiency, including rising water and sewer costs, pretreatment regimens, compliance with discharge permits, and limited water supplies. Since industries pay for wastewater treatment and discharge by volume, using less water is nearly always economical because it reduces overall wastewater treatment costs. Almost universally, the cost of pretreatment of wastewater and disposal exceeds the cost of potable water. In addition, many water purveyors offer financial incentives to industrial customers who make strides in water conservation.[12, 13, 14]

As in-plant water treatment technologies become more sophisticated, discharge permits more stringent, and water more costly, older industrial plants may find it increasingly cost-effective to find ways and means to recycle water in-plant. Within all categories of manufacturing are opportunities for sequential use of water, with water routed in series to processes that can tolerate a lower quality of water.

Water recycling systems can show advantageous returns on investment. Four semiconductor fabrication plants, for instance, show a payback of as short as 5 months to 4 years on their water recycling strategies.[5,13]

But the cost of water is only one consideration. Increasingly stringent laws regulating environmental impacts of industrial discharge have also motivated industries to minimize the amount of effluent leaving the plant. In some cases, wastewater recycling is introduced as industries strive to comply with permits, or even to achieve zero discharge. In zero discharge situations, all wastewater, after treatment, is converted to a solid waste by concentration and evaporation, or is reused on site.

A comparison of selected ICI water-conserving practices is shown in Table 2 on page 21.

Achieving Water Savings in Industry

Case studies and water-efficiency audits show typical potential demand reductions of 15 to 50 percent and payback periods of between one to fours years with hardware changes, according to water conservation consultant Amy Vickers[9]. These hardware changes include—

- use of "captured" water for cooling tower evaporative makeup,
- use of reclaimed water for landscape irrigation,
- use of reclaimed water for industrial process water, where appropriate,
- enhancing cooling tower efficiency and increasing cycles of concentration,
- use of recycled water and captured water for industrial process water,
- replacement of once-through cooling apparatus with either air-cooled equipment or recirculating water-cooled equipment,

- audit of automated sprinklers in landscaped area,
- use of captured rainwater for landscape irrigation.,
- retrofit of older toilets in high-traffic areas,
- replacement of conventional landscapes with water-thrifty landscapes.

Financial Incentives

One of the most practical ways for a manufacturing plant to save water is to use wastewater for other plant applications tolerant of lower-quality water, such as the use of captured rinsewater for evaporative makeup water for cooling towers.

Capture and use of effluent within a plant or campus serves to reduce the cost of purchased water. The most obvious financial incentive for industrial, commercial and institutional entities to conserve water is an improved bottom line. Industrial customers pay an average of $6 per thousand gallons for potable water from a water supplier. Industrial reuse programs can have payback periods of less than one year, sometimes as short as six months.

The wide variety of processes and clientele served make it difficult to generalize conservation strategies costs and benefits across the ICI spectrum, even within similar industries or institutions. For instance, one refining plant may use once-through saline cooling water, another may recirculate effluent captured from process water.

Water Audits

For the past five years, staff members of the Water Conservation Division of the Texas Water Development Board (TWDB) have conducted ICI workshops targeted variously at the hospitality industry, manufacturing plants, hospitals, and schools.

In preparation for the workshops, TWDB staff members choose an institution or plant, obtain previous usage statistics, then perform a site survey and water audit. Workshop participants learn simple and complex methods for using water more efficiently. For example, an audit at a hotel in Corpus Christi indicated a 9-month payback period for a conservation program that included automatic shutoffs in sinks, replacement of water-cooled ice machines with air-cooled units, serving water only upon customer request, and retrofit of toilets in high traffic restrooms. Irrigation audits of commercial business landscapes have saved as much as six inches per year of excess irrigation.

Semiconductor manufacturing: conservation of many streams

Semiconductor fabrication plants are in an ideal position to enact sequential water reuse within the plant. The manufacture of semiconductor wafers requires prodigious amounts of ultrapure water for rinsing—the production of a single semiconductor wafer requires between 1,600 and 2,400 gallons of potable water. Refining potable water into ultrapure water by reverse osmosis produces a waste stream of reject brine amounting to about 25 percent of the input stream volume. Most Texas semiconductor fabrication plants have devised methods to clean up a portion of the brine for reintroduction into the reverse osmosis input feedwater.

A sampling of Texas semiconductor plants in Austin, San Antonio, and Dallas, showed a return on capital investment of between 5 and 7 months for water recycling systems, as described below.

Also, ultrapure water used for rinsing silicon wafers is practical for use in other plant applications, such as in flume scrubbers, acid waste drains, and of course, cooling tower evaporative makeup. In continuing efforts to reduce both water and sewer costs and to comply with discharge permits, semiconductor manufacturers vigilantly capture this process water for use in other plant applications tolerant of a lower-quality water.

- At SEMATECH, a semiconductor industry consortium plant in Austin, a water reclamation retrofit showed a 7-month payback for a system that recycles reverse osmosis reject (the brine solution remaining after membrane treatment) to cooling towers, vacuum pumps (for cooling seals) and acid scrubbers for removing vented fumes.
- Motorola's Austin wafer fabrication plant reclaims 50 percent of reverse osmosis reject—about 200 gallons per minute—formerly discharged to the sewer. Motorola modified its existing reverse osmosis system by forcing the reverse osmosis reject through a "looser" nanofiltration system and returning this product water to a storage tank to be recycled as reverse osmosis feedwater.
- Philips Semiconductor saves 462,000 gallons per day at its San Antonio site by judiciously routing rinsewater from the wafer manufacturing process for repurification and reintroduction as reverse osmosis feedwater, as well as for acid dilution in acid waste drains and in fume scrubbers. As an incentive, the San Antonio Water System rewarded Philips with a $1.1 million rebate on past water bills.

- Several semiconductor fabrication plants repurify reverse osmosis brine for reintroduction to the purification process.

Enhanced cooling tower efficiency

Cooling tower makeup (water added to cooling tower reservoirs to replace and equal volume lost to evaporation or discharged to the sanitary sewer to control concentration of contaminants) forms the bulk of industrial water consumption. Cooling towers remove heat from air conditioning systems of large buildings, refrigeration systems of food processing plants, and process heat from manufacturing plants by absorbing heat from a refrigerant in a closed system. Water used for cooling accounts for about 95 percent of water used by a steam electric power plant and 55 percent of water used by petroleum refining overall.[15]

Water from cooling towers is lost in two ways: evaporation and blowdown. Evaporation is the means by which water gives up its heat. Blowdown is the water that is discharged to the sanitary sewer to maintain a concentration of dissolved salts and other materials that will minimize scaling or other fouling of the tower. By carefully adjusting the chemical treatment in cooling tower water, a cooling tower operator can increase the cycles of concentration.

By increasing the number of times water is recirculated through the tower before discharge to the sanitary sewer, water savings are achieved. For instance, a 1,000-ton cooling tower will save 140 gallons per minute going from 1.2 cycles of concentration to 4 cycles.

By targeting industrial customers with the heaviest consumptive (evaporative) demand for city-sponsored cooling tower audits, both the City of Houston and San Antonio Water System hope to lessen demand for potable water.

The City of Houston is looking to cooling tower audits to reduce water consumption by 375 million gallons per year, or about 5 percent of the total water savings generated by its comprehensive water conservation program. For every $1 spent on the program, the City expects to realize $18.60 in reduced water and wastewater costs.[6]

Reverse osmosis reject brine, captured condensate from refrigeration systems, silicon wafer rinse water, groundwater seeping into below-grade basements, and event captured stormwater are types of captured effluent that have been successfully used for cooling tower makeup water in Texas industries and institutions. The City of San Antonio projects that if all 129 customers operating cooling towers increased from three to four cycles of concentration, they could save about 239 acre-feet of water annually.[5]

In both programs, the water utility increase cycles of concentration by recommending more appropriate chemical treatment and automating blowdown disposal with a conductivity meter. Leaks and malfunctioning equipment are identified and corrected. Some smaller systems may be candidates for replacement with air-cooled systems.

Opportunities for conservation at commercial properties

Commercial operations can apply a myriad of practices to conserve water. For instance San Antonio-based La Quinta Inns implemented an aggressive water conservation program, starting with a retrofit of faucets and showerheads in its 35,000 existing rooms, with new properties fitted with pressure-assisted low-flow toilets. Toilet tanks are routinely tested for leaks with dye tablets. In addition, La Quinta uses a proprietary energy and water management information system to flag deviations from normal use patterns. La Quinta has also developed an irrigation auditing program for its landscaped areas.

Many hotels and motels give guests staying more than one night the option of foregoing fresh towels and bed linens, saving as much as 30 gallons per room per day. The Renaissance Austin Hotel installed an ozone laundry system which reduced water and energy use by 35 percent. The kitchen removed the water-wasting garbage disposal and instead tosses scraps in the trash can.

Many kitchens have replaced ice machines with water-cooled condensers with air-cooled units. It takes about 150 gallons of condenser cooling water to produce 100 pounds of ice. Conserving or reusing cooling water delivers a rapid return on investment. Air-cooled ice machines can save $50 to $100 per month in water costs.

The Texas Water Development Board calculated estimated payback for several other conservation practices. For instance, at a conference hotel in San Antonio, replacing all toilets in public areas with ultra-low flush toilets at a cost of $3,250 would show a payback in 2.1 years. At another hotel, installing a $200 solenoid valve in an ice machine would render an immediate payback and an annual water savings of 1.9 million gallons per year.

Use of reclaimed water

The San Antonio Water System has found that some customers are willing to pay the same price for reclaimed water as for potable water, because reclaimed water is not affected by mandatory curtailment measures.

- Since 1965, Central Public Service, San Antonio's gas and electric utility, has primarily utilized recycled wastewater to cool power plants. Now that San Antonio is making 35,000 acre-feet per year of recycled water available, more and more cooling towers have come on line, including a large installation at Brooks Army Medical Center and a smaller one at Trinity University.
- The University of Texas at Austin has achieved nothing short of a paradigm shift with its water reclamation system. By capturing once-through cooling water from centrifuges, scanning electron microscopes, and even drinking water fountains to be used for evaporative makeup in cooling towers, the water capture system saves 70 million gallons per year. Recovered water accounts for 8 percent of the university's consumption, a savings of about $3 million annually. Older buildings had to be replumbed, but specifications for all new buildings required the dual-pipe plumbing infrastructure necessary for reuse. A network of french drains and sump pumps also collects groundwater from a shallow aquifer for evaporative makeup. The University of Texas is also studying the use of captured air conditioning condensate, which lacks dissolved solids and salts, for boiler feedwater.
- Southwestern Public Service Company in Amarillo annually conserves about 6 billion gallons of fresh water by substituting wastewater for fresh water in its cooling towers. Blowdown is sent to irrigate adjacent forage land, figure 9.
- Other steam electric power plants in Denton, El Paso, Lubbock, and Cleburne have been using treated effluent for cooling water for years.
- San Antonio's Trinity University, having built an irrigation distribution network for reclaimed water, extended the infrastructure to include cooling towers as an end use.

Reclaimed water and captured water in industrial process water

- The Sherwin Alumina plant of Gregory in the Coastal Bend area requires about 9 million gallons of water per day for refining bauxite into alumina, but does not require high-quality water. The San Patricio Municipal Water District devised a resource-sharing arrangement, sending 4 million gallons per day of blowdown from power plant cooling towers directly to the Sherwin Plant (see story, page 25). Sherwin also captures stormwater in retention ponds for use as process water to such an extent that its water purchases from the nearby San Patricio Municipal Water district are driven not by production but by rainfall.
- In another public-private partnership, a commercial venture was attracted to a water-scarce area with the promise of dependable supply of specially treated wastewater. In 1988, Fruit of the Loom sought to locate a bleach-and-dye facility in the Lower Rio Grande Valley, but the large volume of process water required would have strained both the limited water resources and the capacity of any treatment plant in the area. In order to attract the new industry, Harlingen Water Works System, the Harlingen Chamber of Commerce, and the City of Harlingen proposed treatment of municipal wastewater by reverse osmosis to serve the processing needs of the plant. Since initial installation, wastewater treatment capacity has been doubled from 2 million to 4 million gallons per day, and now the factory even returns process water to Harlingen for reprocessing, figure 10.

Figure 9. Southwestern Public Service in Amarillo uses treated wastewater in cooling towers at its Panhandle power plants. It sells wastewater from cooling tower operations to a farmer for forage irrigation.

Figure 10. Purple pumps and pipes designate recycled wastewater at Harlingen Water Works wastewater treatment plant. After a stringent treatment regiment, wastewater is pumped to an adjacent bleach-and-dye plant.

Landscape Irrigation Audits

An irrigation audit measures sprinkler performance; and identifies sources of irrigation inefficiency, such as broken or leaking system components, and misaligned spray patterns. The irrigation auditor tailors an irrigation schedule for each customer considering types of plants, soil, and climatic conditions. In addition to a reduced water bill, the customer benefits from a healthier landscape and improved nutrient retention.

The City of Houston expects its free irrigation audit for customers with large landscaped areas to save 860,000 gallons of water annually.

Tax incentives

- In 1997 Senate Bill 1 extended the sales tax exemption for pollution-control equipment to include water-reuse equipment.
- In 1997, Texas voters approved an amendment to the Constitution authorizing taxing entities to grant exemptions from ad valorem taxes on water conservation equipment (30 TAC 17). The purpose of the amendment is to ensure that compliance with environmental mandates does not increase a facility's property taxes.

Regulatory Oversight

Title 30 Texas Administrative Code, Chapter 210, Subchapter E. Special Requirements for the Use of Industrial Reclaimed Water provides for the beneficial reuse of air conditioning condensate, cooling tower blowdown, noncontact cooling water, wash water from fruits and vegetables, nonprocess stormwater, once-through cooling

Table 2. Water savings from selected ICI conservation practices

Conservation practice	Water use, 2000[1]	Target savings	Potential water savings	Potential monetary savings[2]	Persons served by saved water
	acre-feet	%	acre-feet/year	$	
Cooling tower cycle optimization at electric power plants	530,000[1]	33[3]	175,000	$227,965,000	2,257,000
Landscape audits and optimization of ICI irrigation[4]	362,000	20	72,400	$94,366,450	934,321
Semiconductor in-plant water reuse[5]	1,430	60[6]	858	$1,118,400	11,100

[1] Adapted from *Industrial Water Conservation and Reuse in Texas: The Big Picture,* H. William Hoffman, Texas Water Development Board, undated.

[2] Assumes retail water cost of $4/1,000 gallons.

[3] Adapted from Cost Containment Engineering presentations; increasing cycles of concentration from 3 to 4.

[4] Assumes landscape irrigation of 20% of ICI total of 1.81 million acre-feet/year.

[5] Texas Economic Development Business and Industry Data Center.

[6] Recommendations from International Technology Roadmap for Semiconductors.

water, and steam condensate. The code exempts producers or users of reclaimed industrial wastewater within the boundaries of facility or compound from the requirement to—

- hold a permit for treatment and disposal
- notify the Texas Commission on Environmental Quality to obtain approval for the use of reclaimed water
- obtain a permit to use reclaimed water
- color-code in purple piping carrying reclaimed water
- post signage warning of reclaimed water at valves
- build reclaim infrastructure to special design criteria

Conveyance within a facility does not constitute a discharge and does not require authorization. Use of reclaimed water is permissible after the wastewater has been treated in accordance with the producer's permit and the producer provides for an alternative means of disposal when there is no demand for the wastewater.

Chapter 210 also authorizes the use of industrial reclaimed water outside the plant for the following purposes: landscape irrigation, athletic field and golf course irrigation, fire protection, dust suppression, soil compaction, maintenance of impoundments, and irrigation of nonfood crops.

Clean Water Act of 1972. The primary objective of the Clean Water Act of 1972 was to restore and maintain the integrity of the waters of the United States. This objective translates into two fundamental goals:

- Eliminate the discharge of pollutants into the nation's waters.
- Achieve water quality levels that are fishable and swimmable.

The Clean Water Act focuses on improving the quality of the nation's waters. It provides a comprehensive framework of standards, technical tools and financial assistance to address the many causes of pollution and poor water quality, including municipal and industrial wastewater discharges.

For example, the Clean Water Act requires major industries to meet performance standards to ensure pollution control; charges states and tribes with setting specific water quality criteria appropriate for their waters and developing pollution control programs to meet them. The Clean Water Act has been the impetus for ICI water users to reduce chemical requirements and waste loads by better pretreatment systems and more precise use of chemical treatments, such as in cooling towers.

Under the Texas Pollutant Discharge Elimination System (TPDES), the USEPA delegated responsibility to the Texas Commision on Environmental Quality (TCEQ) for the quality of water discharged from those industrial facilities not falling under the jurisdiction of the Texas Railroad Commission. (After September 1, 2002, the Texas Natural Resource Conservation Commission changed their agency name to Texas Commission on Environmental Quality.) The Texas Railroad Commission regulates water produced as a by-product from oil and gas production.

Barriers to Implementation

A unique workshop organized by TWDB in partnership with the Texas Chemical Council; the Environmental Solutions Program of the Center for Energy Studies, University of Texas; and the TCEQ, brought together state, industry, and academic counterparts to begin a dialog on removing barriers, and searching for innovative institutional and financial incentives to promote industrial water reuse.

The public, utility personnel, and elected officials need to be made aware of the possibilities, benefits, science, and risks associated with water reuse so that logical decisions can be made.

- Use of full-cost accounting. Industrial water reuse costs are more complex than comparing the cost of installing a reuse system versus the cost of potable water. Full-cost accounting embodies other factors—location, infrastructure, community issues—that may vary between regions and the type of industry. Although initial retrofits for reuse may be costly, reclaimed water is likely to be cheaper than future supply alternatives.
- Information sharing by industry. There is a need to develop "how to" information and effective ways to trade success stories and methodologies.
- Organizational issues. If extensive water reuse is to be implemented, local utilities or water districts will need to be established, and "across-the-fence" issues resolved. That is, will one company be able to reuse directly another company's effluent without its first being treated to discharge standards.

Regulation, Incentives, and Policies

- Hazardous waste rules sometimes discourage water reuse within a facility. According to US Environmental Protection Agency regulations, if hazardous waste comes into contact with water, that water by definition becomes hazardous waste and cannot be reused, even if the hazardous waste is undetectable.

• Water rights. Water rights holders are concerned that the water they conserved or reuse will be subtracted from their permit. Texas law currently protects against such loss, but industry representatives still feel this concern needs to be addressed.

• Establishing financial incentives to encourage water reuse. The State currently lacks sufficient policies supporting training and technical assistance. Two state-level tax incentives specifically targeting industrial water reuse are in effect; however, federal tax incentives remain undeveloped.

• The effect of conservation and reuse on discharge permits. Concentrations of organic, chemical, plastic, and synthetic fiber in effluent increase while the volume of water decreases. Possible solutions to this dilemma include increased flexibility in the application of rules that address in-stream water quality protection and the calculation of mass limit based on nonconservation flow.

Coastal Bend refinery: symbiotic relationships

A symbiotic relationship between a heavy industrial plant, a municipal water district, and a power plant is saving millions of gallons per day on the north shore of Corpus Christi Bay.

The refining process at the Sherwin Alumina Company in Gregory needs great volumes of water to process alumina (aluminum oxide) from bauxite earth material. The process, which involves a chemical slurry pumped in a continuous loop, can tolerate lesser-quality water, including captured stormwater, treated effluent, and tailings leachate.

When it became apparent more than 10 years ago that urban competition for raw water from the Nueces River might leave the Sherwin plant short on water, the plant operator, Reynolds Metals at the time, got creative in finding sources of water.

First, Reynolds built large earthen impoundments to capture and store rainwater to be used as process water, which serves as both a transport and extraction medium. The captured rainwater proved so effective that during a particularly wet spring, the alumina plant operated for 93 days without purchasing water from San Patricio Municipal Water District. Captured water trickling through old tailings beds became another "found" source of water. The Sherwin plant piped in treated effluent from the Aransas Pass wastewater treatment plant for dust control on the tailings beds. In what turned out to be a win-win situation, the effluent has rehabilitated the tailings beds to enable them to support plant and bird life, and the percolating water is redirected to the plant for recovery of dissolved materials.

More recently, a 400-megawatt cogeneration power plant was built adjacent to the Sherwin refinery, presenting opportunities for more symbiotic relationships. Cogeneration refers to putting to productive use the waste heat generated in steam electric power plants. After pressurized team drives turbines in the power plant, the residual steam is sent to the refining plant, satisfying 100 percent of its steam requirements. Sherwin returns the spent steam as hot water to the power plant, where it is treated and again used for steam and cooling tower makeup water. In addition, The power plant also provides half the electricity needed by the refining operations.

From the plant's large cooling towers and water treatment plant, 2 million gallons per day is routed to the Sherwin Plant for use as process water in the continuous loop refining process. Ultimately, the entire system results in zero discharge, as Reynolds does not discharge process water or even stormwater from events up to 9 inches in 24 hours.

At the Sherwin Alumina Company plant in Gregory on the north side of Corpus Christi Bay, stormwater is captured in large earthen impoundments for later use in processing alumina. Tom Ballou, environmental quality superintendent at the Sherwin Alumina Plant is shown.

Cooling tower audits: Going for behemoths

Cooling towers, those sometimes obvious, sometimes well-camouflaged industrial hulks, can be huge water wasters. Cooling towers serve large cooling and refrigeration applications, such as in food processing and electronics component manufacturing plants as well as providing for the air conditioning of large buildings. Cooling tower water absorbs heat from the refrigerant fluid in a closed system, changing the refrigerant from a gas to a liquid. The water then returns to cascade through the cooling tower to lose its heat. Much water is lost to evaporation in the process.

The two largest cities in Texas—Houston and San Antonio—are seizing the opportunity to help customers more efficiently operate their cooling towers with utility-sponsored audits. The City of Houston's Water Conservation Program initiated a cooling tower audit program with the goal of saving 375 million gallons annually, or 5 percent of the city's total water conservation program. According to the Water Conservation Plan, the program is projected to yield a high cost-benefit ratio—for every $1 spent on the program, the City expects to realize $18.60 in reduced water and wastewater costs.

Houston Flags Big Users

In Houston, utility personnel identify cooling tower customers by scrutinizing the wastewater credit on their water bills, and have found that about half of the City of Houston cooling tower customers would be good audit candidates. (Cooling tower customers are eligible for a wastewater credit, as much of the water is lost to evaporation in the cooling process rather than sent to the sanitary sewer.)

In Houston, the average cooling tower account uses 500,000 gallons per month, and the audit contractor projects a realistic goal of improving the efficiency of 250 towers by 25 percent. On the high end, the George R. Brown Convention Center uses 4.5 million gallons per month of cooling tower makeup.

In addition to evaporative loss, however, much water is discharged as blowdown, an amount of water intentionally wasted to control salt and other contaminants which would cause corrosion, fouling, and scaling of the cooling tower structures. Water in a cooling tower is continually recycled from a sump. Contaminants become more concentrated with each cycle, so a portion of water is discharged and replaced with fresh water to maintain an acceptable water quality.

First, the Houston cooling tower audit engineers will seek to increase cycles of concentration by recommending more appropriate chemical treatment and automating blowdown disposal with a conductivity meter. Increasing cycles of concentration has the effect of decreasing the amount of water that must be blown down.

Second, leaks and malfunctioning equipment will be identified. Some smaller systems may be suitable for replacement with air-cooled systems.

Although large cooling towers are generally more efficient and usually more actively managed than small towers, the consulting engineers may introduce operators to the possibility of using rainwater or air conditioning condensate as makeup water.

The City of Houston's Water Conservation Program's budget for this project is $208,000 over the first three years, saving 289 acre-feet annually.

SAWS offers audits

SAWS recently issued a request for proposal for cooling tower audits in San Antonio. SAWS is first targeting 129 general class customers eligible for sewer credits due to evaporative loss, as the City of Houston has done. These 129 customers account for a combined monthly average consumption of more than 54 million gallons or about 1,992 acre-feet annually.

For purposes of estimating water savings. Ed Wilcut, SAWS conservation planner responsible for industrial programs, figures that if all 129 businesses increased from three to four cycles of concentration, SAWS could realize an annual savings of 239 acre-feet, or 12% savings. Cooling towers in San Antonio run between 2.5 and 4 cycles of concentration.

Wilcut estimated that there are as many as 500 cooling towers in the SAWS service area.

The cooling tower audit will provide the customer with a detailed engineer's report specific to that tower, including recommendations for more efficient operation for achieving water and energy savings, capture of blowdown water for reuse in other applications, and leak identification.

Agricultural Water Conservation

Two trends will create major implications for the future of rural Texas: decreased irrigation due to depletion of groundwater resources and increased demand for water resources by urban areas.

Irrigated agriculture has historically been the largest water user in Texas, accounting for almost 70 percent of water use during the past four decades. Irrigation water demand, however, is expected to decline by 12 percent in the next 50 years, and by 2040 municipal use of water is expected to surpass agriculture uses.[1]

Because of population growth and market forces, water will be drawn to higher-valued municipal uses. Well known are the efforts of water entrepreneurs who have been actively speculating in groundwater as a commodity in the High Plains and in south central Texas.

Agricultural water conservation can assist the state in meeting the water needs of its growing population while maintaining the productivity of the agricultural sector.

Rural areas and the agricultural community, with 15 percent of the state's population but 80 percent of the state's land area, are integral parts of the Texas economy as well as its culture. Total economic activity from agriculture brings $75 billion to the Texas economy, and 20 percent of the labor force is employed in agriculture-related business. In 1998, farmers used about 10.6 million acre-feet of water to grow crops on 6.3 million acres of irrigated land. It is worth noting that the financial impact of irrigated agriculture is more than twice that of nonirrigated agriculture. The past three drought years since 1998, however, have cost agriculture and its associated businesses $4.5 billion in direct losses.[16]

Agricultural water conservation can assist the state in meeting the water needs of its growing population while maintaining the productivity of the agricultural sector. A comparison of selected agricultural water-conserving practices is shown in Table 3 on page 30.

Recognizing the importance of the agricultural sector and the opportunities for increased conservation, stakeholder groups convened to discuss the draft 2002 State Water Plan recommended that the state develop policies to ensure the sustainability, viability, and competitiveness of agriculture.

In the final 2002 Texas State Water Plan, the TWDB proposed the legislature consider the following recommendations—

- Protection of rural community access to water resources to ensure continued economic viability of rural Texas.
- New financing mechanisms to support agricultural water conservation, especially to support the conversion of water saved to other uses.
- Determination of standards for evaluating impacts of water rights amendments and groundwater exports on third parties in rural Texas.

Methods of Achieving Irrigation Efficiency

Water conservation in irrigated agriculture can be achieved by irrigation scheduling, improved irrigation system efficiency, enhanced conveyance efficiency, conservation tillage practices, and economic incentives for irrigation suspension.

Irrigation Scheduling. An idea that originated in the High Plains, irrigation scheduling, has taken hold across much of the state. In the High Plains, farmers have found that, in highly efficient irrigation systems, high-frequency, shorter cycle deficit irrigation at 70 percent deficit irrigation (irrigating only 70 percent of replacement water determined by plant needs and potential evaporation) produces similar cotton yields to 100 percent potential evapotranspiration at shorter-period revolutions.[17,18]

By scheduling irrigation to closely match a crop's needs by using potential evapotranspiration data referenced to the crop, farmers can produce maximum yield per unit of water. Irrigation scheduling relies on networks of weather stations for evapotranspiration data, often referred to as "ET networks." To assist farmers with developing accurate irrigation schedules for their fields, four weather networks targeted to agriculture have been developed.

Of benefit to all farmers, evapotranspiration (ET) networks also enhance water management by urban landscapers, golf course superintendents, and even home gardeners.

Weather data from the 21 stations of the widest-ranging Texas ET[19] network (http://texaset.tamu.edu) can be accessed on the web site for weather information, evapotranspiration, and crop watering recommendations of the Agriculture Program of the Texas A&M University System.

Two other networks on the High Plains, one based in Lubbock and the other in Amarillo, have joined forces to operate more than 20 ET weather stations in the Panhandle. Each night, the networks automatically fax PET and other crop data to subscribers and post the data on the web site. Both networks use the same nationally standardized ET equation and crop coefficients.[19] Other networks rely on international generalized crop coefficients. Crop coefficients for specific crops are multiplied by reference ET to calculate crop water requirement.

The South Plains ET network can be accessed at http://lubbock.tamu.edu/irrigate/et/etMain.html. The North Plains ET Network can be accessed at http://amarillo2.tamu.edu/nppet/petnet1.htm.

A fourth network of 22 stations is based at the Corpus Christi Agricultural Research and Extension Center.

Irrigation System Efficiency. There is great potential to reduce the need for irrigation water by improving the systems used to deliver water to the plants. Two major variables affect irrigation system efficiency: application efficiency, a function of evaporation and runoff; and distribution uniformity, a function of the mechanics of the irrigation system.

Compelled by the incentive of lower operational costs and a favorable return on investment on equipment, Texas farmers continue to embrace new technology and best management practices to optimize the use of irrigation water. Farmers are able to adopt water-efficient practices using the constantly expanding universe of irrigation technologies.

In the High Plains, farmers are clearly aware of the need and the advantage of conserving—nearly every one of more than 16,000 center pivots use highly efficient technology with the sprinkler nozzles installed on drops closer to the ground. About 80 percent of new center pivots use this technology, which yields a 95- to 98-percent efficiency (figures 11 and 12). The primary hurdle of upgrading from a less-efficient irrigation system to an efficient one, of course, is the cost. The cost of installing a quarter-mile low-energy precision application center pivot sprinkler is about $35,000 to $40,000, with the return on investment a function of energy costs.

Figure 11. Low-energy precision application (LEPA) center pivot systems can achieve efficiencies as high as 95 to 98 percent.

The crop itself sometimes determines irrigation techniques. For instance, in the Lower Rio Grande Valley, where high-valued crops such as melons are produced, farmers find that using relatively costly drip irrigation and plastic mulch gets their product to market earlier and with better quality, therefore fetching a higher price.

Irrigation Conveyance Efficiency. Urban population in the Lower Rio Grande Valley is increasing at a higher rate than almost anywhere in the state, and is expected to grow by almost 230 percent in the next 50 years. Agriculture now

Figure 12. Furrow dikes retain water to allow more time for infiltration. Furrow dikes are an integral part of the low-energy precision application system.

accounts for nearly 90 percent of total water use in the region, but municipal and industrial use is expected to increase by 220 percent, or from almost 15 percent to 40 percent of total water use, according to Texas Water Development Board projections. Since water supply in the region is finite, some degree of transfer of water rights will be required.[20]

In the Lower Rio Grande Valley, virtually all water used is surface water. The 28 active irrigation districts deliver water to both farmers and to municipal water districts via a network of 1,460 miles of irrigation canals. In times of scarcity, however, the municipal interests have precedence.

A study by Texas Cooperative Extension determined that rehabilitation of Lower Rio Grande irrigation canals and laterals could save almost 160,000 acre-feet in a drought year and almost 211,000 acre-feet in a normal-rainfall year (figure 13).

Reducing conveyance losses could involve a combination of canal lining to reduce seepage, installation of nonleak gates, replacement of open canals with pipelines, and spill loss reduction. The average conveyance efficiency in the 28 districts is 71 percent.

Construction costs and water conserved under a similar program undertaken by the Imperial Irrigation District in California showed a range of $37 to $132 per acre-foot of water saved in 1988 dollars.

Conservation Tillage. Conservation tillage is a farming practice that leaves the stubble from the previous crop on the surface of the field. Plowing during the growing season is kept to a minimum (figure 14).

For generations, farmers tilled the soil at least 4 inches deep 9 to 11 times per growing season with plows powered by mules, oxen, or tractors. Conventional wisdom determined that plowing broke up the soil in preparation for the next crop. Using conservation tillage practices, the number of tillages would be halved, or less. The stubble acts as a mulch to retain moisture to keep the soil cooler, to inhibit weed growth, and to lessen the erosive effects of rainfall and wind erosion. More organic matter gives better soil permeability and water holding capacity.

Conservation tillage has been shown to save one irrigation per growing season.

One test of conservation tillage near Corpus Christi by Texas Agricultural Experiment Station researchers showed a 37-percent increase in cotton yield over a conventionally tilled field.

Plant Breeding

Researchers worldwide are studying plant–water relations at several scales to develop crop varieties that stand up to water deficit. It has long been known that crop cultivars vary in their ability to produce under limited water supply. Texas has the technology and scientific personnel to increase drought-tolerance and water-use efficiency in its major crops: cotton, corn, sorghum, and wheat. Drought tolerance is the ability of the plant to

Figure 13. Improvements to canals such as this one in the Lower Rio Grande Valley will mean a net increase in available water due to lessened conveyance losses.

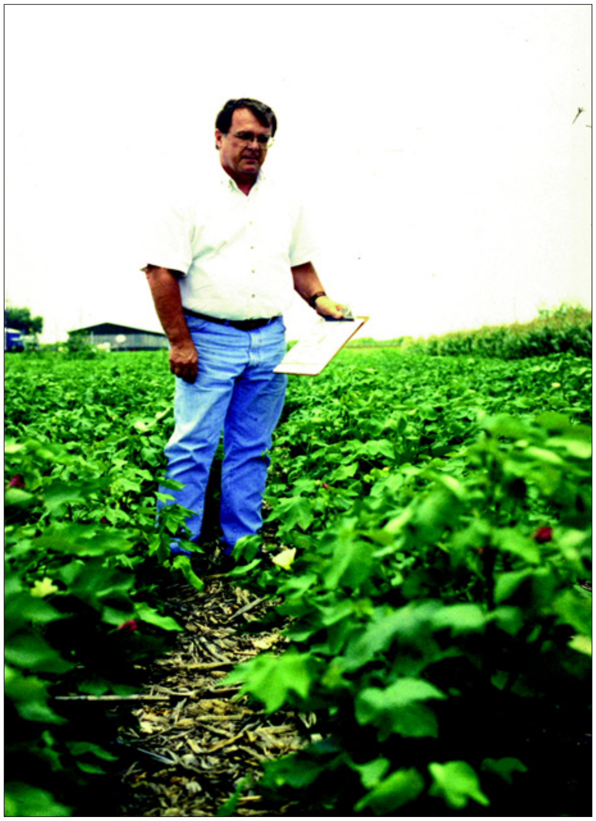

Figure 14. Conservation tillage beats plowshares. Conservation tillage, which residual from a previous crop serves as mulch, has proved more water-efficient than traditional tillage on cotton, corn, and grain sorghum. Shown here is Joe Bradford of the Agricultural Research Service in Weslaco.

recover from a period of low irrigation. Water-use efficiency refers to the crop's ability to produce under a regime of deficit irrigation. Plant breeders create hardier cultivars by finding existing plants with drought-tolerant or efficient water use mechanisms, then introducing these traits into crop varieties.

A coordinated effort to identify and breed cultivars better adapted to low water supply could have enormous economic benefit for relatively minor additional investment in support personnel, equipment, and operating expenses.

Financial Incentives

Due to the fact that agriculture is a business, the bottom line is the most compelling reason for farmers to reduce water use. In the case of groundwater, if less water is pumped, less fuel and operational and maintenance costs are incurred. Because agricultural water conservation can make water available to people and the environment, State support for conservation practices is appropriate.

Loans for water-conserving farm equipment. The Texas Agricultural Finance Authority was created in 1987 as a unit of the Texas Department of Agriculture to provide financial assistance through lending institutions to producers and providers of goods and services in rural areas. The Linked Deposit Program provides commercial loans at below-market rates of up to $250,000 for water-conserving equipment or projects.

The Texas Water Development Board grants water districts up to 75 percent of cost toward the purchase of equipment to evaluate or demonstrate efficient agricultural water uses on private property. The Board also loans funds to districts for purchase and installation of water-conserving equipment on private property.

Market-Based Incentives

Dry year option. Irrigation suspension programs offer an economic mechanism for temporarily shifting water from agricultural use to higher-valued uses. In this set-aside program, farmers are offered compensation for abstaining from irrigating crops in dry years. Depending upon the stage of the growing season when the dry-year option is offered, farmers can pursue several alternative courses of farming practices. Early in the season, crop mixes can be changed to more drought-tolerant crops. Later, crops can be abandoned or managed using deficit irrigation or dryland farming techniques. Because water shortages are an intermittent event, utilizing dry year options as part of standard drought contingency plans can be a much more cost-effective way of meeting water needs than building new reservoirs.

Irrigation suspension programs. The optimal application of water marketing would provide a means for cities to provide financial assistance for agricultural water conservation. The farm would remain in production, and the cities would acquire the saved water. Some portion of the saved water could be left in the stream to provide environmental flows. In some Western states, the water rights are transferred in perpetuity. There exists, however, a need for short-term transfers, such as irrigation suspension programs, due to the fluctuation of water supply and the unpredictability of drought year

The Edwards Aquifer Authority implemented a pilot irrigation suspension program in 1997 on nearly 10,000 acres in Medina and Uvalde counties with the objective of increasing springflow at Comal Springs and providing relief to municipalities during drought. Although 1997 turned out to be a wet year, based upon calculations with historic pumping rates, had conditions been dry in 1997, suspending irrigation on acreage would have reduced pumping by 23,206 acre-feet at a cost of about $99 per acre-foot. This relatively high price might be due to several factors, including lack of experience with an irrigation suspension program, late start-up, tendency to bid high enough to compensate for a worst-case scenario.[21,22,23]

Education and Outreach

The Texas A&M University System (TAMUS) Agriculture Program transfers knowledge to the producer. Dedicated to a 125-year land-grant responsibility, the TAMUS Program has been serving the agricultural community by distilling research results for efficient water use technologies into practical real-world applications, delivered by a wide-ranging network of county extension agents.

County agricultural extension agents and extension specialists transfer new knowledge and technology on more efficient cropping to producers with annual field days, on-farm and pilot demonstrations, seminars, conferences, television and radio broadcasts, and newspaper columns. Research and extension activities take place at 14 research and extension centers, in 250 county offices, and in 12 district centers. Each year, Texas Cooperative Extension makes more than 17 million educational contacts.

For instance, Texas produces more cotton than any other state, but this abundance is due to a vast land resource. Limited seasonal rainfall and groundwater reduce yields to among the lowest in the country. TAMUS Agriculture Program researchers are investigating ways to increase cotton yield, such as more efficient irrigation scheduling technology, subsurface drip irrigation and low-energy precision application center pivots, drought-tolerant crop germplasms, and improved cropping techniques.

County agents in Pecos County installed a demonstration plot showing an improved cropping technique at a privately-owned farm. Yields at the demonstration plot indicated that highly efficient subsurface drip irrigation system and cotton planted at ultranarrow row spacing produce the same yield with 45 percent less water in this particular study (figure 15).

Figure 15. Cotton farmers in Pecos County tour a demonstration field planted with various row widths and planting patterns. Ultranarrow row showed better yield than wider-spaced rows in this study at a demonstration plot.

Many variables—soil type, climate, irrigation techniques, cultivation practices—affect water savings, so it is worth noting that results of studies are site-specific.

Local cotton growers are invited to tour the demonstration plots at the Fort Stockton Agricultural and Extension Center's annual fall crops tour.

Texas farmers embrace proven technologies and methods to effect water conservation. Ongoing research will continue to boost productivity using less water. On the horizon are advances in precision agriculture: interpreting satellite imagery to make irrigation decisions; drought-tolerant plant germplasms; and radio- or telephone-controlled automated irrigation systems.

While Texas has made important strides in researching agricultural conservation opportunities, providing outreach and education services, and instituting agricultural loan programs, the full potential for water savings has yet to be realized.

Conversions

1 acre-foot	325,851 gallons
1 million gallons	3.07 acre-feet
1 acres	43,560 square feet
100 cubic ft	748 gallons
1 million gal./day	1,121,000 acre-feet/yr

1,000 square feet of collection area yields 625 gallons/inch rainfall

Table 3. Water savings from selected agricultural conservation practices, Texas cotton[1]

Agricultural Practice	Capital cost	Effective efficiency [2,3,4]	Volume of water saved	Cotton acres potentially irrigated with conserved water
	$/acre	%	acre-feet	acres
Microirrigation	$800-$1,500	97	925,000	1,381,000
Low Energy Precision Application, deficit irrigation	$325-375	95	893,000	1,305,000
Surge valve furrow irrigation	$800-$2,000	75	485,000	560,000

[1] From National Agricultural Statistical Service, in 2001, 2,238,000 irrigation acres of Upland cotton in Texas.

[2] From Amosson, et al, *Economics of Irrigation Systems,* Texas Cooperative Extension, December 2001.

[3] Effective efficiency is defined as the volume of irrigation water beneficially used/volume of irrigation water applied x 100.

[4] Water savings calculated using microirrigation as the standard.

Note: Water savings quantities are for illustrative purposes only. It is difficult to derive accurate agricultural water savings as no single data base exists with the necessary information, no statewide records are kept on the irrigation types used on farms, and there are no statewide figures on actual water consumption on an on-farm basis. Also, the water savings from the table are not additive; if a farmer were to implement microirrigation, he would not also implement LEPA.

Irrigation district swaps water rights for rehab

As project manager for the City of Roma Economically Distressed Area Program (EDAP), a Texas engineering firm, Turner Collie & Braden, found an innovative solution to the city's water needs. The engineering firm proposed that the $2.8 million available to the City of Roma through EDAP to purchase water rights be instead used to fund improvements in irrigation canal conveyance efficiency within Cameron County Irrigation District No. 2. The irrigation district could then transfer approximately 4,100 acre-feet of "saved" agricultural water rights to the City of Roma.

The City of Roma needed major improvements to its water and wastewater facility to bring its system into compliance with state standards, to provide service to the residents of existing colonias, and to meet future needs. Overall, the planned improvements would serve approximately 20,000 people. TWDB financing for the planned improvements was contingent upon the City of Roma acquiring additional water rights sufficient to meet project demands. (Colonias are economically distressed subdivisions lacking state-approved water supply and wastewater collection systems.)

Since irrigated agriculture is a major component of the economy of the Lower Rio Grande Valley, it was important to maintain supplies needed for agriculture while making additional water rights available for conversion to municipal and industrial uses.

This exchange of "conserved" water satisfied the city's need for more water without impacting agricultural irrigation water. In fact, rehabilitating irrigation canals would save about 4,900 acre-feet annually, leaving the district with a net gain of approximately 800 acre-feet per year. Through conservation, agricultural land was not taken out of production to sell water rights.

Legislative remedies

• Senate Bill 1, the omnibus water planning bill passed in 1997, requires that reuse be considered in all future water resources planning and that addresses certain water rights issues relating to reuse. This legislation mandated that alternative water strategies, such as desalination and weather modification, be considered as part of the state's water management policy.

• Senate Bill 1 also expanded the sales tax exemption for pollution control equipment to include water-conserving equipment for manufacturers.

• Senate Bill 1 allows the Texas Water Development Board to use principal from the Agriculture Trust Fund to provide financial incentives and/or low-cost loans for the installation of water-conserving devices.

• Senate Bill 2 establishes a framework for supporting alternative water strategies, such as desalination, brush management, weather modification, and water conservation and drought management projects.

• Senate Bill 2 offers a sales tax break on equipment whose primary function is water conservation, including rainwater harvesting equipment, equipment for water reuse, conservation, and desalination.

• Senate Bill 2 also expands the list of water rights that cannot be canceled for nonuse due to water conservation. If an entity reduces water use due to conservation, that portion of reduced use cannot be cancelled under the use-it-or lose-it cause under water rights.

• The revision of Texas Commission on Environmental Quality water reuse rules under Chapter 30 Texas Administrative Code (TAC) 210 to allow utilities and industries to provide water for reuse without having to amend wastewater discharge permits.

• Development of rules in 30 TAC 285 governing on-site wastewater treatment systems that allow for reuse.

• HB 2401 adds water conservation to the types of projects local governments can enter into; for example, the Education Code is amended to allocate incentive funding for achievement of water conservation goals by institutions.

• HB 3286 makes water conservation projects eligible for performance contracting as a separate item by extending existing legislation pertaining only to energy conservation. In a performance contract, a company enters into an agreement with an entity to provide up-front capital to pay for improvements resulting in water or energy savings. The company is paid back out of the revenue stream based on conservation savings.

• HB 2403 again piggybacks water conservation on energy-related legislation, requiring clothes washer manufacturers to report to Texas Commission on Environmental Quality each year beginning in 2003. Water savings are achieved via energy savings, in that heating less water will result in decreased energy use.

• Chapter 210 TAC regulates the quality, end use, restrictions, design, and operational requirements for the beneficial use of reclaimed water, which may be substituted for potable or raw water..

Financial Incentives

• HB 2404 specifies that all new construction of multifamily after January 1, 2003 be submetered by unit. Properties applying for a TCEQ permit to allocate water (by apartment size or number of tenants) or to submeter after that date would have to be audited for leaks, to install low-flow showerheads and faucet aerators, and must replace the highest-volume toilets.

• In 1997, Texas voters approved an amendment to the Constitution authorizing taxing entities to grant exemptions from ad valorem taxes on water conservation equipment (30 TAC 17). This amendment gives political subdivisions the option to decide whether the benefits from the water conserved by the equipment would be more beneficial than the forgiven tax revenue.

• Equipment for water reuse is eligible for exemption from property taxes under a constitutional amendment effective January 1, 1994, now in the rules as Chapter 30 Texas Administrative Code. The intent of the amendment was to ensure that compliance with environmental mandate did not increase a facility's property taxes.

• Water conservation equipment. Equipment for water reuse is eligible for exemption under Title 30 TAC 277.

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Prepared by Texas Water Resources Institute,
Texas Agriculture Program with funding
from a grant from Environmental Defense.
September 2002