Counting on Quality of Place
Water Quality, Green Buildings & Water Supply

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Cover photo by: Justin Bower

Acknowledgments

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Thank You

Executive Summary

The Center's Renewed Commitment

The Center for Houston's Future, with the help of many colleagues, presents the third report in a series of peer-reviewed quality-of-place report cards. *Counting on Quality of Place: Water Quality, Water Supply & Green Buildings* (2010) gives a snapshot of where the Houston eight-county region stands in relation to these critical areas.

In December 2007, the Center for Houston's Future, in its original publication, *Counting on Quality of Life: An Environment Indicator Report*, made a promise to monitor and report on essential regional sustainability indicators. The driving objective behind the report's publication is that reliable, longitudinal data must be made available to citizens, business leaders, and elected officials in order to facilitate good public policy decisions about our future.

The 2010 Report builds on the original framework developed in the 2007 benchmark study. Two of the nine indicators included in that first study, water quality and green buildings, are updated in this report. The chapters on water supply and water & health represent new areas of data collection. *

This edition includes a new chapter, "Policy Analysis and Implementation," which places public decision making in context. Prepared by the Hobby Center for Public Policy at the University of Houston, it offers an important tool for those concerned with managing limited resources and understanding the tradeoffs inherent in policymaking. It summarizes academic thinking on the issue, including work by 2009 Nobel Laureate and author Elinor Ostrom, and provides valuable concepts to use in water management.

Just as the production of this report would not have been possible without the expertise of our many partners, the solutions to these sustainability challenges also require a collaborative approach. For this reason, the Center for Houston's Future convenes a regular Counting on Quality of Place Symposium to engage all stakeholders in the region's progress. It is hoped that both this published report and the event itself will foster collaboration across multiple sectors.

Why track sustainability indicators? ***Sustainability is meeting the needs of the present generation without compromising the ability of future generations to meet their needs.*** The region's continuing population growth will challenge efforts to maintain and enhance the region's quality of place. Houston's business community has contributed to a thriving economy, which has in turn attracted increasing numbers of newcomers. Today college graduates stress quality of place when making decisions about jobs. Economic progress now requires the preservation and enhancement of natural assets. This report advocates a "three-legged stool" definition of sustainability, one based equally on social, environmental, and economic considerations.

A Regional Perspective

The 2010 Report documents progress on important issues in the eight-county region. Since publication of the 2007 Report, the Center has called on existing organizational resources to expand data collection beyond the initial Harris County focus. The 2009 Report, *Counting on Quality of Place: Air Quality, Parks & Trails, and Trees*, provided detailed information from Fort Bend and Montgomery, as well as Harris, Counties.

*The initial 2007 Report created indicators for the following topics: air quality, billboards, litter & graffiti, parks & trails, tax delinquent/abandoned lots, trees, water quality, and resource use.

At a Glance: 2010 Regional Findings

What is the State of Water Quality?

In the Clean Rivers Program watersheds of the 13-County H-GAC Region, 87% of the classified water bodies were impaired by 2010, an increase of 6% from 2007 when 81% were impaired. Although the causes vary, bacterial contamination from wastewater treatment plants, septic systems, wildlife, and urban and agricultural runoff constitute the most significant water quality problems. Since the publication of the 2007 Report, the number of failed streams has increased.

The current bacteria levels in Galveston Bay exceed allowable levels for oyster harvest, leading to a closure of almost half the bay and threatening a $10 million/year industry. Furthermore, the beaches and parks along the banks of the region's waterways provide recreational opportunities, and they support the $8.6 billion tourism industry, responsible for more than 100,000 jobs. Given the anticipated population growth and increased land use, without significant investments in infrastructure, the region's water resources will be severely strained.

What is the State of Water Supply?

This chapter presents new data not previously covered in the *Counting on Quality of Place* Reports. It addresses the water supply issues that the region will face because of the rapid increase in population expected during the next 40-50 years. To accommodate the projected growth, it is estimated that a supply of at least an additional 1,150,000 acre-feet/year of water (about 1 billion gallons of water per day) over and above what is used today will be required, to be obtained primarily from surface water. There appears to be sufficient water available, but three major challenges stand out.

The first is the need to continue the Houston region's transition from groundwater to surface water because of subsidence concerns. Within the Harris-Galveston Subsidence District (HGSD), groundwater pumpage must not exceed 20% of the total water supply within the next 20 years, and no more than 40% within most of Fort Bend Subsidence District (FBSD).

Second, according to the Region H Plan, a substantial investment in infrastructure will be needed, on the order of $13 billion, largely to be paid by user fees.

Third is the challenge of balancing human needs with the needs of the ecosystem that ultimately sustains human life. Some tradeoffs, perhaps involving considerable conservation efforts, will be inevitable. Consumers have not yet been asked to pay the true cost of water. There is ample opportunity for substantial water savings from conservation practices without causing noticeable lifestyle shifts. For those opportunities to be realized, both an informed public and a strategic set of incentives will be necessary.

What is the State of Drinking Water & Public Health?

This illustration shows the influence of water supply and water quality on health.

Source: Vincent Nathan, Ph.D., Texas A&M University

The condition of drinking water in the eight-county region generally meets or exceeds federal and state regulations and is considered excellent for community systems. Because of concerns about the national and international incidence of water-borne diseases, however, it is important for this report to examine for the first time the health implications of the region's drinking water. Sources of water contamination that are of particular concern include: surface water (lakes and rivers), water treatment systems, production systems (wells) from groundwater, and an aging water infrastructure.

Information on these issues is incomplete because many of those who get sick are not aware that water may have caused their disease. For this reason, the chapter recommends the development of a tracking or surveillance system for gastrointestinal illnesses in the eight-county region. Further, water quality indicators suggest that portions of the region are in noncompliance for recreational and seafood consumption. This is also a public health concern. Thus, the chapter recommends more effective education and outreach programs regarding water warnings and postings, especially in connection with seafood consumption.

What is the State of Green Buildings?

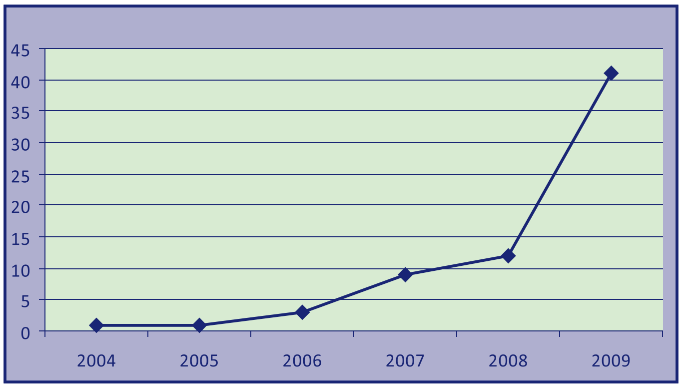
As of April 2010, the greater Houston region had a total of 78 green-certified buildings, up from 5 in 2007, when the Center for Houston's Future issued its first Indicator Report. Of all the major cities in the United States, this region now ranks third in the nation for the number of green buildings.

For this Report, the United States Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) rating system is used to define and measure green buildings. Energy-efficient buildings are hugely important for their impact on the environment. They can reduce energy consumption by as much as 50%, $CO2$ emissions by 35%, water consumption by 40%, and the waste stream into landfills during construction by 50-75%.

The growth in LEED certifications has been driven by the market. The role that governmental activity can play is perhaps best exemplified by the City of Houston and NASA, which are leading by example. Not surprisingly, most of the region's green buildings are located in Harris County.

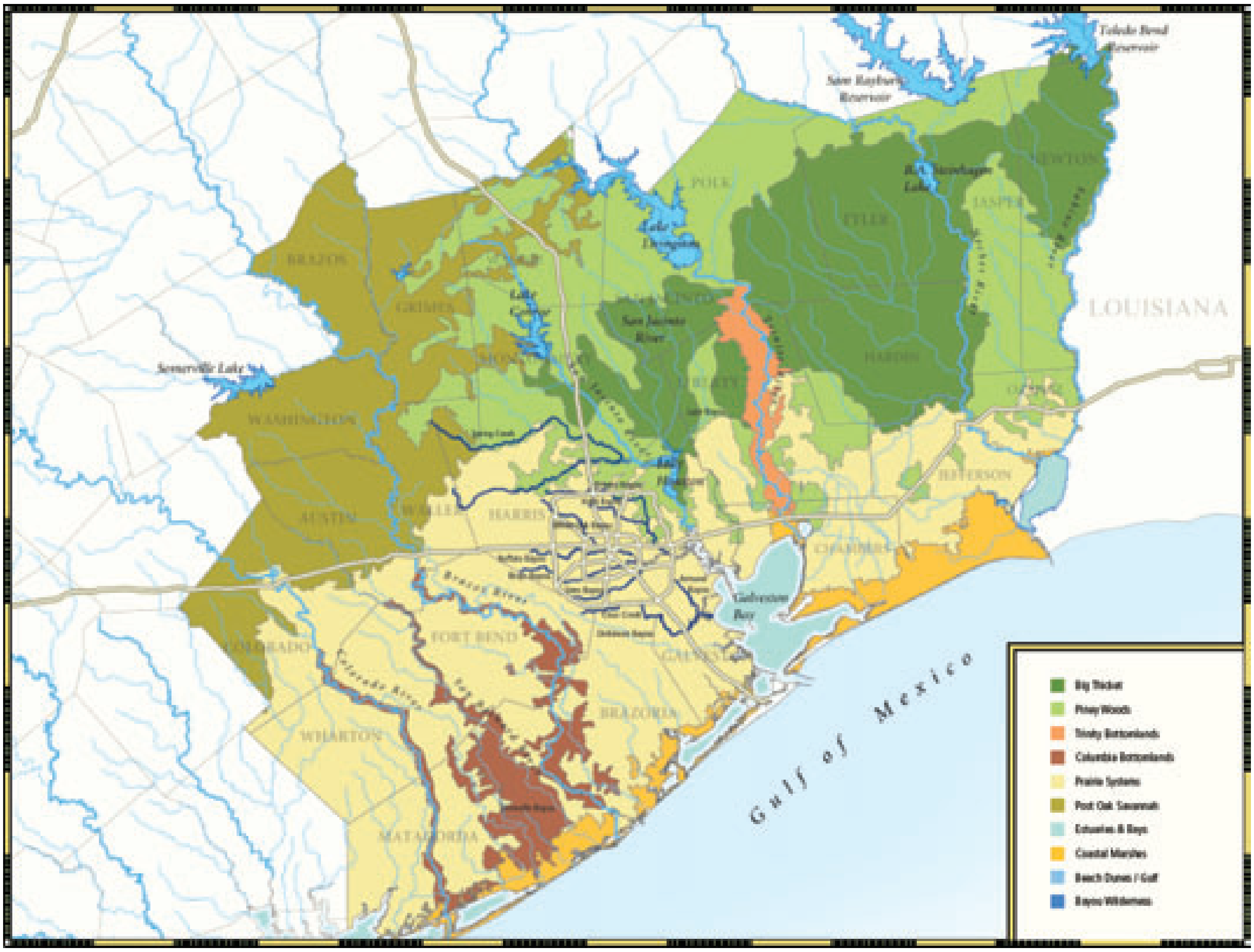
The graphic below demonstrates the dramatic increase in the number of LEED-certified buildings in the Houston Region.

Total LEED Certified Buildings Per Year



Source: USGBC

Ecology of the greater Houston region



Source: Houston Wilderness, Jim Blackburn

Water Quality

Author: Kevin Wagner, Associate Director, Texas A&M Water Resources Institute

Executive Summary

The Greater Houston region is surrounded by valuable water resources that affect its economic well-being, health and quality of place. In the Clean Rivers Program watersheds of the 13-County H-GAC Region, 87% of the classified water bodies were impaired by 2010, an increase of 6% from 2007 when 81% were impaired (Figure 1). Although the causes vary, bacterial contamination from wastewater treatment plants, septic systems, wildlife, and urban and agricultural runoff is the most significant water quality problem[13]. As a result, most streams are unsuitable for swimming. In addition, elevated nutrients affect 74% of the waterways, and 27% have low levels of dissolved oxygen which harm fish and other aquatic organisms[13].

Galveston Bay is characterized as having good water quality. Since the 1970s nutrient levels have improved due to the success of wastewater permitting[15]. From 2003-2006, the number of samples exceeding beach advisory criterion for bacteria in Galveston and Brazoria Counties steadily increased, but has declined since 2006. All five sub-bays are currently rated good for bacteria for contact recreation. However, bacteria levels exceed allowable levels for oyster harvest, leading to a closure of almost half the bay, threatening a $10 million/year industry. Between 2003-2008, 2.8% of the 386,329 acres of shellfish harvesting area was lost to increased bacteria[11]. Overshadowing this situation is the loss created by Hurricane Ike, which buried approximately 60% of the oyster reef in sediments. Until the reefs recover, commercial oyster harvesting in Galveston Bay will suffer[33].

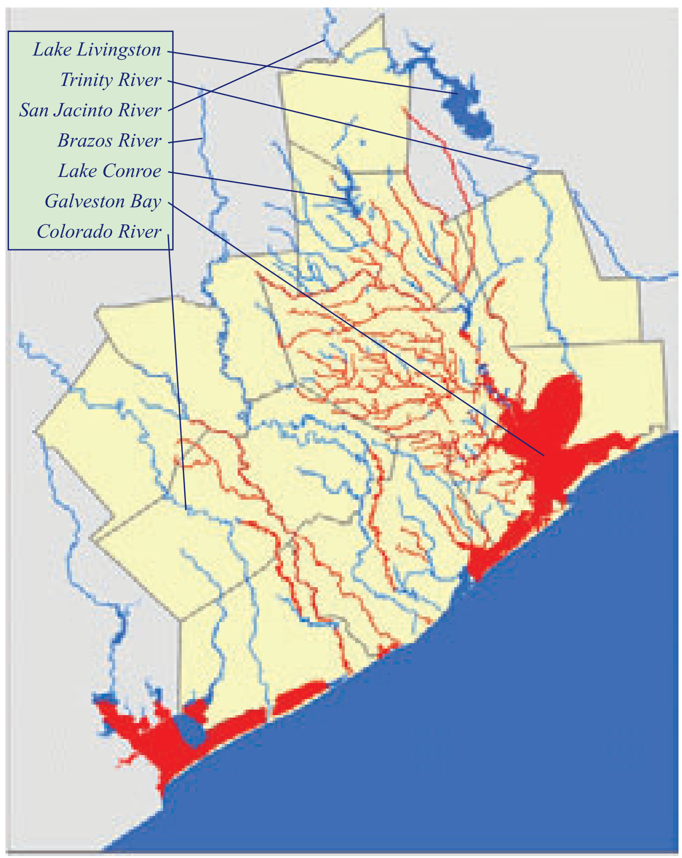
According to TCEQ, the number of permit violations for the region's water quality peaked in FY05-06 and has declined since[32]. The number of fish kills and spills reported to the Texas Parks and Wildlife Department (TPWD) steadily increased from the 1970s through the early to mid-1990s. However, since then, the number of fish kills and spills has declined, indicating some water quality improvements.

Dioxins (the most toxic man-made organic chemical, second only to radioactive waste), poly-chlorinated-bi-phenyls (PCB – highly toxic; banned in 1979, difficult to degrade), mercury (poisonous) and zinc (causes neurological deficits and growth retardation) continue to be serious problems in many of the bays, estuaries, and tidal sections of the rivers, creeks and bayous. Fish, contaminated primarily by dioxin and PCBs, is a problem in 75% of the tidal waterways, particularly the Houston Ship Channel, Clear Creek and Galveston Bay.

Although contamination exists in some shallow groundwater, the water from the Chicot and Evangeline aquifers is of relatively high quality. Most commonly reported contaminants come from petroleum storage tanks. In a small percentage of wells, contaminates such as arsenic and radionuclides also exceed water standards. In addition, many parts of the Chicot and Evangeline Aquifers are becoming increasingly salty and unusable[2].

Figure 1

Impaired water bodies, shown in red, on Texas 303(d) List13



Source: H-GAC

While some progress has been made, especially with regard to permitted point sources, many challenges remain. Aging wastewater infrastructure and nonpoint source runoff from yards, streets and agricultural fields are major challenges. With population growth and land use changes, the region's water resources will be strained severely without huge infrastructure investments. Continued coordinated regional planning, adaptation to new ideas, alertness to new sources of contamination, vigilance about implementing point and nonpoint source measures, improvements in understanding water resources and public education of new findings will be required. It is only by working together that the region's waters can become healthy, ensuring they provide sustenance and enjoyment for generations to come.

Why is water quality important to quality of place?

Water is life sustaining. It defines the region and supports major portions of its economy. It is everywhere, from the San Bernard River to the Trinity River, and from Galveston Bay and the Gulf of Mexico to Lake Conroe. Two of the state's largest rivers, the Trinity and Brazos, end their journeys to the Gulf here. The region's ports fuel much of the economy. Other rivers, such as the San Jacinto River, help define our state's history and now provide much of the drinking water through Lake Conroe and Lake Houston. The beaches and parks along the banks of these waters provide recreational opportunities and support the $8.6 billion tourism industry, providing more than 100,000 jobs[34]. Moreover, the region's bays sustain a $77 million fish and seafood industry creating 1,385 jobs (2007[34]). The region's bayous and streams contribute mightily to flood control and produce other immeasurable ecological benefits. Water resources are essential for a healthy environment, quality of place, and continued economic growth. Preserving these resources is essential.

Water is also under us. The region sits atop the Gulf Coast Aquifer system. Much of the area once relied on this aquifer system, especially the Chicot and Evangeline aquifers, for drinking water, but land subsidence forced a switch from ground water to surface water. This change did not come without a price; water bills increased because surface water required purification. The cost of purifying water for drinking or industrial use is significant.

The value of water to municipal and industrial users is commonly overlooked. According to a 2005 Texas Water Development Board (TWDB) report municipal and industrial (M&I) water uses support 99% of economic activity in Region H, the state water planning area for the greater Houston region. In 2000, M&I water users generated $407.9 billion in sales, provided $199 billion in salaries for area residents, added nearly $19.8 billion in state and local taxes, and provided more than 2,966,000 jobs in the region[29].

Galveston Bay is one of the area's and the country's greatest water resources with enormous recreation and economic impacts, measuring in the billions of dollars. The Bay depends on the water quantity and quality that enters it from the streams and bayous. The Bay boasts:

- The second most productive fishery in the United States*
- More oyster production than any other estuary in the nation*
- The largest commercial harvest of blue crabs of any Texas estuary
- One-third of Texas' commercial fishing revenue
- More than one-half of Texas' recreational fishing revenues
- The 2nd highest concentration of recreational boats in the nation
- Forty percent of the nation's petrochemical production
- The 2nd largest port in the United States[6]

Galveston Bay has a tremendous impact on the region's economic well-being, health and quality of life. Keeping it and all other waters healthy is vital to ensure the sustainability of this region.

* until Hurricane Ike

What are the community goals?

In general, goals are to protect the region's water resources, improve water quality and ensure the quality of habitats and estuaries[12].

These goals are consistent with the Clean Water Act: that the region's waters meet water quality standards and are fishable and swimmable (Appendix A). By achieving these goals, the community will protect human health, recreation, aesthetics and the economy as well as support the needs of fish and wildlife.

Water quality must be such that water is safe for swimming, wading and other recreational activities; treated surface water and groundwater is safe to drink; and, fish and shellfish are free from substances harmful to human health. To achieve this, bacterial infectants must be reduced to acceptable risk levels and PCBs, dioxin, bacteria and pesticides must be reduced to protect fish and shellfish harvesting.

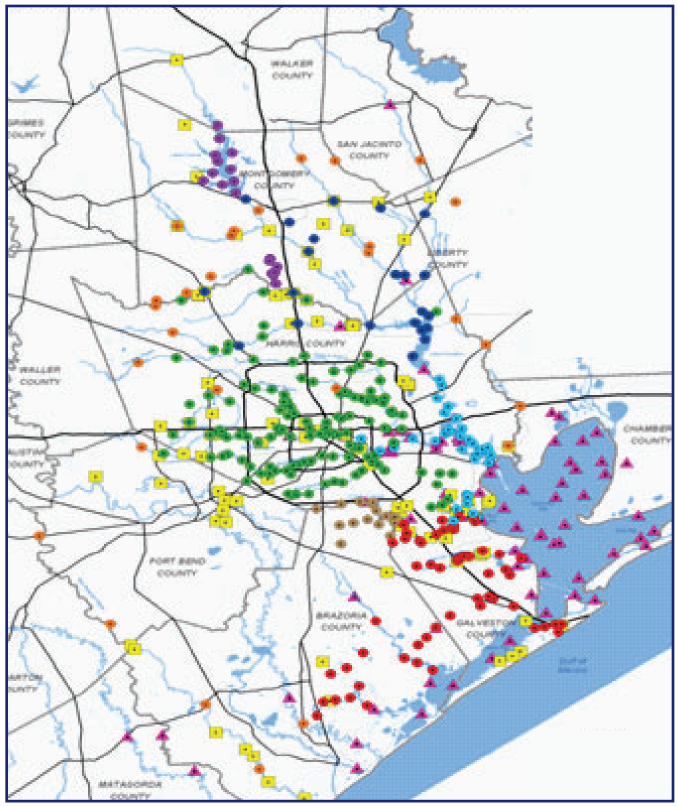
How can we measure progress?

Several important metrics have been developed to evaluate water quality status and trends and to determine how it affects the use of the waters, including:

- Water body status on Texas Integrated Report for Clean Water Act §305(b) and 303(d)
- Water quality trends
- Performance of wastewater plants in the region
- Number of beach advisories*

The greater Houston region is one of the most intensively monitored regions in the state. Surface water quality is monitored by seven local agencies and TCEQ at more than 370 sites (Figure 2). Appendix B is a description of each agency and its responsibility.

Figure 2
Water Quality Monitoring Stations



Source: H-GAC

* for statistics, see Appendix C

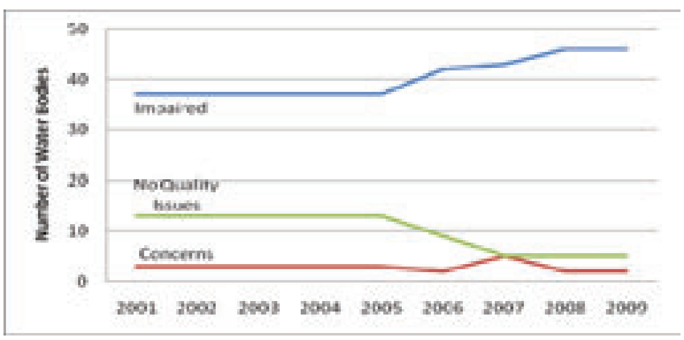
What is the current situation?

In the Clean Rivers Program watersheds of the 13-county H-GAC region, 87% of the classified water bodies were impaired by 2010, an increase of 6% from 2007 when 81% were impaired. Although the causes vary, bacterial contamination is the most significant water quality concern[13]. Only six water bodies - Lake Creek, Chocolate Bayou above Tidal, Oyster Creek Tidal, Bastrop Bay/Oyster Lake, Christmas Bay, and Drum Bay - are free of impairments and acceptable for contact recreation.

Elevated levels of nutrients are in 74% of the region's waterways; 27% have low levels of dissolved oxygen which harms fish and other aquatic organisms[13]. Since 2005, the number of impaired classified water bodies in the Clean Rivers Program watersheds of the 13-county H-GAC Region has steadily increased. Between 2007 and 2009, the number of impaired classified water bodies has increased from 43 to 46.

Figure 3

Number of Classified Water Bodies Impaired, With Concerns, and With No Water Quality Issues[13]



Source: H-GAC

Water Quality Trends

Since 1995, studies report that despite the impairments, Galveston Bay has relatively good water quality in open bay segments. Water quality problems primarily occur in the western, urbanized tributaries. In general, the water quality in these areas has shown substantial improvements; however, localized problems remain[8, 11, 15, 16].

Although 74% of water bodies in the region have nutrient concerns[13], nutrient levels have improved in Galveston Bay since the 1970s, due to the success of wastewater permitting[15] and monitoring. These lower nutrient levels reduce the probability of algal blooms and dissolved oxygen depletion.
Dioxins, PCBs, mercury and zinc continue to be serious problems in many of the region's bays, estuaries, and tidal sections of the rivers, creeks and bayous entering them. This is particularly true in the Houston Ship Channel (Figure 4 & Figure 5). However, improvements have been observed and most bays are now rated good or very good for heavy metals and organic pollutants in sediment[11].

All five sub-bays are currently rated good for contact recreation in terms of bacteria (Figure 6); however, as discussed in the previous section, bacterial levels in bay tributaries are the most significant water quality concern. Most bay tributaries are rated moderate or poor for bacterial contamination with the exception of the Galveston Channel, Texas City Channel and Trinity River which are rated good[11].

Figure 4a

Heavy metals in sediment 1970s vs. 2000s[11]

	1970s	2000s
Christmas Bay Complex	Good	Good
West Bay	Good	Very Good
East Bay	Very Good	Very Good
Upper & Lower Galveston Bay	Good	Very Good
Trinity Bay	Very Good	Very Good
Houston Ship Channel	Moderate	Moderate

Houston Ship Channel:

	1970s	2000s
Arsenic	Very Good	Very Good
Cadmium	Moderate	Very Good
Chromium	Good	Good
Copper	Good	Good
Lead	Poor	Good
Mercury	Moderate	Poor
Nickel	Good	Good
Silver	Poor	Good
Zinc	Poor	Poor

Rating	Percentage of Samples Above Marine Probable Effects Level
Very Good (blue)	0
Good (green)	1-9
Moderate (yellow)	10-25
Poor (red)	>25
Not enough data (open circle)	

Figure 4b

Organic pollutants in sediment 2000s[11] *vs. 1970s*

Industrial Organics	1970s	2000s
Christmas Bay Complex	Not enough data	Not enough data
West Bay	Not enough data	Not enough data
East Bay	Not enough data	Not enough data
Upper & Lower Galveston Bay	Not enough data	Very Good
Trinity Bay	Not enough data	Not enough data
Houston Ship Channel	Moderate	Poor

Houston Ship Channel → PCBS: Poor

Semivolatile Organics	1970s	2000s
Christmas Bay Complex	Not enough data	Very Good
West Bay	Not enough data	Very Good
East Bay	Not enough data	Very Good
Upper & Lower Galveston Bay	Not enough data	Very Good
Trinity Bay	Not enough data	Very Good
Houston Ship Channel	Good	Poor

Houston Ship Channel:

Compound	Rating
1,2,5,6-Dibenzanthracene	Moderate
Acenaphthene	Poor
Acenaphthylene	Poor
Anthracene	Poor
Benzo-a-anthracene	Moderate
Benzo-a-pyrene	Moderate
Chrysene	Poor
Fluoranthene	Poor
Fluorene	Poor
Naphthalene	Moderate
Phenathrene	Poor
Pyrene	Poor

Organic Pesticides	1970s	2000s
Christmas Bay Complex	Very Good	Not enough data
West Bay	Very Good	Moderate
East Bay	Very Good	Very Good
Upper & Lower Galveston Bay	Very Good	Very Good
Trinity Bay	Not enough data	Very Good
Houston Ship Channel	Moderate	Good

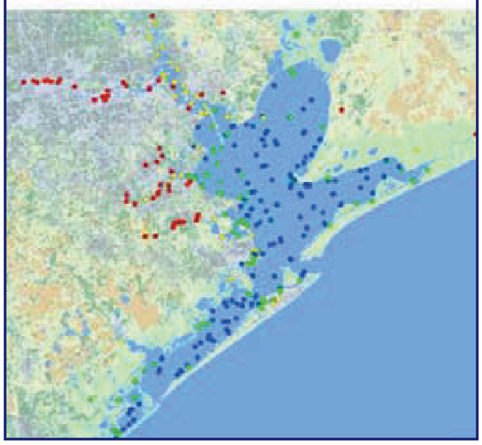
West Bay → Lindane, Chlordane, Dieldrin, DDT: 2 samples of lindane and chlordane out of 16 total samples exceeded the Marine PEL

Source: HARC

Figure 5

Bacterial contamination in 1970s vs. 2000s[11]

Rating	% Above Screening Level
Very Good (blue)	0
Good (green)	1-9
Moderate (yellow)	10-25
Poor (red)	>25
Not enough data (open circle)	

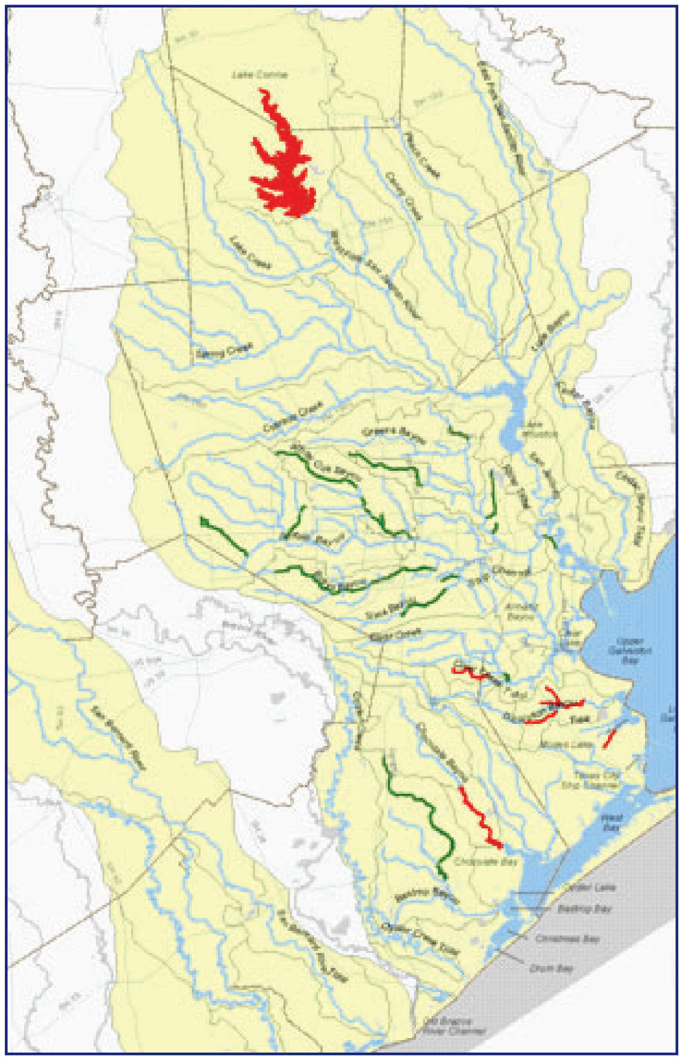


	1970s	2000s
Christmas Bay Complex	Very Good	Good
Bastrop Bayou	Poor	Moderate
West Bay	Good	Good
Chocolate Bayou/Bay	Good	Moderate
Galveston Channel	Moderate	Good
Texas City Channel	Good	Good
East Bay	Very Good	Good
East Intracoastal Waterway	Good	Moderate
Oyster Bayou	Not enough data	Moderate
Upper & Lower Galveston Bay	Good	Good
Dickinson Bayou/Bay	Moderate	Poor
Clear Creek	Poor	Poor
Armand Bayou	Poor	Poor
Houston Ship Channel	Poor	Poor
Buffalo Bayou	Poor	Poor
San Jacinto River	Moderate	Moderate
Cedar Bayou	Poor	Poor
Trinity Bay	Good	Good
Trinity River	Moderate	Good

H-GAC data indicate that outside of Galveston Bay, little change has occurred between 2000 and 2010 in the levels of ammonia, chlorophyll, dissolved oxygen, E. coli (may cause severe anemia and kidney failure), Enterococci (may cause serious infections), nitrate, nitrate + nitrite, orthophosphate, and total phosphate (Appendix C). Recently White Oak Bayou, the Houston Ship Channel and the Buffalo Bayou Tidal segment have shown improvement. A 75% reduction in bacterial levels has been observed in White Oak Bayou, and a 66% reduction in bacterial levels has been observed in the Houston Ship Channel and the Buffalo Bayou Tidal segment. These improvements may have resulted from changes in joint stormwater permitting, including the construction of stormwater detention basins; rehabilitation and maintenance of sewer lines; and repair of several major sanitary sewer bypasses. Other streams showing improvement include Greens Bayou above Tidal, Clear Creek Tidal, Buffalo Bayou above Tidal, Houston Ship Channel San Jacinto River, and Bastrop Bayou[13]. Despite some improvement, these water bodies still exceed water quality criteria.

Degradation has been observed in Clear Creek above Tidal, Dickinson Bayou Tidal, Chocolate Bayou Tidal and Lake Conroe (Figure 7). In Clear Creek above Tidal and Dickinson Bayou Tidal, 900% increases in bacteria levels (Enterococcus) have been observed, while a 300% increase in bacteria has been observed in Chocolate Bayou Tidal[13]. The specific sources for these increases are undetermined; however, more development and sewer line breaks surrounding Dickinson Bayou are potential contributors.

Figure 7
Waterways Showing Change in Bacteria Levels According to H-GAC 2010 Basin Highlights Report[13]



Source:H-GAC

Legend

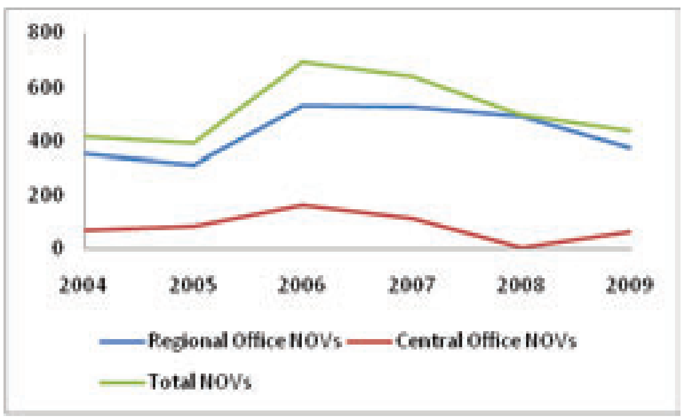
- Improvement
- Deterioration
- No Change
- Not assessed by H-GAC

Performance of Wastewater plants

There are 1,340 permitted wastewater treatment plants in the eight-county region, more than 50% of them in Harris County; and Harris County has more than any other entity of comparable size in the nation. For comparison, the state of Rhode Island is the size of Harris county and has only 19 wastewater treatment plants.

TCEQ is responsible for conducting on-site investigations of domestic and industrial wastewater treatment plants and sewage facilities to determine if violations exist. When TCEQ finds violations, a Notice of Violation (NOV) is issued forcing the entity to comply with regulations. The number of NOVs for water quality in Region 12 issued by the TCEQ peaked in FY06 (Figure 8 and Appendix D)[32], declining since then.

Figure 8
NOVs for Water Quality within Region 12



Source: TCEQ

Emerging issues

Increased Population and Development

The big issue affecting water quality is the tremendous increase in population and the physical growth that will be required to accommodate it. It is well understood that land use, particularly impervious cover which accompanies development, adds significantly to water quality problems. To prevent additional water quality problems, the use of "green infrastructure", i.e. stormwater wetland detention basins and low impact development, must become a regular part of development considerations. Protecting and conserving open areas, habitat, riparian zones and wetlands are essential to quality of place. In addition, it is more cost effective to preserve habitats than to rebuild or restore them.

The Galveston Bay Plan identified the loss of wetlands as a top priority. New data shows that the region loses freshwater wetlands at a rate of 3% annually. Between 1996 and 2005, almost 26,000 acres of wetlands were lost, a huge loss of one of the region's most precious assets. New development practices exist that promote modifying plans to avoid sensitive areas and create dense walkable communities that use less costly methods for maintaining water quality and use the natural landscape as a buffer to the bayous, streams, and bay. It is important to integrate water quality, water supply, and land use as plans are made and implemented for the future.

Marsh from Sabine and Neches Rivers and Sabine Lake

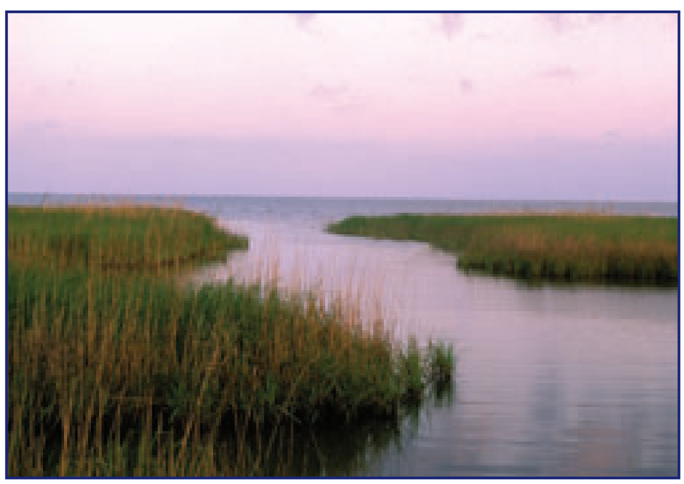


Photo by: Earl Nottingham, Texas Parks and Wildlife Department

What is being done?

Many groups are addressing water quality issues (Appendix D). Municipalities throughout the region are investing in water quality. H-GAC, in conjunction with TCEQ and other local partners, continues to collect data to improve the understanding of the region's water quality. Many of the region's water quality problems are being addressed through formulation of TMDLs, TMDL Implementation Plans (I-Plans), and watershed protection plans (WPPs). The Bacteria Implementation Group (BIG), consisting of H-GAC and local stakeholders, is working on a plan outlining activities that governments, businesses, and individuals can employ to reduce bacteria in 72 area water bodies. Several local efforts have undertaken the improvement and remediation of on-site sewage facilities (OSSF), wastewater treatment facilities (WWTFs) and collection systems to reduce human health threats and their environmental impact. Urban stormwater is being addressed through implementation of Phase I and Phase II stormwater permits. The public receives educational information and notices for public discussion from a variety of agencies. Small businesses are implementing voluntary pollution prevention actions; flood control districts are restoring stream banks through re-vegetation efforts[9]; and, rural landowners are implementing best management practices to improve water quality through the TSSWCB Water Quality Management Plan program. These activities provide just a sampling of efforts to preserve and protect water quality.

Where do we go from here?

While water quality has improved, especially with permitted point sources, many challenges remain. Aging wastewater infrastructure and nonpoint source runoff from yards, streets and agricultural lands are major challenges. To address these and emerging challenges, there must be ongoing efforts to adapt to new issues, remain vigilant about implementing point and nonpoint source measures, improve the general understanding of water resources and pass along new findings to the public.

Holistic Planning

Planning is an imperative. The best approach to water resource issues is holistic, one that involves developing an ecosystem-level adaptive management approach to water quality. Locally led, consensus-based partnerships among stakeholder groups and natural resource organizations are needed to develop and implement TMDLs, bacteria implementation plans, WPPs, and other natural resource plans. In addition, a considered approach to develop and implement community ordinances, policies and plans to control or prevent polluted runoff along with the establishment of subdivision and development guidelines at the municipal and county levels would benefit the region's water quality. Through locally developed solutions, the region's water quality can be improved, critical habitat preserved and restored, and good stewardship of the region's water resources can be realized[15].

Implement Existing Plans

Since 1998, extensive research and planning has been conducted on water quality issues, such as the Texas Coastal Management Program, Texas Coastal Nonpoint Source Pollution Control Program[5], The Galveston Bay Plan[8], the Gulf Coast Region Water Quality Management Plan[12], and numerous TMDLs and WPPs. Now the plans need to be implemented.

Implement Nonpoint Source Pollution Measures

The Galveston Bay Plan[6] recognized nonpoint sources of pollution as the second priority problem for the Bay. Reducing nonpoint source pollutants from urban and agricultural areas, construction sites and developments, marinas, and industrial facilities will require implementing municipal stormwater requirements, correcting malfunctioning septic tanks and constructing stormwater detention basins, treatment wetlands, and other stormwater management practices. Other measures to consider include Low Impact Development (LID) and other land use techniques such as infill, Smart Growth, and redevelopment of brownfield sites; agricultural best management practices; and, the Clean Marina program, which ensures proper pump out, storage and treatment of wastes.

Improve Wastewater Infrastructure and Treatment

Much work remains to ensure proper treatment of wastewater and reduce point sources of pollution. Due to the character of growth and sprawl in the region, the wastewater infrastructure network is extensive, fragmented, and in some cases, insufficient to meet needs. Malfunctioning septic systems, inefficient or inadequate treatment systems, and ill-maintained sewer collections systems are significant sources of contamination requiring improvements and proper maintenance. Millions of dollars are needed to: determine the location and extent of sewer bypasses and overflows and eliminate or reduce them; rehabilitate and maintain sewer lines; regionalize small wastewater treatment systems; and, improve compliance monitoring and enforcement. More routine, unannounced inspections of WWTPs are essential to ensure proper functioning.

To ensure proper treatment of wastewater and removal of bacteria, a 2008 Harris County report[19] recommended that 1) field reviews and chlorine-contact time studies be conducted on all newly constructed WWTPs to ensure they are built according to TCEQ requirements and 2) bacterial limitations for WWTP effluent be fully implemented. The report also recommended that better monitoring programs be established and composite sampling for WWTP effluent be required to characterize discharges of bacteria and other contaminants, allowing contaminant fluxes to be assessed instead of only concentrations assessed.

To address the issue of large numbers of package wastewater treatment plants, efforts are needed to automate these plants and better monitor discharges using cameras and other means. These changes will enable quick detection and resolution of wastewater treatment problems, thereby significantly reducing water quality impacts.

Finally, considering that most streams contain bacteria, it is time to evaluate wastewater treatment service consolidation and regionalization and the potential impacts on water quality. Studies have established that failing septic systems are a pervasive problem in the region. Efforts are needed to formulate and implement a regional plan and cost-effective solutions to reduce the impact of septic systems on the region's waterways[12].

Support Research

Because of limited understanding of the complexities of the region's bay system, additional research is needed to help us better understand and manage the bays[15]. Research is also necessary to improve the science and affordability to measure bacteria and emerging contaminants. Developing analytical methods to measure emerging contaminants, determining their occurrence and sources in the environment, and understanding the potential effects from exposure to these chemicals or microorganisms are major challenges to be addressed in coming years[32].

Emerald Stream from Barker Reservoir

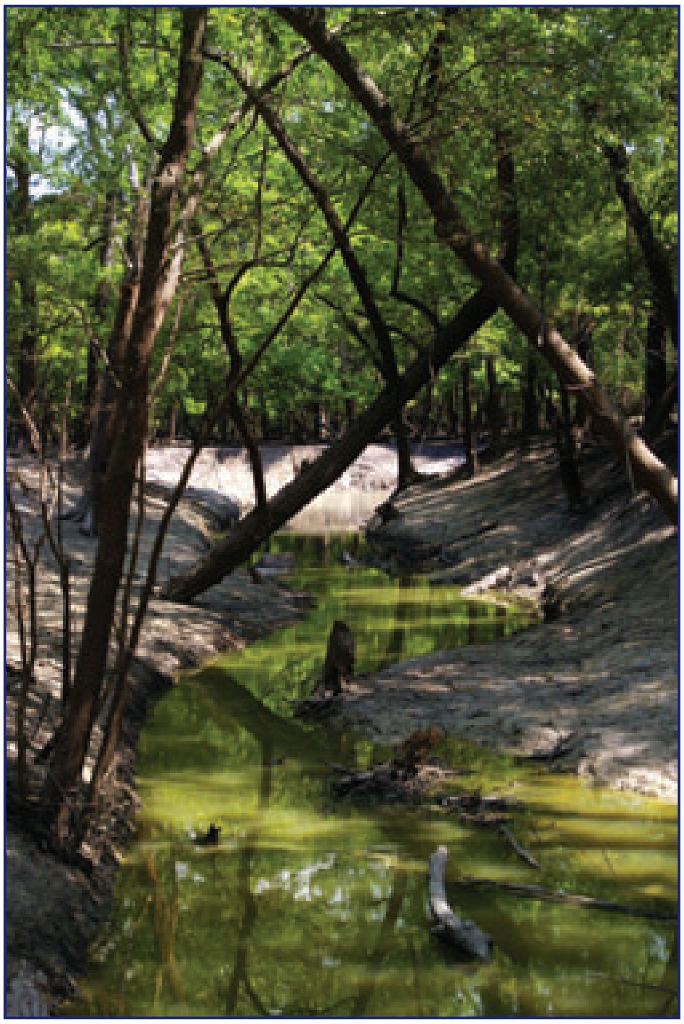


Photo by: Justin Bower

Increase Community Involvement

Because Galveston Bay watershed is a significant part of the regional community, preserving and sustaining it is everyone's responsibility. There must be a continued focus on education and outreach. Extensive opportunities exist for citizen education and community involvement. Renewed efforts to reach the public and promote practices will lead to water quality improvements across the region. Public participation and education are critical elements for the long-term management of water[6]. The most important thing is for everyone to get involved and take action at a "personal level" by:

- appropriately disposing of pet waste
- participating in recycling programs
- reducing unnecessary use or overuse of pesticides
- volunteering on a stakeholder group
- participating in the Trash Bash© or Texas Stream Team
- landscaping with native plants
- conserving water
- educating neighbors, friends and decision makers about protecting water resources[9].

Working together, the region's waters can be improved and protected, ensuring that they continue to provide sustenance and enjoyment for generations to come.

River Bend from Buffalo Bayou

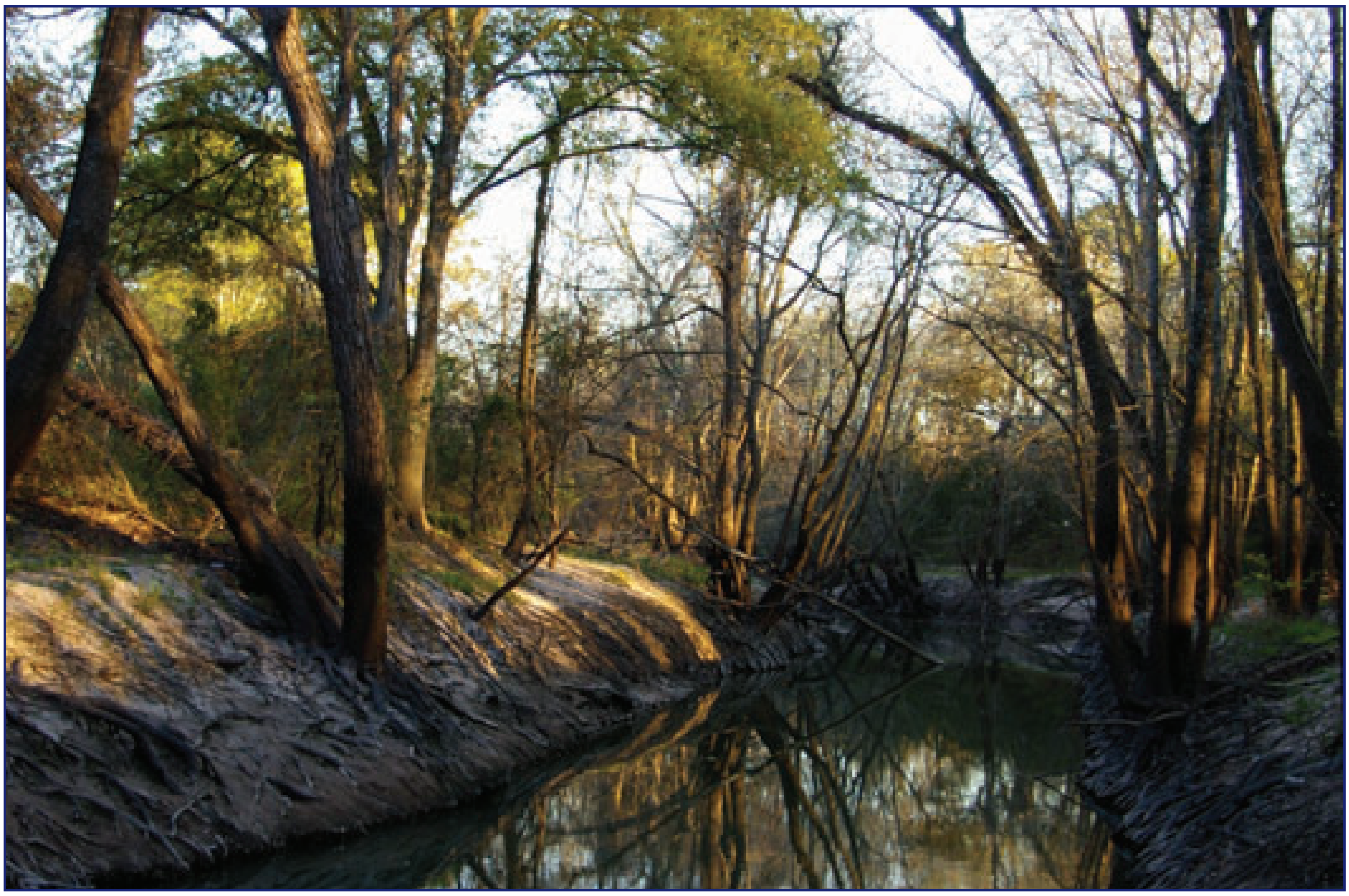


Photo by: Justin Bower

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APPENDIX A:

Explanation of Clean Water Act & Texas Surface Water Quality Standards

Congress enacted the Federal Clean Water Act (CWA) in 1972. The law employs a variety of regulatory and non-regulatory tools designed to restore and maintain the chemical, physical and biological integrity of the nation's waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water." Water quality standards are the foundation of water quality-based pollution controls established through the CWA. The Texas Commission on Environmental Quality (TCEQ) establishes water quality standards for the state. The CWA requires Texas to identify lakes, rivers, streams and estuaries failing to meet, or not expected to meet, water quality standards and not supporting their designated uses (e.g. swimming, drinking and aquatic life). To do this, a network of agencies and programs were established to collect water quality data. TCEQ assesses these data biennially and compiles a report assessing the status of the water quality in each water body, known as the Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d).

For water bodies that do not meet water quality standards and are "impaired," the state establishes total maximum daily loads (TMDLs) or watershed protection plans (WPPs) to restore the water quality. TMDLs define pollutant reductions needed to restore water quality. After TMDLs are established, local stakeholders develop TMDL Implementation Plans (I-Plans) to describe how the reductions will be achieved. TCEQ and the Texas State Soil and Water Conservation Board (TSSWCB) are the state agencies responsible for developing and implementing TMDLs. Similarly, WPPs are voluntary, locally led, stakeholder-driven processes that address water quality impairments by implementing voluntary management practices and outreach efforts.

The U.S. Environmental Protection Agency (EPA), via TCEQ, requires that entities discharging point source pollution be permitted to discharge into local waterways. These Texas Pollutant Discharge Elimination System (TPDES) permits restrict the amount of contaminant and/or pollutant concentration that can be introduced into local waterways. All municipal wastewater treatment and industrial plants must be permitted to discharge. In addition to the TPDES permits, construction projects, industrial facilities, and large municipalities and county and state entities that maintain municipal separate storm sewer systems (MS4s) that meet certain criteria are required to maintain stormwater permits (either Phase I or Phase II). These permits require steps to prevent or reduce contaminant levels in stormwater prior to discharge to reduce or eliminate contamination of local waterways.

Finally, Texas maintains a Water Quality Management Plan (WQMP) that deals with wastewater treatment capacity and planning. The WQMP is updated quarterly to reflect current effluent limits for TPDES permits, designation of management areas, service area population for municipal wastewater facilities, and TMDL requirements. All applications for new and amended permits are reviewed for conformance with applicable WQMP recommendations and used for water quality planning purposes in TPDES permit actions. Locally, the Houston-Galveston Area Council (H-GAC) maintains the Gulf Coast Region WQMP.

APPENDIX B - Monitoring

Surface Water Monitoring

In 1991, the TCEQ established the Texas Clean Rivers Program (CRP) to assess the quality of local bayous, streams, lakes and estuaries. The CRP, a collaboration of 15 partner agencies and the TCEQ, is a state fee–funded program for water quality monitoring, assessment, and public outreach. Water quality is determined by collecting samples and measuring them against defined parameters, and evaluating the results against the federal standard.

H-GAC administers the CRP with local monitoring agencies participating voluntarily. CRP funds are used to augment existing monitoring programs, to further the program objectives of participating agencies, and to allow access to a much larger dataset. Special studies are developed, as needed, based on local stakeholder input and the results of TCEQ or H-GAC assessments. Currently, seven local agencies and TCEQ are involved in monitoring a combined total of more than 370 monitoring sites in the region (Figure 2). All data is collected under the approved regional Quality Assurance Project Plan. The sites and data collected can be viewed on the H-GAC Water Resources Information Map found at http://webgis2.h-gac.com/CRPflex/.

The Regional Monitoring Workgroup coordinates monitoring activities which are scheduled at varying frequencies and determined by the concern for individual streams and/or proximity to a monitoring agency's field office and lab. Frequencies vary from quarterly to monthly in highly affected urban areas. Water bodies are selected for baseline monitoring if there is a high public interest, if it has a high potential for impairment, or if there is a need for continuous up-to-date water quality information. H-GAC collects quarterly samples at 30 water quality monitoring sites throughout the region. Most sites are located in the upper portions of watersheds or those that fall outside the jurisdiction of local partners. Through routine monitoring water quality trends and progress can be assessed, providing a view of water quality throughout the region. The data are used to develop the Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d).

Wastewater Treatment Plant Monitoring

Under the CWA, TCEQ issues TPDES permits to regulate discharges into state waterways. A common requirement of a TPDES permit is regular—typically monthly-self-monitoring of permitted parameters. The permit-holders submit results of self-monitoring to the TCEQ on a Discharge Monitoring Report form.

APPENDIX C

Changes in Water Quality Conditions in Classified Water Bodies as Indicated by Regression Analysis of 2000-2009 Annual Means for Ammonia (NH3), Chlorophyll, Dissolved Oxygen (D.O.), E. coli, Enterococci, Nitrate (NO3), Nitrate + Nitrite (NO3 + NO2), Orthophosphate (Ortho-PO4), and Total Phosphate (PO4).

Number of Notices of Violations for Water Quality-Region 12

Fiscal Year	Regional Office NOVs	Central Office NOVs	Total NOVs
2004	350	67	417
2005	310	82	392
2006	530	163	693
2007	526	115	641
2008	492	4	496
2009	370	65	435

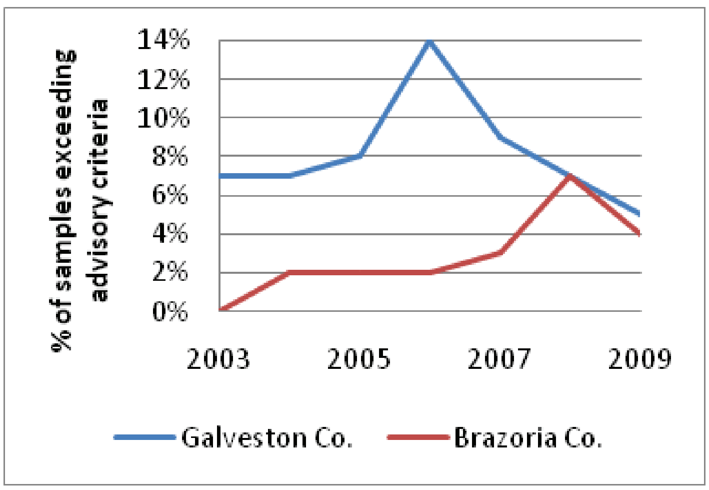
Source: TCEQ, 2004-2009

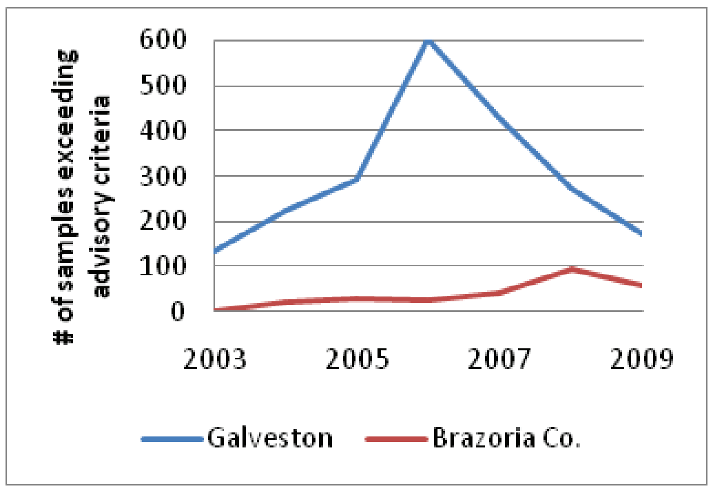
Number, % Samples Exceeding Beach Advisory Criterion (104 cfu/100mL)

County	Year	# of Samples Exceeding Advisory Criterion of 104 cfu/100mL	Total Number of Samples Collected	% of Samples Exceeding Advisory Criterion
BRAZORIA	2003	3	658	0%
BRAZORIA	2004	22	1318	2%
BRAZORIA	2005	29	1260	2%
BRAZORIA	2006	27	1294	2%
BRAZORIA	2007	42	1429	3%
BRAZORIA	2008	94	1415	7%
BRAZORIA	2009	56	1361	4%
GALVESTON	2003	135	1813	7%
GALVESTON	2004	223	3297	7%
GALVESTON	2005	291	3729	8%
GALVESTON	2006	606	4280	14%
GALVESTON	2007	431	4638	9%
GALVESTON	2008	274	3953	7%
GALVESTON	2009	170	3752	5%

Source: TCEQ, 2003-2009

Percentage & Number Exceeding Beach Advisory Criterior (104cfu/100ml)





Source: Texas Beach Watch Program

APPENDIX D

Initiatives to Improve Water Quality

Data Collection – The primary source of ambient water quality data is the CRP. The CRP coordinates data collection by the H-GAC and its local partners, compiling and maintaining a regional database(s) containing decades of data regarding the conditions in local waterways from more than 300 monitoring sites. Data from dischargers to local waterways (industries, wastewater plants, etc) is also significant in determining inputs. There continue to be specific studies looking at pollutants, often in conjunction with TMDL studies, WPPs, or other efforts.

The Bacteria Implementation Group (BIG)[1] – Consisting of H-GAC and 30 stakeholders representing agriculture, business, municipal and county government, ongoing TMDLs, conservation organizations, and the public, BIG works on a Bacteria Implementation Plan outlining activities to be used by governments, businesses, and individuals to reduce bacteria in 72 bacteria impaired water bodies.

TMDL Development – There are numerous existing and ongoing TMDLs and I-Plans (http://www.tceq.state.tx.us/implementation/water/tmdl/nav/tmdlprogramprojects.html) to assess pollutant reductions and measures to restore impaired water bodies, including:

- Armand Bayou
- Buffalo and White Oak Bayous
- Clear Creek
- Dickinson Bayou
- Houston Metropolitan Area
- Houston Ship Channel
- Lake Houston
- Oyster Waters, Galveston Bay System
- Patrick Bayou
- San Jacinto River
- Upper Oyster Creek

Watershed Protection Plan (WPP) Development – In addition to TMDL activities, there are voluntary efforts to develop WPPs to restore water quality (www.tsswcb.state.tx.us/wpp) in:

- Armand Bayou
- Bastrop Bayou
- Cedar Bayou
- Dickinson Bayou
- Double Bayou
- Highland Bayou
- San Bernard River
- Westfield Estates

[1]The Bacteria Implementation Group, familiarly known as the BIG, is a thirty-member committee that is preparing an implementation plan, or I-Plan, to remedy high levels of bacteria in waterways identified in four TMDL projects in the Houston Region. The BIG is responsible for receiving input, establishing workgroups, facilitating communications, developing recommendations, and providing oversight in the development of the I-Plan.

Wastewater Infrastructure Improvement – Local efforts are underway to improve and remediate septic tanks (on-site sewage facilities, OSSF)[2], wastewater treatment facilities (WWTFs) and collection systems to reduce threats to human health and the environmental.

- *OSSFs* – Harris County, the H-GAC and the City of Houston have prioritized efforts to identify and remediate malfunctioning septic systems. The goal is to extend sanitary sewer service to those areas served by septic systems with high failure rates. When replacement is not an option, the strategy is to fix or replace the system and/or install water reduction features. The solution may be to educate the user, e.g. not use anti-bacterial soaps or overload the system by running too many appliances simultaneously. Lessening the impact of faulty septic systems is the goal.

- *WWTFs and Collection Systems* – The TMDLs, I-Plans and WPPs address these potential sources. New state regulations require bacteria monitoring to help deter this prevalent water quality issue. Requirements are being put in place as permits are renewed. Many localities have developed rigorous maintenance and rehabilitation programs to serve fiscal and regulatory purposes. The City of Houston is repairing more than 950,000 linear feet of sewer lines per year, cleaning sewer lines to prevent clogging and sanitary sewer overflows, and repairing major sanitary sewer bypasses[13].

Stormwater Pollution Prevention – Stormwater collects and puts pollutants into waterways. Stormwater Management Joint Task Force[3] is the primary Phase I permit holder responsible for preventing stormwater contamination in the area. Pasadena, Sugar Land, Baytown and Pearland also have a Phase I permit. Harris County and the Harris County Flood Control District have developed detention basins and other structural elements that by design are intended to improve water quality as well as deter flooding.

Citizen Education and Outreach – There are many opportunities for citizen education and public involvement. Check out www.h-gac.com/go/getinvolved,
www.cleanwaterways.org and www.cechouston.org

[2] On Site Sewage Facilities (OSSF) are wastewater systems designed to treat and dispose of effluent on the same property that produces the wastewater. A septic tank and drainfield combination is the most common type of OSSF, although newer aerobic and biofilter units exist.

[3] In a cooperative effort to address the stormwater permit requirements, four local entities chose to work together through a Joint Task Force (the "JTF") to prepare and submit a two-part joint permit application. Effective October 1, 1998, EPA Region 6 issued a NPDES stormwater permit to the City of Houston, Harris County, Harris County Flood Control District (HCFCD) and Texas Department of Transportation (TxDOT) as co-permittees.

Green Buildings: 1100 Louisianna St., Williams Tower, Bank of America, and JP Morgan Tower

Green Buildings

Author: Brian Yeoman, Houston Director, Clinton Foundation

Executive Summary

As of April 2010, the greater Houston region had 78 green buildings, up from five in 2007 when the Center for Houston's Future issued its first *Counting on Quality of Place Indicator Report*. Of the major cities in the United States, this region ranked third in the nation for green buildings. The growth in Leadership in Energy and Environmental Design (LEED®) certification has been entirely driven by the market. Governmental activity, best described as light handed.

A green building is one that is an environmentally responsible, profitable, and a healthy place to live and work. For this Indicator Report, the United States Green Building Council's (USGBC) LEED rating system has been adopted as the way to define and measure green buildings.

The benefits of green buildings to the Houston region's quality of place are many. Green buildings have a significant positive effect on human health and well-being. Used as a place of business, green buildings typically have superior ventilation and indoor air quality that result in fewer sick days, increased worker comfort and control, and more productive office workers. Children have higher test scores in green school buildings. Patients in green hospital buildings recover faster and are discharged earlier, resulting in lower health care costs. Lastly, factory workers are more productive in green manufacturing facilities and have fewer injuries, reducing workers' compensation costs.

Not only are LEED buildings important for the environment and health, they also make good business sense[4]. LEED buildings increase a building's value by 7.5%, decrease total operating cost by 8-9%, increase occupancy rates by 3.5%, and increase rental rates by 3%[1].

Given that green buildings use fewer resources and have a lighter footprint than conventional buildings, they present great upside potential for quality of place in the greater Houston region. It is important to note that the LEED green building concept is a holistic view of quality of place, encompassing the environment, the human interface and economic considerations.

In the United States, buildings consume 40% of the primary energy, 72% of electricity, 13.6 % of potable water, and are responsible for 39% of CO2 emissions[2]. Buildings consume energy at every step of their life cycle from construction to operation to maintenance.

Green buildings are hugely important when considering the impact of the built environment on resource use. They can reduce energy consumption by as much as 50%, CO2 emissions by 35%, water consumption by 40%, and the waste stream into landfills during construction by 50-75%.

The USGBC LEED program was launched in 1998; however, the first Houston area building to be LEED certified did not occur until 2004. While the Houston region was slow to adopt green building concepts and practices, the end of the decade showed significant growth. There are now 78 buildings with a total of 22,603,025 square feet of space. The USGBC allows building owners to keep data on their projects confidential; as a result, there are eleven additional certified buildings about which little is known.

Certified LEED apartments

Photo by: New Hope Housing

Why are green buildings important to quality of place?

Green buildings are important to quality of place because they can be a significant contributor to the region's competitiveness by making the region more affordable, attractive, and healthy. There is an inextricable link between the built environment and health. Because this region has no mountains or major rivers, the region's landscape is dominated by buildings. Here people spend much of their time in buildings. People work, eat, raise their families and sleep in buildings as much as 90% of a typical day[3].

A green building is a high-performance commercial, institutional or residential building with energy, economic, and environmental performance that is substantially better than standard practice. It must be certified by the USGBC's LEED program. Residential buildings are not a part of this Indicator Report as the data for residential structures are not readily available.

Green buildings use scarce resources wisely. Moreover, they are proven to be hugely beneficial to those who live, study, shop and work in them. As stated previously they provide significant bottom-line economic benefits. Moreover, greater long term economic benefit is realized through reduced total cost of ownership and operation. Employee productivity and business profitability are inextricably linked to green buildings. Research suggests that a well-designed workplace can increase employee productivity by 10-15%[5]. Studies have shown an increase in employee productivity when buildings are designed with occupants in mind—natural light, non-toxic materials, comfortable working temperatures, and a quiet work environment being important issues[6]. Further, studies show that a safe, pleasant and healthy environment helps to attract and retain employees for employers and desirable tenants for building owners.

What are the community and policy goals?

The Houston region is undergoing a rapidly evolving transformation in building construction and retrofitting. Driven by the market, the green building movement began in Houston's central business district and is spreading. Local government leadership has contributed significantly to the transformation, but government has resisted the temptation to enact policies which attempt to dictate the nature of buildings, preferring to lead by example. All major cities in the eight-county region have followed suit.

Green Design and Construction - Explaining LEED

LEED, an internationally recognized green building certification system, requires third-party verification that a building was designed and built using specific strategies to improve building performance, including stewardship of resources, CO_2 emissions reduction, improved indoor environmental quality, and sensitivity to building impact. It is a concise framework for implementing practical and measurable green building design, construction, operations and maintenance solutions.

LEED has specific requirements for different building types that acknowledge their lifecycle, i.e. design and construction, operations and maintenance, tenant build-out, and significant retrofits. Through a consensus process, the USGBC promulgated multiple versions of LEED which have transformed the marketplace. LEED is updated periodically to ensure that its tools accommodate new technologies and techniques.

All LEED programs follow the same general framework which uses six green building categories (Appendix 5.1):

- Sustainable sites
- Water efficiency
- Energy and atmosphere
- Materials and resource
- Indoor environmental quality
- Innovative design

Green roofs are a new innovation being incorporated into buildings. Although substantial data is not yet available, green roofs are expected to reap such benefits as cooler external air temperatures, reduced energy consumption and cleaner air inside the building. Storm water runoff is also a major expected benefit as a four-inch thick green roof can hold a gallon of water per square foot.

LEED Standards, City of Houston Buildings

On June 23, 2004, Resolution No. 2004-15 was passed by Houston City Council and signed by Mayor Bill White authorizing the city to establish the USGBC's LEED certification as a standard for new or replacement facilities and major renovations of city-owned buildings and facilities with more than 10,000 square feet of occupied space. The resolution requires the City to use LEED "to the greatest extent practical and reasonable," with a target of LEED Silver. Since signing the resolution, the City has initiated more than 34 LEED projects, thereby contributing significantly to the capacity building of design and construction professionals' green building knowledge and helping to launch a broader green building initiative for the region. The City also established and staffs a Green Building Resource Center that is open to the public. It also instituted a permit program which reduces construction and renovation fees in a LEED planned building, but few building owners have taken advantage of the program.

Tax Abatements

In May 2008, Harris County Commissioner's Court passed the LEED Tax Abatement, providing for a 10-year tax abatement program for qualifying commercial buildings within certain tax reinvestment zones. The abatement is intended to offset the additional tax liability that may result from the increased appraisals. The scope of the abatement program is limited to Harris County taxes on eligible projects in unincorporated areas. The economic incentive is small; however, this program points to a national trend of governments seeking ways to promote green building. The cities of Sugar Land and Friendswood have also adopted their own version of a tax abatement ordinance for tax investment zones.

How can progress be measured?

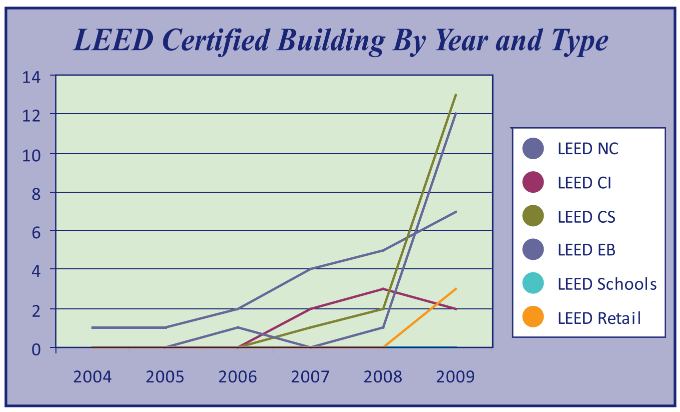
The Center for Houston's Future, in its 2007 Indicator Report on Green Buildings, endorsed the USGBC's definition of green buildings. This report repeats that fundamental assumption.

The metrics for the commercial and institutional sector are the number of LEED certifications by type and square footage in both the aggregate and annual increments. Other metrics are the number of LEED registrations by type and square footage in both the aggregate and annual increments. This Report adds a third metric, the number of LEED accredited professionals in the eight-county region both in total and annual new accreditations.

Number of LEED Certified Buildings

The region's growth of LEED buildings has been dramatic. Its first LEED certified building occurred in 2004. In 2009, 37 buildings were certified. In the first four months of 2010, the area gained 18 new certified projects bringing the total to 78. To put this in perspective, as of September 2009, there were 3,855 LEED certified buildings in the nation.[1] Figure 1 illustrates the region's dramatic growth between 2004 and 2010 by category.

Figure 1
Certified Buildings by Year and Type, 2010



- New Construction (NC)
- Core and Shell (CS)
- Commercial Interiors (CI)
- Existing buildings (EB/O&M)
- Schools
- Retail

Source: USGBC

While some believe that green buildings are little more than specimen buildings, nothing could be further from the truth. The square footage of the 78 LEED certified buildings total 22,603,025 square feet, equating to 289,782 square feet per building – a far cry from a specimen building. For context 22,603,025 square feet of certified buildings represents 3.7% of the LEED national total.

Most, but not all green buildings are being built in Houston/Harris County. Three other counties have LEED certified buildings with more to come. The green building movement is a regional phenomenon. Figure 3 shows progress in LEED buildings by county.

Figure 2
LEED Certified Buildings by County

County	Certified Buildings
Brazoria	**2**
Ft. Bend	**1**
Harris	**73**
Montgomery	**2**

Number of LEED Registered Buildings

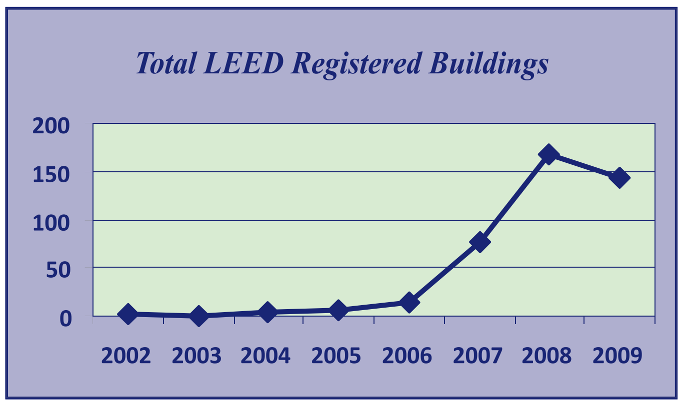
The second set of metrics is based on the number of buildings *registered* to be certified, including square footage in aggregate and annual increments. This is very important data for a simple reason. Registrations are the "pipeline" for green buildings to come, a broad indicator of green building activity. As of this writing, there are 416 buildings in the region's registration queue, more than five times as many buildings as the total number of certified buildings in the area!

It is important to note that the greater Houston region ranks third when compared to other major U.S. cities.

Figure 3
LEED Certified Buildings in the America's Largest 10 Metropolitan Regions

LEED Certified Buildings Largest Ten Metropolitan Regions	
Chicago	146
New York City	91
Houston region	**78**
Los Angeles	66
Phoenix	30
Philadelphia	33
San Antonio	16
Dallas	59
San Diego	53
San Jose	21

Figure 4
Total LEED Registered Buildings in the Houston Region by Year



Source: USGBC

It is impressive to note that of the 102 existing LEED registered buildings, the total square footage of 76.2 million square feet is 2.5 times that of currently certified square footage. A surprise in the data is that 35 schools are now registered and seeking certification, which will result in adding 2,565,142 square feet of green schools in the region (Appendix 5.3). This indicates a clear commitment to provide healthy learning environments for the region's children.

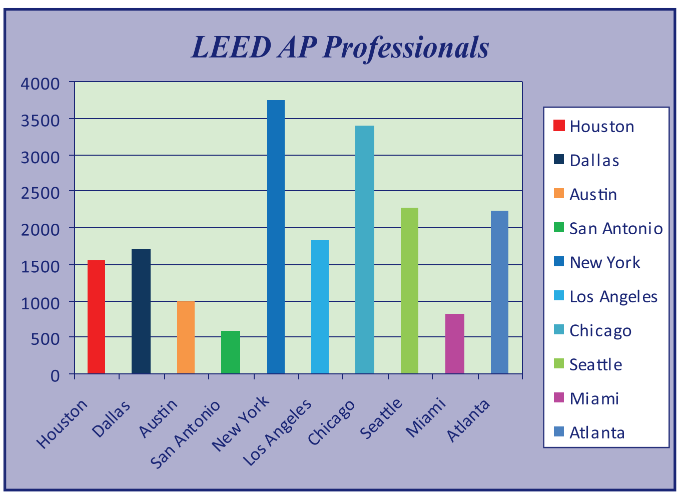
Number of LEED Accredited Professionals

The third major metric for green buildings is the number of LEED accredited professionals. This indicator addresses the capacity of the region's workforce to support green building design, construction and operations. Without sufficient trained and experienced workers, the ability to produce high quality green buildings could be at risk. Green building professionals are a regional resource, totaling 1,609; however, Houston/Harris County dominates with 1,544, or 95%.

Fortunately, demand for highly skilled professionals is continuing, driven by all sectors of the economy. The local chapter of the USGBC partners with professional organizations is delivering quality professional development programs.

The region's capacity to design, build and operate green buildings compares well to other large urban areas. The benchmark is the attainment of the USGBC's LEED Accredited Professional. This bodes well for owners of the 213 registered, but not certified buildings currently in the design-bid-build process, and the 73 existing buildings that are seeking LEED EB/OM certification. Figure 5 illustrates that the region is competitive with the ten largest metropolitan areas.

Figure 5
LEED Accredited Professional in Major Urban Areas, 2010



Atascocita Springs LEED certified Elementary School from Humble ISD

Source: Humble ISD, courtesy of Jamie Mount

What is the current situation?

Significant progress in green buildings has been made since the 2007 Indicator Report.

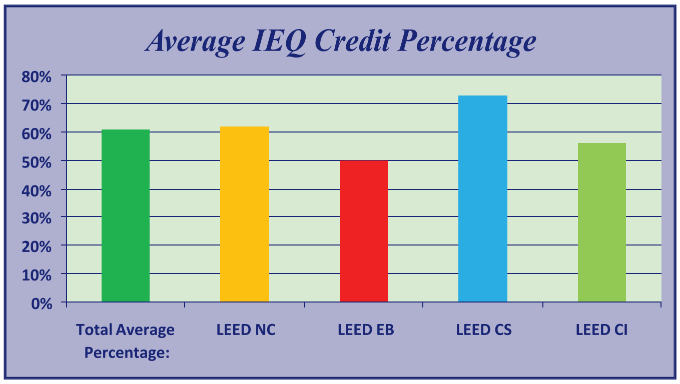
Green Buildings and Health

It can be argued that of the six major LEED categories, the category that most affects public health is the IEQ category. IEQ encourages the use of low-emitting adhesives and sealants, paints and coatings, and carpets. It discourages the use of indoor chemicals. IEQ was not established to address health; however, even if the IEQ category is not precisely designed to measure the direct health benefits of green buildings, it is worth exploring.

A sample of 18 IEQ projects, representing 23.1% of the LEED building population, was analyzed from multiple LEED types. Of the available data, Core and Shell types scored highest with 73% of available IEQ credits. Lowest was Existing Buildings with 50% of IEQ credits. To be clear, the requirements by LEED types vary, so there cannot be a direct credit by credit comparison. Thus, the percentage of attainment was used to calculate Figure 6. A total average percentage attainment score of 61% is positive, indicating that green buildings might be healthier than traditional code buildings.

Figure 6

Average IEQ Credit Attainment Percentage



Source: USBGC

Where do we go from here?

There is still considerable debate surrounding costs of green buildings. A recent survey by the World Business Council for Sustainable Developments found that green costs are overestimated by 300%. The true average cost difference between construction of a green building and a conventional building is approximately 5%. Although some individuals still express concern, the market has largely settled this issue given the number of existing green building certifications and registrations. Other sources have reported on cost/benefit based upon national data[5].

National laboratories, private companies, universities and industry are conducting research on green buildings. New materials, procedures and technologies will likely be developed to improve their performance. According to the USGBC, more than 70% of the green building research is focused on energy and atmosphere. The next largest category is materials and resources. Improvements to indoor environmental quality, including issues pertaining to air, are also being studied.

The three critical metrics going forward include:

- The number of USGBC registrations by type, square footage, and year,
- The number of USGBC certifications by type, square footage, and year, and
- The number of USGBC accredited professionals in aggregate and by year.

To date, the market has worked to transform the green building movement in the region, albeit a little slowly. Many building owners and managers have seen the advantages of green buildings from economic and competitive standpoints. That said, few small to medium-sized building owners have adopted this philosophy, perhaps because of the economies of scale issue. As this small to medium-size market segment is educated on the economic, environmental and health benefits of green buildings, a similar acceptance can be expected.

The region's considerable move toward green buildings has begun. Houston has embraced LEED *Existing Buildings* with 102 existing LEED *registered buildings*. That translates into 52,940,308 square feet of green buildings on the horizon. Houston is undoubtedly setting a trend through the LEED *Existing Building*. In fact, the largest five certified buildings in the region are LEED Existing Buildings. (Figure 7)

As of April, 2010, he five largest certified LEED buildings in the greater Houston area are as follows:

Figure 7

LEED certified buildings/year/type, raw data

Largest Five Certified Buildings	*Square Footages*
Chase Tower Houston	1,981,571
Williams Tower	1,771,370
Bank of America Center	1,715,266
First City Tower	1,421,105
1100 Louisiana	1,410,801

Green Building Appendix 5

5.1: LEED: Six Major Categories

The LEED framework has six major categories, each of which has performance objectives that exceed the industry norm.

Sustainable Sites

Selecting and managing a building's site during construction is a very important consideration for a project's sustainability throughout its lifetime. Greenfield development, i.e. previously undeveloped land, is discouraged; limiting a building's impact on ecosystems and waterways is encouraged; regionally appropriate landscaping is promoted; smart transportation choices are rewarded; controlling storm water runoff is promoted; and, erosion, light pollution, urban heat island effect and construction-related pollution are strongly discouraged.

Water Efficiency

Buildings and their landscape can be huge users of water. The goal of the LEED water efficiency credit is to encourage smart use of water, inside and outside the building. Water reduction is achieved through more efficient appliances, fixtures and fittings and water-wise landscaping.

Energy & Atmosphere

This category encourages a variety of energy strategies: commissioning; energy use monitoring; efficient design and construction; efficient appliances, systems and lighting; the use of renewable and clean sources of energy, generated on-site or off-site; and other innovative strategies designed to reduce consumption.

Materials & Resources

Buildings generate a lot of waste during construction and operation using massive amounts of materials and resources. The reduction of waste, as well as reuse and recycling of waste, is encouraged and rewarded. Also the selection of sustainably grown, harvested, produced and transported products and materials are rewarded.

Indoor Environmental Quality

This category promotes strategies to improve indoor air quality during construction and occupancy. The use of low or no emitting paints, sealers, adhesives, and carpets is also rewarded as is providing natural daylight, green views and improved acoustics.

Innovation in Design

This category challenges projects to use new and innovative technologies and strategies to improve a building's performance well beyond what is required by other LEED credits or in green building considerations that are not specifically addressed elsewhere in LEED.

5.2: Figure 2

Registered Buildings by year and LEED Type

	LEED Type						
Year	LEED NC	LEED CI	LEED CS	LEED EB	LEED Schools	LEED Retail	Total
2004	1	0	0	0	0	0	1
2005	1	0	0	0	0	0	1
2006	2	0	0	1	0	0	3
2007	4	2	1	0	0	0	7
2008	5	3	2	1	0	0	11
2009	7	2	13	12	0	3	37
2010	9	2	5	2	0	0	18
Total	29	9	21	16	0	3	78

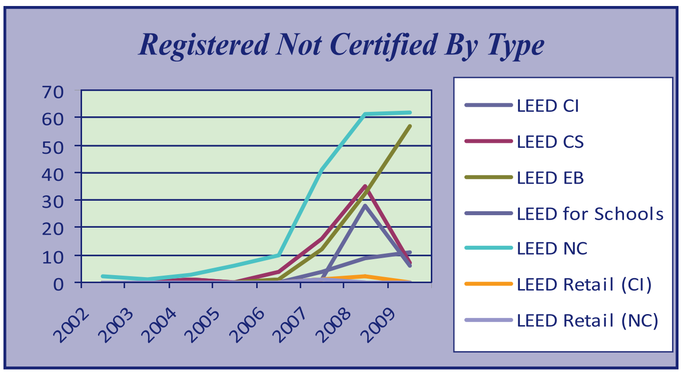
5.4: Figure 3

LEED Registered Buildings/Square Footage

Registered Not Certified By Type	NC	CI	CS	EB	Schools	Retail	Total
2001	195,000	0	0	0	0	0	195,000
2002	65,285	0	0	0	0	0	65,285
2003	34,197	0	0	24,000	0	0	58,197
2004	188,378	0	0	0	0	0	188,378
2005	606,000	12,852	0	0	0	0	618,852
2006	1,139,868	45,000	1,405,524	1,800,000	0	0	4,390,392
2007	2,892,563	234,260	234,260	2,733,078	0	144,812	6,238,973
2008	2,868,766	2,032,913	2,032,913	29,426,746	2,232,142	16,508	38,609,988
2009	5,638,180	443,766	443,766	18,956,484	333,000	2,801	25,817,997
2010	0	0	0	0	0	25,022	25,022
Total	13,628,237	2,768,791	4,116,463	52,940,308	2,565,142	189,143	76,208,084

Figure 4

LEED Registered Buildings/Square Footage



Endnotes

1 USGBC; figures based on U.S. buildings only

2 Environmental Information Administration (2008) EIA Annual Energy Outlook and US Geological Survey 2000

3 USGBC; U.S. Dept. of Energy; UNEP, Buildings and Climate Change: Status, Challenges, and Opportunities, 2007

4 The Total Exposure Assessment Methodology (TEAM) Study, EPA 600/S6-87/002 US EPA 1987.

5 Doing Well by Doing Good? Green Office Buildings, Piet Eichholtz, Nils Kok and John M. Quigley, University of California Energy Institute, August 2009.

Surface Water Supply

Author: John Jacob, Ph.D., Texas A&M University Professor & Extension Specialist

Executive Summary

The greater Houston region appears to have a plentiful and sustainable water supply sufficient to accommodate foreseeable growth, with proper management and conservation, for the next 30-40 years. A dual system of ground and surface water supplies endows the region with a fair amount of resilience, although groundwater supplies must be managed very carefully to avoid further subsidence. An important question is whether or not there will be sufficient water to sustain both population growth and a robust Galveston Bay ecosystem. While there is not yet a solid scientific consensus on exactly how much water, both in terms of quantity and flow patterns, is needed to sustain the Bay, it is clear that instituting a more aggressive conservation program would pay substantial dividends for fresh water inflows to the Bay.

The main driver of policy for the next decade or so will be the continued shift of reliance from groundwater to surface water for most supplies, and how that shift is balanced to accommodate growth. Groundwater should account for no more than 20% of the water supplies of most of the significant water user groups within the next two decades. This conversion will be perhaps the most important short-term water supply indicator followed in the region.

The principal indicators for gauging long-term sustainability of water supplies for the greater Houston region include the state of source-water watersheds, and a number of demand-side indicators relative to efficiency and conservation. Maintaining total withdrawals of surface water at or below historic *firm yield* volumes should ensure sufficient fresh-water inflows to maintain a healthy Galveston Bay ecosystem.

Why is water supply important to Quality of Place?

The next 30-60 years will see greater population growth than any previous time. The challenge is to maintain the ecological as well as the built infrastructure for the water supply necessary to accommodate this growth. This will not be a trivial or inexpensive undertaking.

No town can become a city without a guarantee of safe and plentiful water, and no city can have pretensions of being a major global contender without enough water to sustain a vibrant industrial and commercial core. The greater Houston region does not have an infinite supply of water, but with foresight and good management, enough high quality water can be supplied to sustain a dynamic economy well into the future. The region is endowed with a remarkable ecological infrastructure that includes a rich network of bayous, prairies, and forests that in large part is the foundation for a plentiful supply of both surface and groundwater. This endowment is our security against a future that will likely contain economic dislocations as well as possible ecological shocks associated with climate change. This chapter looks at the evolution of water supply in the greater Houston region and lays out a set of basic indicators for gauging trends of greater or lesser sustainability and resilience of water supply.

What are the community and policy goals?

The goal of the greater Houston region is to meet the challenge of maintaining a sustainable water supply while accommodating growth. People in the Houston region want a prosperous and beautiful city that is a major global competitor. They also want an environment that sustains its citizens with healthy air and water and an enduring sense of place. A healthy and sustainable water supply intersects these large community goals at a fundamental level.

A resilient water supply is an absolute necessity. Change is in our future, not just massive population growth, but also unknown ecological shocks that might be associated with climate change or natural disasters. Plans must be put in place for growth and for episodic swings in climate such as drastic droughts, not to mention flooding. To prepare for change that cannot be predicted, as much resilience as possible must be built into the water supply system.

How can we measure progress?

Progress can be measured by establishing indicators that reveal trends towards greater or lesser sustainability and resilience. These indicators can range from the simple and direct—such as how much water is consumed relative to long-term available supply, to more indirect indicators such as the condition of the watersheds that are the source of water.

What is our current situation?

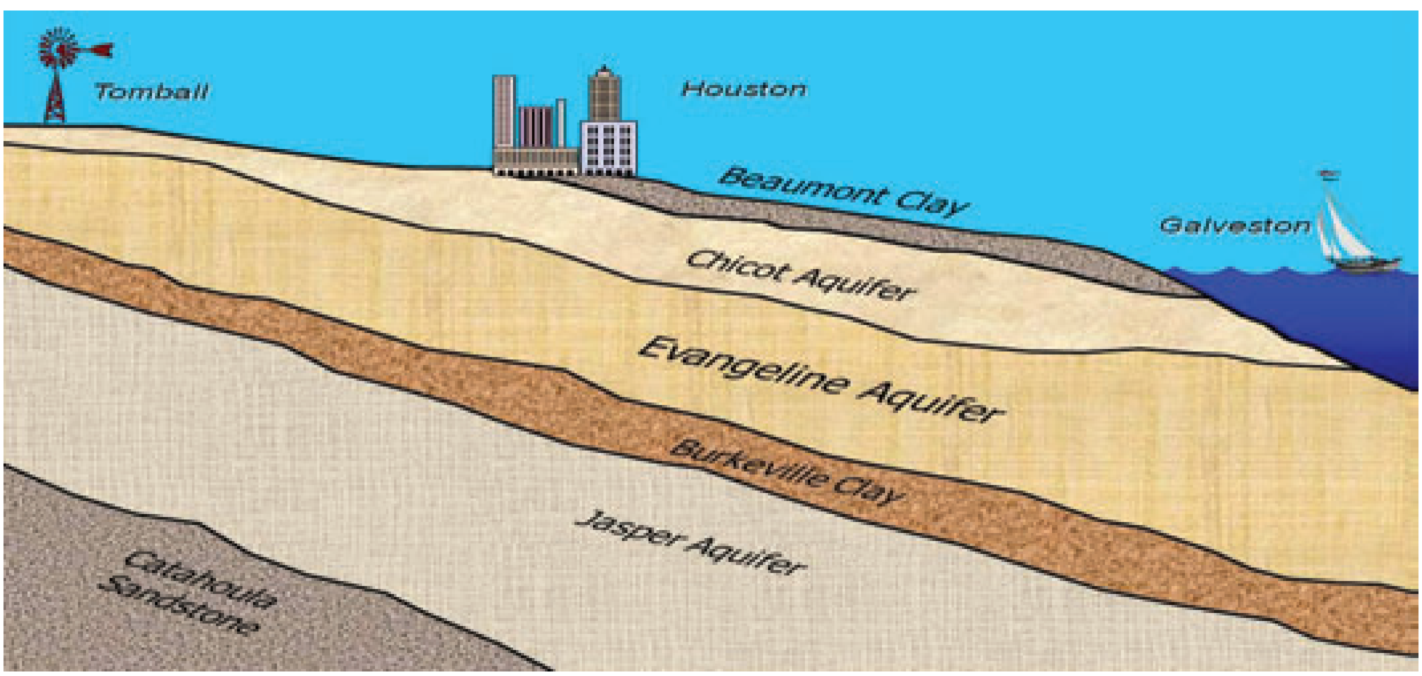
The Houston region has had abundant water supplies. So it is thought. Growth has not been limited by water supplies, but serious limitations have been faced in terms of getting the water from the sources at hand. Several times in the region's history, dramatic shifts in infrastructure and sources have been required to insure continuous water supplies. The next 50 years promise to test the region's ability to supply all the water that will be wanted. The population will double, causing a much greater impact than at any previous period, particularly given the region's per capita demand for water and other resources. Under current development patterns, between 700 square miles and 1000 or more square miles of farmland and natural areas will be consumed in the region during the next 30-plus years.

The regional water plan and forecasts suggest that the challenge of supplying water can be met for the next 40 years or so, but meeting it will require significant new conservation and/or infrastructure measures.

As with other aspects of the region's history, the story of water is about the interplay between a free market, individualistic approach to water supply and the need for planning and government intervention, with the former holding sway until limitations periodically forced a more structured approach. An abundant supply of surface water brought people to Houston, and in the beginning, water was extracted from Buffalo Bayou and supplemented by rainwater cisterns person by person, house by house and farm by farm. The inability to fight fires resulted in the City of Houston contracting with the newly formed Houston Water Works to distribute water to the City and the Fire Department. In 1906 muddy water eventually forced the City to buy out the private company and get into the water supply business, where it has remained ever since. This was the first of several inevitable interventions.

Figure 1

Illustration of regional geology. The Chicot and Evangeline Aquifers are the main source of groundwater for the region.



Groundwater is what really allowed the region to take off. Artesian or free flowing wells drilled in the late 1880s revealed a seemingly inexhaustible source of water, which boosters would tout for decades. Groundwater became for all practical purposes the sole source of water for the first half of the 20th Century. The ease of extraction complemented the area's free market approach to development, embodied in the municipal utility district or MUD. More MUDs are found in this region (roughly 700 at last count in Harris County alone) than any other region of Texas. Developers did not need to depend on a city water supply corporation for water, they just had to drill a well, and groundwater would flow, freeing them from the constraints of adjacency to water supply infrastructure, resulting in a fragmented, "hopscotch" pattern of development.

The groundwater supply was not to be inexhaustible. As far back as 1926 there were indications that falling water levels in the aquifer had more significance than just declining water supplies. Land subsidence, the result of irreversible collapse of clay layers as a consequence of excessive groundwater withdrawal, would become more noticeable over the years. Subsidence levels as great as 8-10 feet in some areas forced a reckoning. Subsidence, which can result in increased flooding and structural instability, is a very serious issue in flat and low terrain. In 1975, the Harris-Galveston Counties Subsidence District (HGSD) was formed to regulate the pumpage of groundwater in the counties for which it is named. The creation of this district, the first of its kind in the United States, was significant in that groundwater law in Texas is based on the "rule of capture", i.e., if you can capture it –and put it to beneficial use – it is yours, in contrast to the more systematic prior appropriation doctrine that governs rights to the surface waters of Texas.

The upshot of regulating and limiting groundwater pumpage was the eventual need to effect a massive shift from groundwater back to surface-water supplies as the principal source of water. There was no way that several hundred MUDs could individually connect to the few surface water treatment plants. Another significant government intervention was thus needed. A system of three regional water authorities was instituted beginning in the late 1990s to manage this shift.

The needed surface water was available because the City of Houston built reservoirs beginning in the 1950s, initially for industrial water supplies. Lake Houston was completed in 1954, followed by Lakes Livingston and Conroe in 1969 and 1973 (financing for the latter aided by the San Jacinto River Authority).

Weed Clump from Brazos Bend State Park Ecosystem

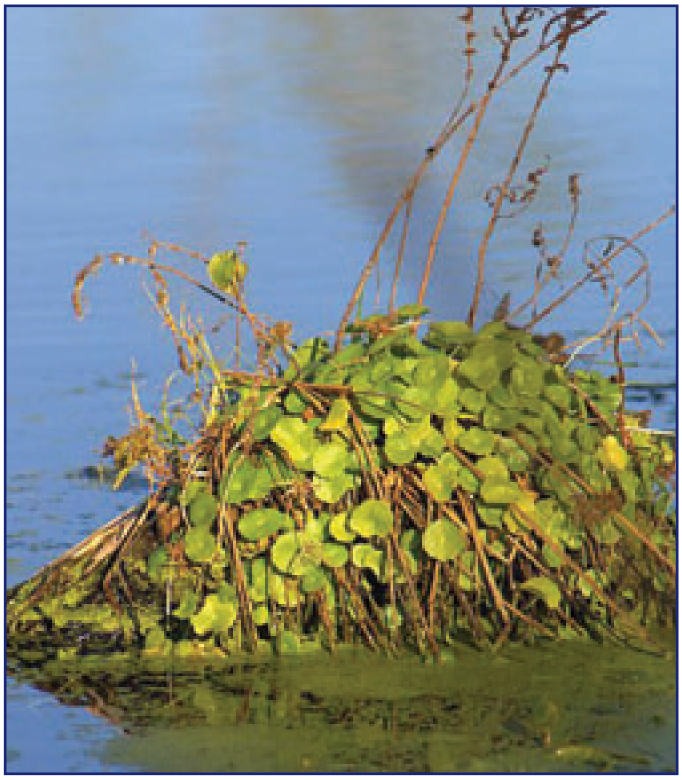
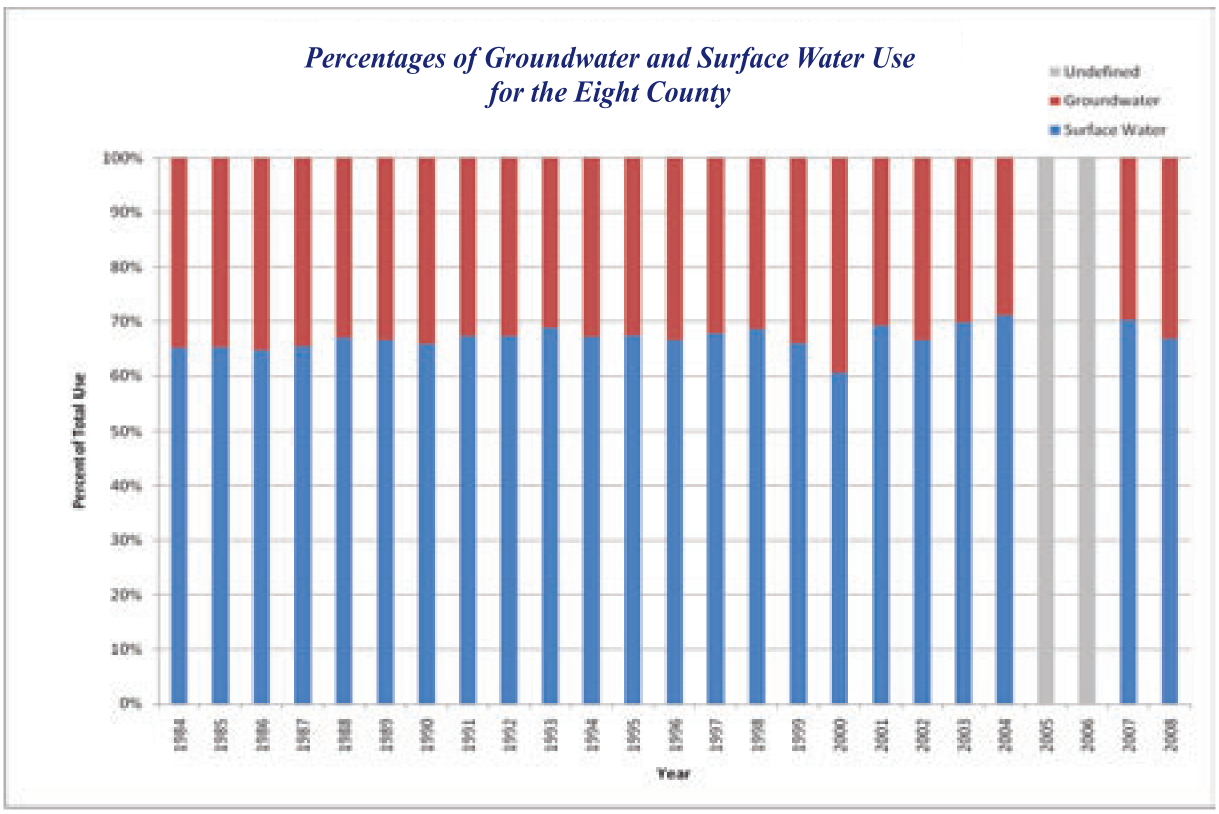


Photo by: Justin Bower

Surface water supply is managed by a few wholesale water providers (WWP). The City of Houston controls the vast majority of water rights, and provides the largest amount of treated water to the region. Other major providers include the Trinity, San Jacinto, and Brazos River Authorities, and the Gulf Coast Water Authority. These entities account for over 80% of the available firm supplies of surface water.

Most of the groundwater used in the Houston region is still pumped by MUDs, but the proportion pumped by WWPs will likely decrease as groundwater conversion takes place. This groundwater to surface water conversion is regulated by two subsidence districts: the HGSD described above and the 1989-created Fort Bend Subsidence District (FBSD). The mission of these two districts is to control subsidence, not necessarily to insure a sustainable groundwater supply. Within the HGSD, groundwater pumpage must not exceed 20% of the total water supply within the next 20 years, and no more than 40% within most of FBSD.

Groundwater outside of these two districts is managed through Groundwater Conservation Districts (GCDs). The Lonestar GCD actively regulates groundwater withdrawals in Montgomery County, with a plan to reduce pumpage to equal or less than aquifer recharge rates by 2015. Brazoria County is the only moderately urbanized county in the Houston region not regulating groundwater, but will likely do so in the not-too-distant future through the Brazoria County GCD. Waller County is part of the Bluebonnet GCD, but is not restricting groundwater pumpage at this time. None of the other counties in the region have GCDs. All of the region is encompassed by a regional Groundwater Management Area (GMA), as required by the Texas Legislature for regional groundwater supply planning. GMA 14, encompassing the region, has developed a set of "desired future conditions" for the aquifers that underlie the area. Outside of the subsidence districts and the Lonestar GCD, none of these "DFCs" appear to be associated with regulatory requirements.



Future needs – Accommodating Growth

The projection for 2060 is that the region will exceed available water supply by about 35% if no action is taken.[1]

If all predictions come true, the region's population will double in the next 40-50 years. Sufficient supplies seem to be available to meet this demand, but to do so will require extensive planning and investment in new infrastructure. Future growth will also entail significant shifts in the allocation of water supplies, for example from agricultural to municipal users.

Planning for future water needs is now accomplished through Regional Water Planning Groups (RWPGs) as established under Texas Senate Bill 1 in 1997, one of the most significant pieces of water legislation in Texas in a generation. Region H WPG includes this region's eight-counties that are the focus of this chapter, along with seven other counties or portions of counties. The Region H WPG includes stakeholders from the entire region and from all major interest groups. The Region H Water Plan is a five-year recurring process. While the plan is not a binding, regulatory document, it does have significant influence in that no state funds are available for projects not identified within the Regional Water Plan. It is the planning document for the region, and thus an essential reference for any discussion of water planning. Providing water during drought is critical, thus water planning in the U.S. is based on a concept known as *firm yield*. Precipitation and river flows are subject to wide variations, such that planning for the future cannot be based on average flow. The *firm yield* is based the "drought of record", which for this region, occurred during the 1950s. The *firm yield* is the diversion that can be supplied continuously without shortage and that just empties the reservoirs.

In most years, much more water is available to our region than this firm yield, but it would be imprudent to depend on this additional amount of water for long term planning. In fact, the region is currently pumping surface water slightly over the firm yield amount. Including available groundwater, the firm yield supply is being exceeded by about 10%. The projection for 2060 is that the region will exceed available supply by about 35% if no action is taken.

According to the Region H planning documents, there should be *almost* enough water to meet overall growth projections *if* the plan is followed. The overall supply is about 3.6 million acre-feet/year, about 75% of that from surface water. That supply will be reduced to about 3.4 million acre-feet/year by 2060 because of mandatory reductions in groundwater pumpage. Total demand will go from the current 2.4 million acre-feet/year to 3.5 million acre-feet/year. To accommodate the projected growth, a supply of a minimum of an additional 1,150,000 acre-feet/year of municipal water (about 1 billion gallons of water per day) over and above what is used today will be required, primarily from surface water. While supplies appear to be sufficient, some areas are going to face significant shortages. The southwestern part of the region, particularly Brazoria County, has the largest projected shortages.

Serious changes will be required to accommodate future growth. There is no question that a major infrastructure investment will be needed on the order of $13 billion, an expense that will largely be borne through user fees. Conservation measures could help meet this new demand with less stress on existing water supplies, and potentially at much less cost. But significant conservation efforts would require extensive public buy-in or more likely substantial incentives and mandatory measures.

Until quite recently, water planning in the Houston region strictly addressed the issue of supply. The integrity of the overall aquatic system, taking into account the needs of the natural system including Galveston Bay, gradually rose in prominence such that by the mid-1980s the State's water regulators were directed to consider those needs in granting permits to impound or divert water from Texas' streams. Currently, Region H has recognized the need for freshwater inflows to Galveston Bay in its plans, and has noted the imminent development of environmental flow standards arising from the Texas Senate Bill 3 (SB3) passed in 2007. The issue of balancing environmental flows against what many see as immoderate water use by urban residents may soon dwarf the groundwater-to-surface water-conversion issue as the major source of contention in the water policy arena.

[1] Accessed at http://regionhwater.org/downloads/planningdocs.html

Indicators for Sustainable Water Supply

This section contains specific indicators that reflect trends leading to a sustainable and safe supply of water well into the future. Future generations may not necessarily need the same per capita usage that is available today, yet their life's choices should not be overly constrained by water. Clean water, and the environment that provides that water, should be enriching of their experience. A sustainable water supply does not provide a license to waste water.

Sustainability will include demand-side management, technology advancement, effective project delivery, and supply chain enhancements, not to mention conservation. Sustainable water supply will also involve more transparency and greater stakeholder participation[2].

Water planners face an uncertain future. To a large degree the projected population growth can be planned. But the energy needed to clean and transport water will be subject to uncertain changes, most prominently the rising prices that will be associated with peak oil costs and more stringent regulatory requirements. Climate change will cause even more uncertainty[3], possibly in terms of overall precipitation amounts and patterns. The only certainty is that the "envelope of variability" is going to increase[4]. Building the most resilient system possible is thus imperative.

The indicators proposed here are very limited selections from the world of possible indicators, of which there are many. This limited set of indicators represents summary variables that account for a range of activities. For example, per capita water use encompasses a number of conservation activities, any of which could be put forth as individual indicators.

Both the quantity and the quality of the water available for the Houston region is ultimately tied to the condition of the land – the watersheds and the *recharge zones* that contribute to both surface water and ground water. A recharge zone is a land area through which water can filter relatively easily into an aquifer so as to replenish it.

Water that flows across natural areas, whether forest or prairie, is cleaned by the vegetation through which it flows. In addition, much of the water that flows across natural areas infiltrates the soil, where it percolates deeply into the subsoil and geology below, recharging underground aquifers, or it seeps gradually into streams and rivers. Slow water seepage in surficial soils and sediments functions in a sense as a large reservoir. Pavement and compaction increase the "flashiness" of the system and diminish the potential for recharge.

Lake Livingston

Source: Lake Livingston water reservoir

[2]Binney, P.D. 2010. Sustainability and how water providers can achieve it. Water Resources Impact. (American Water Resources Association Journal) 12 (4): 6-8.

[3]Means III, E.G., M. C. Laugier, J. A. Daw, D. M. Owen. 2010. Impacts of climate change on infrastructure planning and design: Past practices and future needs. American Water Works Association Journal. 102 (6) 56-65.

[4]Milly, P.C.D. and others. 2008. Stationarity is dead: Whither water management? Science 319:573-574 (1 Feb 2008).

Urbanization is the primary agent of disturbance of the water cycle. Ameliorating this impact is similar whether addressing surface water or ground water. The less disturbed areas there are in a watershed, particularly the less pavement or other impervious surfaces there are, the better the watershed will function in terms of recharge or clean surface water. Impervious surface cover, as a percent of the total land area, is a good summary indicator of watershed condition. Impervious surfaces can be reduced by integrating stormwater infiltration techniques, variously known as green infrastructure or low impact development practices, and include things like pervious pavement and green roofs into new or existing developments. Alternatively, compact development results in substantially less imperviousness per capita, enabling larger areas to remain undisturbed for a given population size.

For this report the main zone of groundwater recharge for our area is restricted to more or less the northern half of the eight-county region. The surface-water watershed for our region is quite large, extending past Dallas. Impervious cover in the entire watershed is important, but given that most of the threat of urbanization occurs within this region, monitoring impervious cover in the recharge zone effectively monitors at least the regional impact on surface water supplies.

Impervious Surface

The amount of impervious surface cover in the groundwater recharge zone.

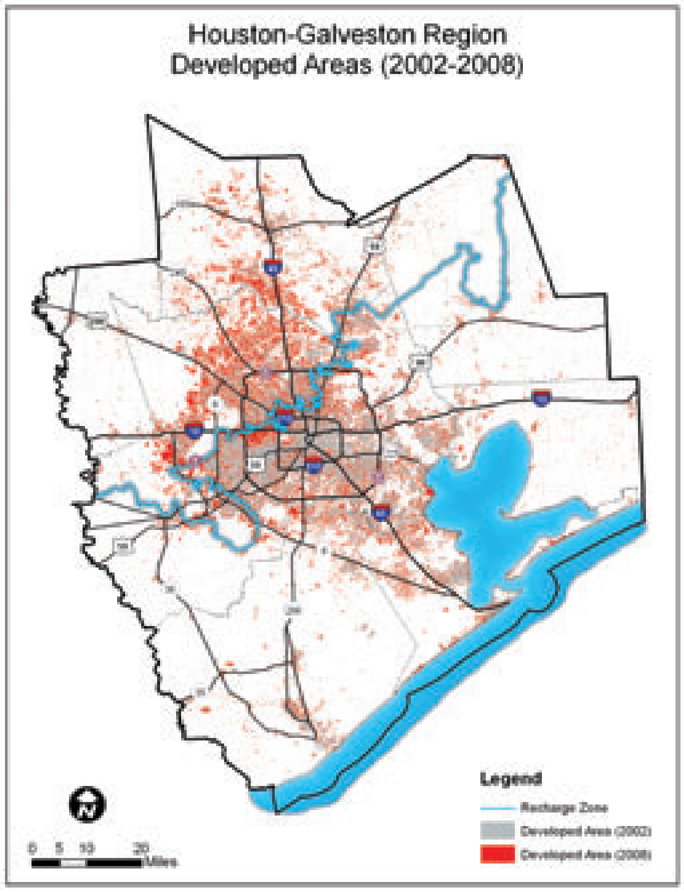
Between 2002 and 2008, in the recharge area (north of the blue line on Figure 2 below) the percent of land that has been developed with impervious cover has increased by 77%, resulting in a total of 20% of the recharge area used for development. This data is summarized in Table 1 in the appendix.

For the same time period, in the southern area (south of the blue line) which is not a recharge zone, there has been a 36% increase of land with impervious cover, resulting in a total of 17% of the land used for development.

As more information becomes available, total impervious surface cover could be modified for so-called "low impact development" subdivisions. Alternatively, a per-capita impervious indicator could be added as well. With current data, a simple percent impervious surface cover is the most straightforward indicator.

Figure 2

Development in recharge and non-recharge zones in eight-county region. Areas to the north of the blue line are in the regional recharge zone.



Source: HGAC.

At present, numbers are only available for developed and undeveloped zones. The data is not of sufficient detail that the numbers could be converted to impervious cover percentages. Nevertheless, the available data does give a sense of current trends. Interestingly, development has proceeded much faster during the past decade over the recharge zone than areas to the south. No data is available on critical thresholds that might exist in terms of decreasing recharge capacity as areas of development grow.

Total Water Usage

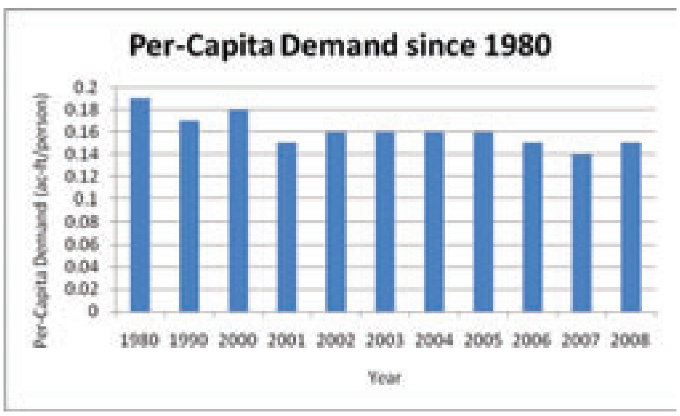
Water used per capita

More water will be used as population increases in the region; however, it is not necessary to use more water per person to accommodate that growth. There are ample opportunities for conservation. Water conservation measures that can be instituted in homes and businesses, from low-flow shower heads to water efficient toilets to automatic faucets.

The biggest use of municipal water by far, at least 50%, is for landscaping. This is clearly an area where conservation could have some significant impacts. Many people unintentionally overwater their yards. Simple irrigation audits could have an impact. Use of compost, top dressed into existing lawns or incorporated into the soil for new lawns, can significantly increase soil water holding capacities, and therefore reduce water use. There are many water saving alternatives to St. Augustine lawns—variously known as watersmart landscapes, water wise landscapes, etc. In addition, many young people and empty nesters are opting for more urban lifestyles living in townhomes or lofts. This trend represents a very significant savings in water use versus maintaining a home and yard.

Figure 3

Municipal per capita water usage, 8-county region



Source: TWDB and U.S. Census reported by the Texas State Data Center

Total water usage does not exactly get at conservation measures because wet or dry years will skew the landscaping numbers in particular, but long term trends in per capita water usage nonetheless will be indicative of the implementation of conservation measures.

Figure 3 illustrates municipal per capita water usage from 1980 to 2008. The data shows that per-capita demand has declined. Further, a comparison with state data in Table 1 indicates that per-capita water usage in the Houston Region is less than Texas per-capita usage. Detailed information on per-capita water usage is available in the appendix.

Table 1

Texas Per Capita Use

Year	Municipal Demand (ac-ft)	Population	Per-Capita Demand (ac-ft/person)	Per-Capita Demand (gpcd)
2000	4,081,013	20,851,820	0.20	174.7
2008	4,209,511	24,326,974	0.17	154.5

Source: TWDB and U.S. Census reported by the Texas State Data Center

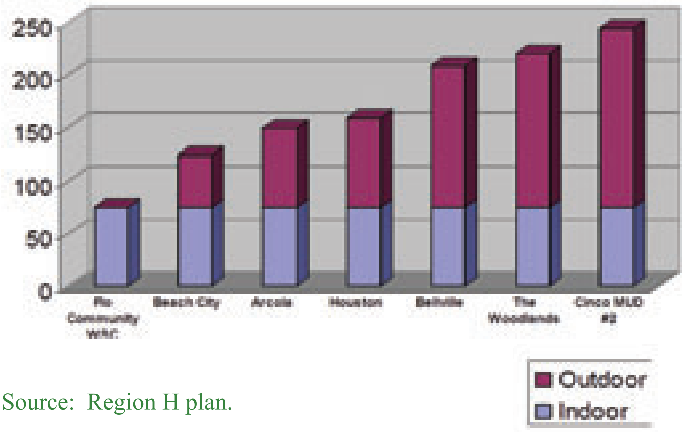
Total Commercial and Residential per Capita Usage

Total non-industrial surface water used in the eight-county region divided by the total population, gallons per day.

Water usage varies with the seasons and with annual rainfall. Very importantly, irrigation demand varies by neighborhood, as shown to the right. Neighborhoods with large lawns tend to be the highest users of water.

Figure 4

Gallons/capita/day municipal water use



Source: Region H plan.

Total Industrial Usage

Total industrial usage, gallons per day.

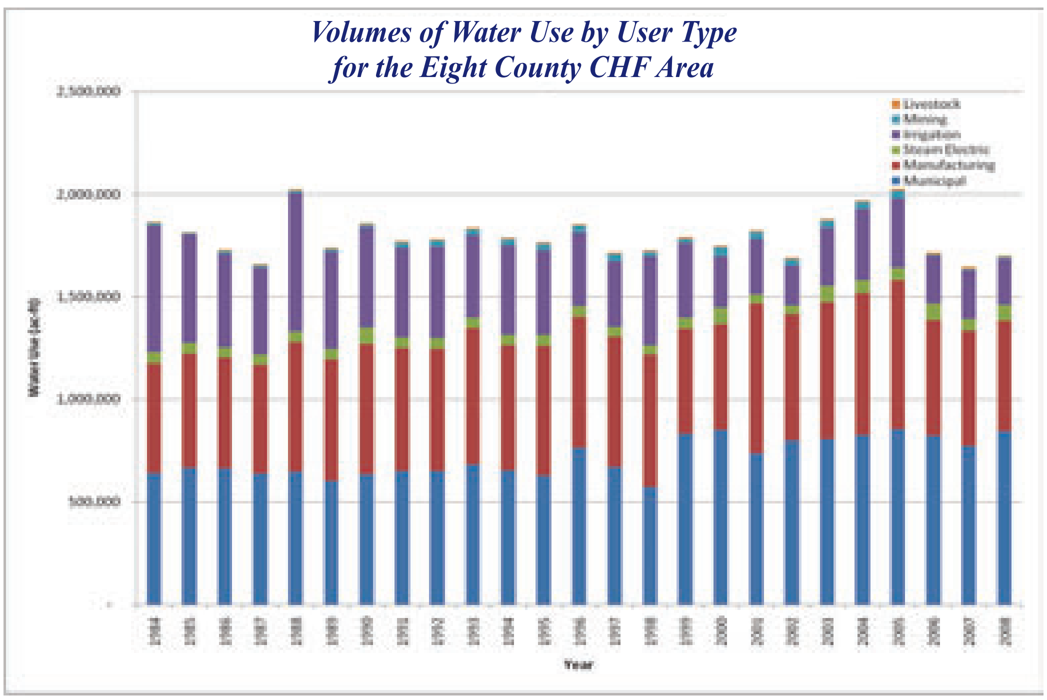
Industrial usage is presented as an indicator, although Figure 4 trends with the available data are difficult to discern. The data is used here as a place marker and to encourage further discussion and research.

Total Ground Water Usage

Most of the eight-county region is under a mandate to convert from groundwater to surface water. Groundwater currently makes up about 30% of the region's total water supply, but it must be reduced to no more than 20% in Harris and Galveston Counties and 40% in Fort Bend County by 2030 to avoid further serious subsidence. The Lonestar GCD has similar regulations to cap the withdrawal of groundwater. The only heavily urbanized area not yet under a groundwater reduction plan is Brazoria County, and there is every reason to believe that they will have such a plan within the next decade. The Subsidence Districts have determined that a percentage-of-total-use target will minimize subsidence from groundwater withdrawals, if the region grows as expected. The Lonestar GCD has attempted to tie groundwater regulations closer to estimated aquifer recharge rates within Montgomery County. Current use of groundwater for the region exceeds 30% of total water usage.

Figure 5

Volumes of water use by type, including manufacturing. Irrigation in this graph is agricultural, not municipal.



Region H Plan 2010

Environmental Flows

- ***Inflows required for maximum bay and estuary fisheries harvest as recommended by Texas Parks and Wildlife Department.***
- ***Minimum inflow required to maintain the bay and estuary fisheries harvest.***
- ***Minimum acceptable inflow required to maintain the salinity needed for bay and estuary fisheries productivity.***

Having a sustainable water supply must include maintaining the ecological integrity of the Galveston Bay watershed, including its tributaries from which the region gets water - the Trinity and San Jacinto Rivers, and to a lesser extent, the Brazos River. These waters provide numerous ecological services beyond clean drinking water. Flowing clean waters are essential, for example, to maintain a vibrant seafood industry in and around Galveston Bay. These waters also carry a significant amount of human waste, but there is a limit to that capacity.

The ecological integrity of the bay system is a function of much more than just the average amount of water that annually flows into it. Texas has adopted a goal of determining flow regimes that are suitable to maintain sound ecological environments in the connected water bodies. These aquatic systems have adapted to flows that have periods of low flow and pulses of higher flow often with overbank flooding. Merging the natural variability of a fluctuating system needed to maintain the ecological health of aquatic systems, with the demands for a consistently reliable water supply for a large and growing metropolitan population is no easy task. It is the responsibility of TCEQ with support from the Texas Water Development Board, the Texas Parks and Wildlife Department, and other experts and stakeholders in a process mandated in 2007 by SB3. The SB3 process is now in progress and is expected to provide recommended environmental flows for tributaries to Galveston Bay within a year.

SB3 requires the identification of environmental flow patterns, sufficient to maintain a sound ecological environment. The State Bays and Estuaries studies conducted over the last two decades established quantities of inflow that would provide for optimized production of a mix of six game species (fish and shellfish) for Galveston Bay. The recommended annual inflow to achieve maximum harvest in Galveston Bay from all sources is 5.2 million acre feet per year, distributed in a monthly pattern that takes into account seasonal requirements. This compares to a median annual inflow to Galveston Bay over the historical period of record (since the 1940s) of about 9.5 million acre feet per year.

Based on these studies, a preliminary indicator of continuing healthy environmental flows to Galveston Bay was developed by the Galveston Bay Freshwater Inflows Group (GBFIG) and incorporated into the Region H Water Plan. A target minimum frequency was identified for each of several flow levels. The Group noted that successful management of inflows to Galveston Bay must consider quantity, quality, seasonality, and location of inflows. The current work will address apportioning inflows by source (the Trinity River and the San Jacinto River) -- recognizing that the Bay derives approximately 20% of its fresh water from direct rainfall, overland flow and ungauged coastal tributaries.

Given the correlation of the inflow scenario to the firm yield numbers for water supply, it would appear that a strict adherence to planning and consumption based on firm yield numbers would, for the most part, accommodate the inflows needed for a healthy Bay ecosystem.

Where do we go from here?

This chapter addresses the water supply issues that the region will face in the next 40-50 years. To accommodate the projected growth, it is estimated that a supply of at least an additional 1,150,000 acre-feet/year of water (about 1 billion gallons of water per day) over and above what is used today will be required, to be obtained primarily from surface water. There appears to be sufficient water available, but three major challenges stand out.

The first is the need to continue the Houston region's transition away from dependence on groundwater to surface water because of subsidence concerns. Groundwater currently makes up about 30% of the region's total water supply, but it must be reduced to no more than 20% in Harris and Galveston Counties and 40% in Fort Bend County by 2030 to avoid further serious subsidence.

Second, according to the Region H Plan, a substantial investment in infrastructure will be needed, on the order of $13 billion, largely to be paid by user fees. Cost to the users will surely rise.

Third is the challenge of balancing human needs with the needs of the ecosystem that ultimately sustains human life. Some tradeoffs, perhaps involving considerable conservation efforts, will be inevitable. Consumers have not yet been asked to pay the true cost of water. There is ample opportunity for substantial water savings from conservation practices without causing noticeable lifestyle shifts. For those opportunities to be realized, both an informed public and a strategic set of incentives will be necessary.

Developed areas in recharge and non-recharge zones of the eight-county region.

	Total Area (Acres) of Developed Land			
	2002	**2008**	**% increase**	**% of total area developed-2008**
Recharge Area	221,759	392,971	77%	20%
Southern Area	444,919	604,485	36%	17%

Source: H-GAC

Appendix

Municipal per capita water usage, 8-county region

Year	*Municipal Demand (ac-ft)*	*Population*	*Per-Capita Demand (ac-ft/person)*	*Per-Capita Demand (gpcd)*
1980	591,154	3,119,831	0.19	169.2
1990	633,826	3,731,131	0.17	151.7
2000	851,754	4,669,571	0.18	162.9
2001	738,913	4,781,077	0.15	138.0
2002	801,604	4,919,189	0.16	145.5
2003	807,781	5,010,925	0.16	143.9
2004	827,497	5,121,840	0.16	144.3
2005	853,891	5,222,861	0.16	146.0
2006	822,629	5,434,051	0.15	135.2
2007	773,891	5,547,134	0.14	124.6
2008	844,339	5,665,822	0.15	133.1

Source: TWDB and U.S. Census reported by the Texas State Data Center

Water & Health

Author: Vincent Nathan, Ph.D.,M.P.H., Associate Professor, School of Rural Public Health, Texas A & M Health Science Center

Executive Summary

As a whole, the eight-county region meets or exceeds regulatory standards for safe drinking water. However, segments of the overall watershed do not. Buffalo and White Oak Bayous fail to meet the regulatory standards.

Water-borne disease associated with water use are seldom recognized; however, the incidence of infections are increasing. Data on the incidence of waterborne illness in the eight-county region is incomplete because many people who get sick have no idea that ingesting contaminated water may have been the cause.

With population growth in the Gulf Coast region increasing, more people could become sick from water exposures unless and until the sources of contamination are addressed. The sources of water contamination that are of particular concern include: surface water (lakes and rivers), water treatment systems, production systems (wells) from groundwater, and aging water infrastructure. The medical infrastructure and the academic community in this region are ideal for collaborative efforts on solutions to these challenges.

The Water Supply and Water Quality chapters offer background to this discussion. The major difference, however, is the focus on drinking water. An important aspect of this chapter is the distinction between the data on water quality and the health implications of drinking water. The direct health implications and the regulatory purpose of surface water quality, under the Clean Water Act, are mainly focused on recreation, wildlife and seafood. While water quality is not unimportant to treated surface derived drinking water, it is the after treatment water quality that is of primary concern. However, according to the Centers for Disease Control and Prevention, even recreational water infection incidence has steadily increased over the past several decades.

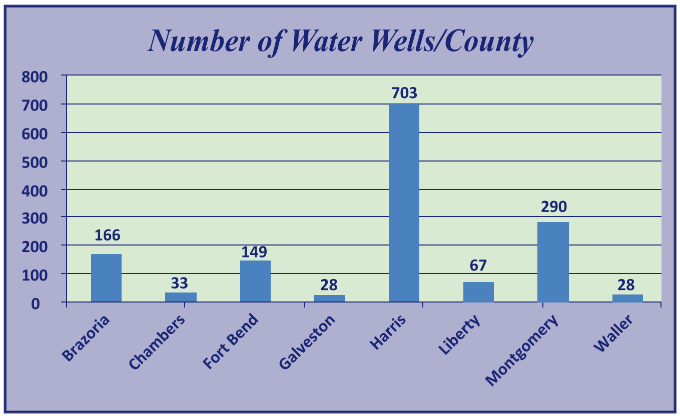
Lake Houston

Photo by: Texas Parks & Wildlife

Regulatory Status & Background of Region

TCEQ, which regulates public water systems, has identified 17 public surface water community systems for the eight-county area. In addition, the area utilizes a number of ground-water wells to obtain drinking water. Table 1 lists community water systems with their respective number of water wells: Brazoria (166); Chambers (33); Fort Bend (149); Galveston (28); Harris (703); Liberty (67); Montgomery (290); and Waller (28).

Table 1
Number of Water Wells/County

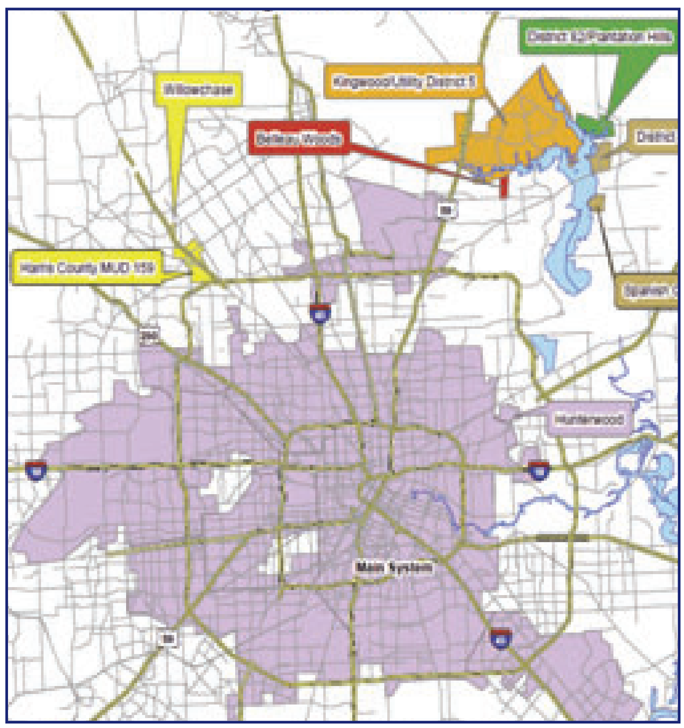


Source: City of Houston

According to the City of Houston's Public Works & Engineering department, the Houston main system (map) provides drinking water and wastewater utility service to approximately 2.8 million customers daily. The Drinking Water Operations Branch is responsible for protecting, operating, and maintaining three water purification plants and 92 ground water pumping stations. Houston's water system, the largest in the region, is spread across a four-county, 600 square mile area, making it one of the most complex water systems in the nation. Surface water makes up 71% of the supply and flows from the Trinity River into Lake Livingston, and from the San Jacinto River into Lake Conroe and Lake Houston. Deep underground wells drilled into the Evangeline and Chicot underground aquifers currently provide the other 29 % of the City's water supply.

As mentioned in the Water Supply chapter, because of subsequent and historic indiscriminate pumping from the aquifers, the region was compelled to convert most of the water supply to surface sources. Existing municipal utility districts, MUDs, have been responsible for supplying water to practically all of the developments in unincorporated areas, including many that have since been incorporated into municipalities. More than 700 MUDs supply needed water and other services. To accomplish the massive transfer to surface water, 3-4 regional water authorities were established to manage the process. Nevertheless, the City of Houston controls the vast majority of the region's water rights, and provides most of its treated water. Other major regional providers include the Trinity, San Jacinto, and Brazos River Authorities, and the Gulf Coast Water Authority. These entities account for more than 80% of the available firm supplies from surface water. Two subsidence districts, Fort Bend (FBSD) and Harris-Galveston (HGSD) regulate the withdrawal of groundwater in their respective counties.

City of Houston Drinking Water Service Areas



Source: City of Houston

The EPA promulgated the Safe Drinking Water Act (SDWA) to protect the quality of drinking water available to the public. This law focuses on all drinking water, whether from above ground or underground sources. SDWA establishes minimum standards to protect drinking water supplies and requires all owners or operators of public water systems to comply with primary (health-related) standards. In Texas, EPA delegates this authority to TCEQ. EPA encourages attainment of secondary standards (nuisance-related). Under the SDWA, TCEQ also establishes minimum standards for state programs to protect underground sources of drinking water from contamination by underground injection of fluids. TCEQ writes, adopts, and enforces Texas specific rules that are at least as stringent as the EPA rules. These rules, measures and requirements ensure that water produced and distributed by a public water system is safe to drink. Currently, TCEQ requires water systems to test for 126 chemicals, of which 72 have maximum contaminant levels (MCL).

These include 21 volatile organic compounds, 33 synthetic organics, 15 inorganic compounds, and 3 radionuclides. In addition, TCEQ requires public water suppliers to test for bacteria, lead and copper, and 16 secondary contaminants such as iron, manganese, and chloride which do not affect human health but lead to odor or taste problems (secondary standards). The Department of State Health Services implements federal Food and Drug Administration and Texas regulations for water haulers, bottlers and vendors. TCEQ enforcement covers restaurants, day cares, hospitals and other entities that may own or operate public water systems.

Table 2 illustrates the primary and emerging contaminants in ground and surface waters and their importance to health. For groundwater, wells are of concern from naturally occurring chemical compounds, such as arsenic, radionuclides, and intrusion of biological agents, such as sewage.

Table 2
Sources of Waterborne Contaminants
(levels of concern 0-4 with 4 being the highest)

			Surface Water				
Constituent of concern (representative examples)	***Unregulated groundwater drinking water***	***Groundwater Production well packing/grout***	***treated drinking water***	***recreational exposure by contact***	***recreational exposure by seafood ingestion***	***Treatment Systems***	***Distribution Systems***
Microbial pathogens/parasites (viruses, bacteria, protozoa)	2	0	0	4	4	0	1
Inorganics (metals, nitrates, asbestos)	2	1	0	1	3	0	1
Synthetic colatile organics (solvents, hydrocarbons)	2	0	0	1	1	0	1
Synthetic semi-colatile organics (pesticides)	2	0	0	3	4	0	1
Emerging synthetic organics (pharmaceuticals, plasticizers, fire retardants, detergents, pesticides)	2	2	4	4	4	2	?
Radionuclides (alpha, beta, radium, uranium)	2	0	0	0	0	0	0
Residual disinfectants (trihalomethanes, chloramines)	0	0	0	0	0	1	1
Lead & Copper	0	0	0	0	0	0	4

Source: Richard E. Woodward, Sierra Environmental Services

The 2009 Houston Drinking Water Quality Report issued by the Department of Public Works and Engineering examined six systems and presented information regarding regulated and unregulated contaminants. Information on the maximum contaminant level goal (MCLG), maximum contaminant level, the averages, and the minimums and maximums were presented for each contaminant.

The Partnership for Safe Water, a national organization whose mission is to improve the quality of drinking water delivered to customers of public water supplies by optimizing system operations, awarded the City of Houston the organization's Director's Award. This award is presented to water systems that have completed a successful review of the organization's self assessment and peer-review phase, in which utilities examine the capabilities of their treatment plant operations and administration and then create a plan for implementing improvements. The City of Houston has maintained the Director's Award for ten consecutive years.

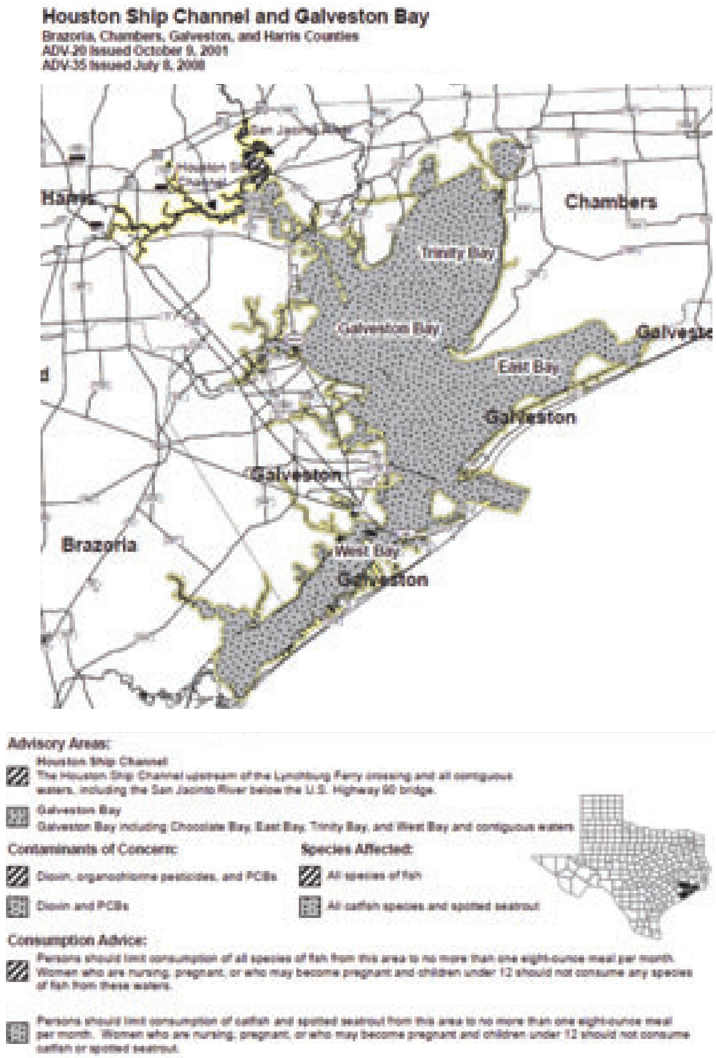
Public postings of contaminated waters are important for community health. The coastal areas have a large busy industrial watershed, the Houston Ship Channel and Galveston Bay. The accidents and spills from the land and water-based petrochemical activities coupled with salinity intrusions from agriculture and hurricanes have left subsistence anglers limited places to catch seafood safe for consumption.

Figure 2 shows the posting from 2001 and 2008 for the Houston Ship Channel and the Galveston Bay pollutants found in seafood. Warnings and postings are often misinterpreted or ignored, especially for seafood. One simple change would be the metrics of seafood consumption because most subsistence anglers probably do not weigh their catch. For example, the use of *n* ounces should be changed to either the number of fish or the size per meal. Educational outreach is needed to address the health effects of contaminated seafood.

Inorganic Contaminants "Metals" Detected in Galveston Bay Seafood Samples

- Arsenic
- Cadmium
- Copper
- Lead
- Mercury
- Selenium
- Zinc

Figure 2



Organic Contaminants Detected in Galveston Bay Seafood Samples

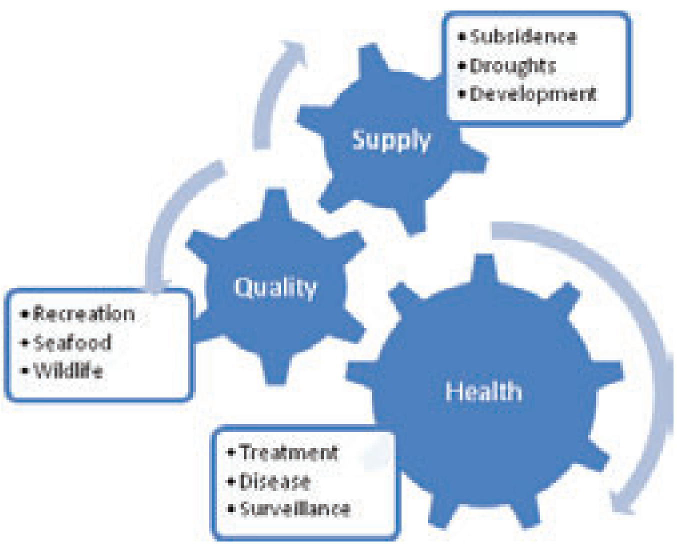
- PCBs
- PCDDs/PCDFs
- Pesticides
  chlorine, dieldrin, endosulfans, pentachloroanisols, pentachlorobenzene, hexachlorobenzene, various DOT derivatives, and mrex
- SVOCs
  phenalate esters, acenaphthane, fluorine, and phenol
- VOCs
  acetone, methylene chloride, 1,2-dichloroethane, acrolein, benzene, toluene, and naphthalene

Surveillance and Public Health Tracking

Surveillance and tracking are important for monitoring and assuring that water supplies are safe. Recent developments in spatial and temporal data tracking and interpretation using GIS may play an important role. Water suppliers need to understand microbes and disease causing agents because they have primary responsibility for keeping drinking water safe.

Pathogens are microbes that cause disease. The term "germ" is commonly used to describe microscopic organisms, parasites, viruses, and fungi that may be in water supplies. Although monitored by health officials, the presence of parasites in public water supplies is seldom considered a health threat. However, when disease-causing organisms are present in sufficient quantities, water-borne outbreaks can affect large populations, if not identified and controlled. Important bacterial pathogens found in this region and transmitted via contaminated water are Vibrio, which causes cholera; enterotoxigenic Escherichia coli, which causes diarrhea; Shigella which can cause dysentery; and, Salmonella or food poisoning. In some cases, animals are more likely to play a role in water-borne disease. Fecal bacteria from animals have caused outbreaks of water-borne disease in areas where water is not properly chlorinated.

This illustration shows the influence of water supply and water quality on health.



Source: Vincent Nathan, Ph.D., Texas A&M University

In addition to assuring that the water supply is free of disease causing substances, some people have focused on presumed noninfectious outcomes such as cancer and birth defects caused perhaps by chlorinated byproducts. As part of the water treatment process, drinking water is usually disinfected to reduce microbial contamination. However, disinfectants, such as chlorine, can react with organic matter in the water, by creating by-products that are thought to cause cancer.

Many chemical contaminants present in drinking water, such as pesticides or naturally-occurring toxins, are not removed by standard drinking water treatment processes. For example, chlorination has no effect on certain waterborne protozoa, such as cryptosporidium, that can cause acute diarrhea. Some diseases are acquired by drinking water contaminated at its source in the distribution system, or by direct contact with environmental and recreational waters. It is also assumed that current water quality standards are sufficient to protect the public against the risk of gastrointestinal (GI) disease. The apparent lack of outbreaks in this region seems to support this view. However, research[1,2] has shown results suggesting that there is a non-trivial widespread level of unreported GI diseases due to the consumption of tap water. In one study, 35% of GI illness was estimated to be attributable to the consumption of drinking water that meets current water quality standards. The main impact of tap water seems to be the growing number of "susceptible" rather than actual cases. This supports a recommendation for a tracking or surveillance system for GI illnesses for the region.

A major challenge to disease surveillance and detection is to not only detect and report known infectious diseases, but also to identify emerging or reemerging diseases. There is a corresponding need to develop redundant and complementary systems for infectious disease detection that go beyond traditional surveillance systems and approaches. Outbreaks of diseases, such as bacillary dysentery and acute diarrhea associated with improper water treatment, caused by cross-contamination of waste-water systems and potable water supplies have been noted in Texas, though none documented in this region. The TDHS Houston regional office stated that no reportable waterborne diseases were found in Liberty and Waller counties. However, it should be noted that the regional office does not have jurisdiction for the other six counties in this study. Therefore, these are the only counties included in their disease surveillance. There were no cases in either county where water was the confirmed cause.

Water Quality & Health

As a whole, the region meets or exceeds regulatory standards for safe drinking water. However, segments of the overall watershed do not, specifically Buffalo and White Oak Bayous. They suffer from being in the heart of a completely urbanized area, including downtown Houston, the theater and entertainment districts, residential development, high volume mixed-commercial development and light industry. In addition to a large number of municipal and industrial waste-water discharges, Houston bayous receive significant amounts of urban stormwater runoff. Interstate-45, Interstate-10, and US Highway 59 are major thoroughfares that converge in downtown Houston. Despite having several parks and natural areas along their banks, intense redevelopment during the past five years as occurred, increasing the surrounding population and contributing to contaminants in the bayous.

Freeway interchange overlooking Buffalo Bayou

Photo by: Tom Fox and Kevin Shanley, Courtesy of SWA Group and BPA

In Harris County there are approximately 450 municipal sewage wastewater treatment plants and 212 active industrial wastewater treatment facilities permitted by TCEQ to discharge treated wastewater to streams. Many facilities in Harris County also issue permits to discharge treated storm water after significant rain. The Water Surveillance Section of the Harris County Public Health & Environmental Services Department is responsible for inspecting wastewater treatment facilities, monitoring discharges, and collecting samples to give to the Environmental Public Health Division for analysis. Violation notices are issued when the collected samples do not meet the permit water quality parameters.

H-GAC Clean Rivers Program reports that bacteria are the major concern in 90% of the streams that do not meet the state standard. Overall, bacteria and nutrient concerns and/or impairments are found throughout Buffalo Bayou. Elevated bacteria levels likely stem from sources such as intermittent municipal collection system overflows, failing septic systems, pet waste, and naturally occurring wildlife and avian populations scattered throughout the watershed. Nutrients can come from the above sources, as well as fertilizers applied to lawns and golf courses. Levels of bacteria and nutrients are usually elevated after rainfall events that result in stormwater run-off.

San Jacinto Waste Pit Superfund site

Photo by: Marilyn Christian

Wastewater and Water Reuse

Contamination events in wastewater systems may also affect drinking water as upstream wastewater outflow enters surface water which in turn will enter the drinking water treatment plant. Many water-borne diseases come from pathogenic organisms that live in water or require water during part of their life cycle. These diseases are passed to humans through ingestion or contact with skin and include most of the intestinal and diarrheal diseases caused by bacteria, parasites and viruses. Evidence suggests that water-borne diseases also contribute to background rates of other diseases that are not detected or explicitly reported as outbreaks.

Many questions and problems complicate the resolution of these issues:

- What will contaminants do to treatment plant organisms?
- Will the treatment process remove contaminants before discharge, or will they pass through to the receiving stream?
- Will contaminants permanently affect pipes, basins, etc. requiring extensive long term remediation and/or replacement?
- How will contaminants affect the receiving stream either from flushing and discharge to the storm water system or through the sanitary sewer system?
- How will downstream users be affected? It is possible for contamination in one water system to affect multiple systems downstream.
- Will the TCEQ and EPA allow discharge to the receiving stream? What will treatment plants do if they cannot discharge to receiving streams?

The impact of an event will depend on the specific contaminants, how much was introduced and how large a contamination plume before detection. To address these issues and protect public health, new technologies are needed for rapid detection, identification, notification, and treatment of conventional and emerging pathogens and contaminants, as well as those resulting from intentional contamination. Less expensive water treatment technologies are also needed to treat pollutants in rural communities.

Disposition of wastewater poses a serious threat to surface water. Organic compounds left untreated are discharged directly into streams and lakes. They then flow downstream to be used as drinking water in some downstream communities. Biosolids containing the accumulated concentration of untreated organic compounds are often spread on agricultural lands where they can be washed into local water sources. The concentration of these compounds increases due to the limited assimilative capacity of receiving streams and reservoirs. Some propose that waste reuse is a solution where biosolids are processed into organic fertilizer which can then be used on grazing land.

Emerging Contaminants

Water related public health issues focus on drinking water. Technologic advances in watershed protection, drinking water treatment, and drinking water distribution system management and protection have helped to ensure that most waterborne agents responsible for human illness are removed and/or inactivated. Critical public health issues of water quality include diagnosis of adverse health outcomes, exposure assessment, bio-monitoring, and illness prevention. Along with pathogens, the presence of "conventional contaminants" continues to be an issue. Nitrates, arsenic, lead, mercury, radionuclides, and other known contaminants exert widespread adverse impact on drinking water and public health.

There are also growing concerns over the presence and impact of emerging pollutants such as endocrine disrupting chemicals (EDCs), and pharmaceutical personal care products (PPCPs), chemicals that may interfere with the normal functioning of the hormone system of people and wildlife. While their impact could be significant, no cost effective analyses have been developed to detect these chemicals in drinking water.

Panorama of development adjacent to Buffalo Bayou

Photo by: Tom Fox and Kevin Shanley, courtesy of SWA and BPA

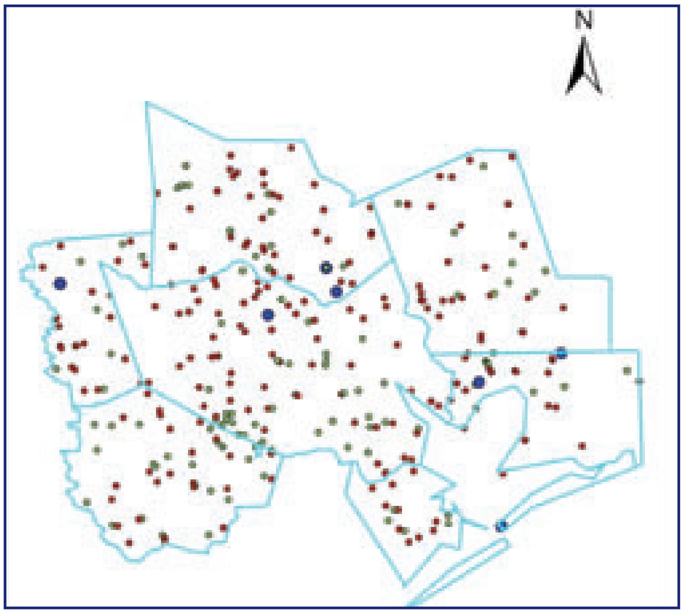
When municipal water treatment systems introduce the use of chloramines for the purpose of reducing carcinogenic by-products from chlorination, they may inadvertently increase exposure to lead in the water supply. Definitive conclusions regarding the use of chloramines are difficult because of the particular combinations of disinfection agents, anticorrosives, coagulants, and fluoride additives used in water treatment systems. Because chloramines can affect kidney dialysis patients, communities must be alerted when chloramines are used for water disinfection.

Arsenic occurs naturally in different forms and is widely distributed in rocks, soil, water and air. The extent of human exposure to arsenic in tap water is especially problematic in wells. Figure 3 shows arsenic levels in the region. The demand on ground water from municipal systems and private drinking water wells may cause water levels to drop and release arsenic from rock formations. Arsenic is potentially hazardous at high levels for private well owners. Because it cannot be seen or tasted, well owners should test for arsenic. Compared to the rest of the U.S., western states have more systems with arsenic levels greater than EPA's standard of 10 parts per billion (ppb). While many systems may not have detected arsenic above 10 ppb, there may be geographic areas that have higher levels of arsenic than what might be predicted .

High levels of inorganic arsenic in drinking water are associated with the prevalence of type 2 diabetes in a representative sample of US adults. However, the effect of arsenic at low to moderate levels is unknown. A cross-sectional study in 788 adults aged 20+ years who participated in the 2003-2004 National Health and Nutrition Examination Survey had urine arsenic tests. After adjustment for biomarkers of seafood intake, total urine arsenic was associated with increased prevalence of type 2 diabetes. This finding supports the hypothesis that low levels of exposure to inorganic arsenic in drinking water may play a role in diabetes. Studies in populations exposed to a range of inorganic arsenic levels are needed to establish whether this association is causal.

Figure 3

Arsenic in Groundwater (Mean Value)



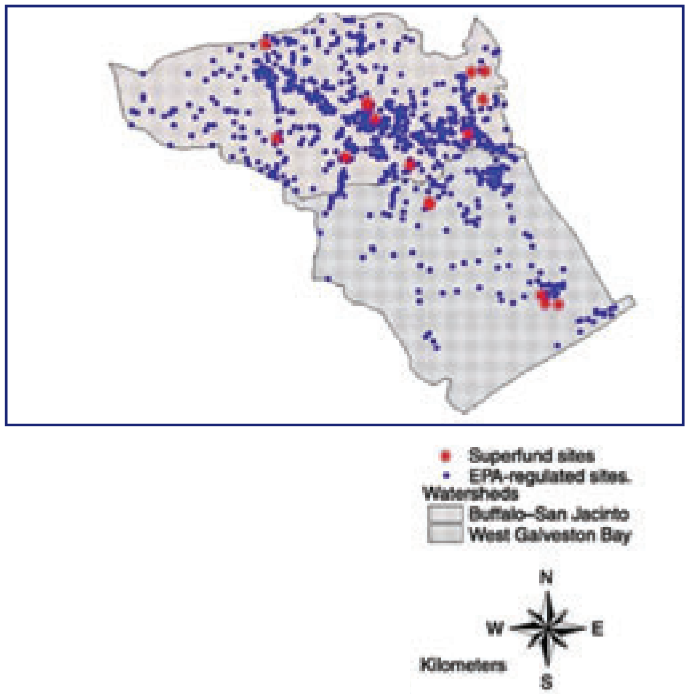
Source: Texas A&M Health Science Center

The extent of human exposure to nitrates in tap water has major reproductive concerns. Texas A&M Health Science Center is leading a National Institutes of Health statewide study on nitrate health impacts. In a case-control study of Mexican-American women in Texas, researchers[5] examined nitrosatable drug exposure and found an increased risk of occurrence of neural tube defects (NTDs) in relation to dietary nitrites and nitrates. A neural tube defect causes anencephaly and spina bifida, among other neural-related diseases. Other studies have found an increased risk for NTDs among babies born to mothers living in areas where the drinking water nitrate level was above the maximum contaminant level (MCL) compared with those in areas below the MCL (Odds Ratio = 2.7; 95% Confidence Interval, 0.76-9.3). Risk estimates were higher among groundwater users; however, other risk factors (e.g., Hispanic ethnicity, young age, low socioeconomic status, and no vitamin use) for NTDs were also more common among groundwater users. Risks doubled for anencephaly when mothers lived in areas where the nitrate level in groundwater was equal to or greater than 5 mg/L compared with lower levels.

Another problem identified is the association of water and cancer. Two watersheds, the Buffalo–San Jacinto and West Galveston Bay area, showed increased risk for renal cancer and acute lymphoid leukemia, respectively[6,7]. Wilms tumors, the most common renal tumor, and other renal tumors peak in very early infancy, suggesting fetal exposure.

Figure 4

Known water hazards near Houston



Source: Journal of Water & Health, Mar2010, Vol. 8 Issue 1, p139-146, 8p, 2 charts, 4 maps, Map found on p144

Table 3

Two watersheds near Houston (Buffalo–San Jacinto and West Galveston Bay) and their increased risk for cancers

		SMR risk percentiles			
	Cancer	*25*	*50*	*97.5*	*Posterior probability that SMR > 1*
Lake Meredith	**Astrocytoma**	**0.94**	**1.52**	**2.73**	**0.95**
Upper Prairie Dog Town Fork Red	**Astrocytoma**	**0.94**	**1.54**	**2.67**	**0.95**
Middle Canadian-Spring	**Astrocytoma**	**0.83**	**1.46**	**3.30**	**0.91**
Upper North Fork Red (BUGS #17)	**Astrocytoma**	**0.91**	**1.54**	**2.85**	**0.94**
Upper Salt Fork Red	**Astrocytoma**	**0.81**	**1.46**	**2.88**	**0.90**
Middle North Fork Red	**Astrocytoma**	**0.77**	**1.50**	**3.36**	**0.90**
Buffalo-San Jacinto	**Renal**	**1.00**	**1.31**	**1.73**	**0.97**
West Galveston Bay	**ALL**	**0.95**	**1.23**	**1.62**	**0.94**
South Laguna Madre	**Atypical leukemia**	**0.92**	**1.54**	**2.58**	**0.96**

Source: Journal of Water & Health, Mar. 2010, Vol. 8 Issue 1, p143

Acute lymphoid leukemia (ALL) is the most common and most studied childhood cancer. Figure 4, shows known water hazard locations of high risk in two watersheds. ALL has been linked to benzene, a known carcinogen, and other solvent contaminants of drinking water[8,9]. ALL has a prominent incidence in early infancy for Caucasian children but not for African-American children, suggesting that the role of prenatal exposures or genetic resistance may be different among these race groups. These two watersheds had 986 EPA-regulated sites, including 15 superfund sites (Figure 4). Further investigation should include a more detailed risk analysis as it is likely that some areas within the same watershed have higher and lower risk likelihoods. Researchers[10,11] have speculated that pesticide exposure is a cause of childhood cancer and it has been the focus of many studies. However, a definitive cause-and-effect relationship has not been demonstrated.

Groundwater and Wells

Approximately 6% of Texas residents obtain drinking water from private wells. Unlike public drinking water systems, private wells are not required to be inspected for water quality before the water reaches the tap. These households must take special precautions to ensure protection and maintenance of drinking water supplies.

Unplugged abandoned wells are also a concern since they can threaten the quality of drinking water from both private wells and those servicing public water supply systems. When a gas or oil well is no longer productive, it must be properly plugged, usually with cement, as mandated by law. However, in Texas[5], officials estimate that 40,000 to 50,000 abandoned wells may pose groundwater pollution problems. Without proper plugging, brine may flow up well shafts and seep into fresh water aquifers or contaminate surface waters. This is an oil and gas problem, but not the same problem as faced in today's water-energy co-production where tremendous amounts of fresh water are turned into brine in establishing oil or gas wells.

In summary, the presence of water-borne contaminants such as lead, nitrates, arsenic, mercury, radionuclides, and other well known microbial contaminants continue to exert widespread impact on drinking water and public health. However, the presence and impact of emerging pollutants such as EDCs and PPCPs need additional study. Researchers[12], found that human and veterinary pharmaceuticals and other organic wastewater chemicals were detected in 80% of streams sampled. The US Geological Service's Toxic Substance Hydrology Program is conducting research on the occurrence of these compounds in susceptible wells and drinking water sources. Little is known about the human or environmental impacts of these compounds in drinking water, especially at low concentrations. Also, the increasing sensitivity of the population of immune compromised or immune-suppressed individuals requires further research.

[5] The Texas Railroad Commission maintains historical information encompassing the history of each Texas oil and natural gas well from the drilling permit application to the final plugging. The Oil and Gas Potential profile includes applications to drill, oil and gas completion reports, plugging reports, producer's transportation authority and miscellaneous records from 1964 to present. The Well Log (WL) profile includes images of all well logs received since July 2004.

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Policy Analysis and Implementation

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Introduction

The Global 2000 Report to President Jimmy Carter released in 1980 by the Council of Environmental Quality and the United States Department of State projected that, by the year 2000, the world would be more crowded, polluted, and susceptible to shortages. The report predicted periodic and severe water shortages accompanied by increased demand for water. Several decades later, the numbers tell a different story:

- During the last 100 years, water supply and quality has increased around the world. The progress particularly accelerated between 1975 and 2002. During this period, access to safe water in low-income countries is estimated to have increased from 19.6% to 76%[8].

- Each year between 1990 and 2000, 70-80 million additional people were provided with improved access to safer water and sanitation[8].

However, despite the undeniable progress, more recent data indicate that 18% of the world's population still lacks access to safe water, and 40% lack access to adequate sanitation, mainly in rural Asia and Africa. The World Health Organization estimated in 2000 that unsafe water and poor hygiene still cause approximately 3.1% of total deaths worldwide[8].

This chapter reviews the theoretical and empirical knowledge about water resource management. It shows that while the progress on water management has been enormous, water management issues, particularly infrastructure and contamination, continue to be at the top of the list of policy makers' agendas. By highlighting best practices as well as potential pitfalls, this chapter can help direct public policies regarding the provision and the safety of water.

This chapter also summarizes the literature on the progress of water management during the last 100 years in the United States generally and in Houston particularly, and determines the key issues that need to be addressed in public policy. It provides an overview of the literature on tradeoffs between costs and risks, and identifies potential pitfalls in designing public policy. Potential pitfalls in implementing public policy are described along with reviews of the best practices in managing common-pool resources, particularly the work of 2009 Nobel Laureate for Economics Elinor Ostrom. The final section summarizes key public policy lessons on water management that could help structure future water-related policies in the greater Houston region.

Turbulence from Buffalo Bayou

Photo by: Justin Bower

Water in the United States

Compared to the rest of the world, sufficient availability of water and better sanitation in the United States has resulted in improved overall health and almost complete elimination of water-related fatalities.

- Pollution incidents as well as toxic residues found in humans have been sharply down[26].

- Water-related deaths were reduced by 100% for typhoid and paratyphoid between 1900 and 1997, by 99.8% for gastrointestinal diseases between 1900 and 1970, and by 99.6% for dysentery between 1900 and 1997[8].

Technological changes have reduced the cost of producing clean water and played a key role in improving water availability and quality.

- Researchers calculated that in high-income countries, desalination is relatively cheap, at costs of $700 to $1900 an acre-foot of desalinated water (325,851 gallons). Even if a household had to pay the highest cost, it would pay a maximum of $500 per year for water[26].

The U.S. federal government also played an important role in improving water supply and quality. It provided funds for construction of water and sanitary facilities, regulation of pesticides, and requirements for fishing and swimming water even before the passage of the 1972 Clean Water Act (CWA) and the 1974 Safe Drinking Water Act.

- The government regulates more than 80 specific contaminants and monitors hundreds of water quality parameters[13].

- The U.S. water infrastructure serves more than 250 million people.In 2002, the total annual expenditures for U.S. public drinking water were approximately $36 billion[13]. In 2009, EPA estimated that U.S. drinking water utilities need $344.8 billion in infrastructure investments during the next 20 years, including publicly owned wastewater pipes and treatment facilities, combined sewer overflow correction, and storm-water management[32].

Despite the great investments and improvements achieved during the past several decades, two issues, water supply and water quality, still cause concern. An examination of these issues reveals that aging water infrastructure and water contamination are at the top of the list of water related issues in many parts of the U.S. today.

U.S. Water Contamination

Despite dramatic improvements, water contamination is still pervasive. The main source of water contamination is local human activity, which affects both ground and surface water.

Agriculture is by far the most extensive source of water pollution, affecting 70% of impaired rivers and streams and 49% of impaired lake acres. Additionally, due to the massive and unregulated use of antibiotics in agriculture and aquaculture, potential health hazards can emerge from waterborne pathogens developing resistance to antibiotics. Besides agriculture, major water pollutants include industrial production, hazardous waste sites, residential development, and transportation. Finally, naturally occurring contaminants such as arsenic and other trace metals can also cause health-threatening contamination[13].

Water in the Region

In 1997, the Texas Water Development Board divided the state of Texas into 16 regional water planning areas headed by regional water planning groups that guide the development of each region's plan. The greater Houston area is located in Region H. Population in Region H is projected to grow from approximately 6 million in 2010 to approximately 11.3 million in 2060[23]. The doubling of population in the coming fifty years will place additional pressure on the existing water infrastructure and water quality.

Water Infrastructure

The Houston region generally does not suffer from a lack of water. Unlike the barren and dry western half of Texas, areas of Texas east of I-35 which include this region are water abundant. The majority of its water supply comes from Lakes Conroe and Houston within the San Jacinto River basin and Lake Livingston within the lower Trinity River basin.

While the region does not generally suffer from lack of water, the city of Houston and other older cities in the area face problems with water infrastructure. The area's typical intense rainfalls are a particular burden for aging flooding and drainage infrastructure:

- Approximately 60-65% of all drainage infrastructure in Houston is past its useful life and 80% will be past its useful life in 20 years[5].

- Approximately 60% of Houston's gravity sanitary sewers are 40+ years old, or of unknown age.

- Approximately 30% of Houston's drinking water infrastructure is 40+ years old, or of unknown age.

Houston Water Quality

The city of Houston has not experienced any major human health impacts from contaminated water. It has made significant progress particularly in the expansion and repairs of its sewage system. With an investment of more than $1 billion since the 1980s, the city has reached a discharge compliance rate of 99%[3].

While the lack of recorded data indicating direct water-related health issues may suggest that the city of Houston does not need to be concerned with water quality, an examination of the key water-quality indicators suggests the opposite:

- Houston's and the region's waterways fail to comply with federal standards set by the CWA. All major bayou and stream systems suffer either from elevated fecal coliform bacteria or industrial contaminants[3].

- Sources of bacteria currently found in the region's waterways come mostly from the following sources: 1) aging wastewater treatment facilities by cities and municipal utility districts (MUDs), package plants, and other system infrastructure; 2) bacteria from animal waste; 3) street runoff; and 4) chemicals in the grass such as fertilizers that drain into the water systems[3].

To meet CWA requirements, the Texas Commission on Environmental Quality (TCEQ) initiated a project called Total Maximum Daily Load (TMDL). TMDL's goal is to determine the amount of a pollutant that a body of water can receive and still support its designated uses. The load is then allocated among all the potential sources of pollution within the watershed, and measures to reduce pollutants are developed as necessary. In this region, this project is led by the TMDL Project for Bacteria. Additionally, the Bacteria Implementation Group, a thirty-member committee which operates under the Houston-Galveston Area Council, is preparing an implementation plan to remedy high levels of bacteria in waterways identified in four TMDL projects in the Houston region.

Risk Assessment and Allocating Resources to Their Best Uses

While the identification of the key water-related issues is relatively easy – aging water infrastructure and water contamination – determining the best solutions require a careful assessment of the tradeoffs between costs and risks. Sometimes, the cost of a solution outweighs its benefits; other times, a cost-effective solution that alleviates one risk introduces a different risk. Furthermore, popular attitudes tend to exaggerate the levels of risk associated with water quality, such as the risk of skin cancer associated with arsenic digestion, or the impact of acid rain on the pH of lakes[29, 33]. These negative public attitudes complicate the prioritization of risks to be targeted. Water treatment decisions can also be obscured by the lack of effective inference methods and reliable data[4].

This section provides examples demonstrating that successful management of water supply and quality involves a blend of policies specifically tailored to local conditions. These policies must carefully weigh all known costs and benefits of available alternatives, involve public as well as private funding, consult and educate the broader public, and take into consideration the interaction of the various agencies controlling water policies.

Efforts to Eliminate Risk: How Much is Too Much?

Public policy analysts have long pointed out the disconnect between public opinion and the actual risk. They generally describe two reasons why adherence to public opinion by policy makers may not be the best solution.

The first reason, availability heuristics, reflects the physiological fact that recent events are stored in short-term memory and are more readily recalled when assessing risks. The second reason, the probability neglect, shows that people tend to overlook real probabilities when making decisions.

Because of the public's tendency to inaccurately evaluate risks, policy makers must carefully weigh costs and benefits to solve the most pressing issues with the most effective methods. An appropriate analysis should consist of measuring the magnitude of a problem, assessing tradeoffs (including the cost of regulation), and using smart tools to reduce cost and maximize effectiveness[29].

Elimination of Risk in Water Supplies

The need for a better assessment of risks vs. costs applies to water management as well. Researchers have found that the practice of complete elimination of potential risk of water shortages is ineffective and that some level of risk may be acceptable.

"In light of the high and growing costs of water development, it may be sensible to revise the water planning paradigm, so that periodic shortfalls are regarded as acceptable, even planned, events"[10].

Some level of risk of water shortages may be justified due to the excessive costs of building and maintaining the municipal water infrastructure, and to the costs for the non-municipal sector, especially for the habitat systems. Unfortunately, non-municipal costs are usually not included in the public policy calculations.

"Given that available water is physically limited in many regions, when municipalities increase water system reliability, they are shifting risk to non-municipal sectors. Obviously, some water users must incur the shortfall during drought situations. Traditionally, risk has been progressively shifted to the riparian and estuary habitat systems"[10].

Elimination of Risk in Water Quality

Like the effort to eliminate risk in water supply, elimination of risk in water quality may not be reasonable or even possible. Case studies focusing on risk-reduction efforts related to water conclude that nothing is 100% "safe" and campaigns to reduce risks to human health and the environment can, and often do, create new risks. Thus, policy makers need to weigh all the risks associated with drinking water and search for solutions that reduce the overall risk.

The risk tradeoffs were demonstrated in the recent fear of water chlorination. Chlorine, despite its potential long-term cancer risk, is the best way of disinfecting drinking water. Efforts to remove the small risk of cancer by terminating chlorination would introduce a far greater and much more acute risk to the population due to waterborne diseases. While these diseases have been largely eliminated in the U.S., they can reappear if disinfection is not sustained[22].

Bureaucratic Cost and Risk

Economists have pointed out the difficulty of appropriately estimating costs and risks in bureaucratic choice for decades. Among the conclusions are the following:

First, in analyzing decisions about the production of public goods, what is considered "true costs" in market choice are not the same as costs in non-market choice. In *market settings*, costs are measured in objective terms as opportunity costs; they are market values of the alternative products that could have been produced with the same resources. On the contrary, in *non-market settings*, costs are subjective. In non-market settings, costs cannot be measured in terms of observed outlays and compared to other alternatives because non-pecuniary elements, or quasi-rents, are usually present in the non-market setting[2].

Second, bureaucratic choice is complicated by the fact that the world is uncertain and that each person evaluates risk differently. Two decision-makers confronted with an identical set of alternatives may choose a different solution according to the subjective probabilities they assign to each alternative[2].

Finally, an analysis of bureaucratic costs differs from an analysis of market costs due to the differing level of responsibility. In market settings individuals bear full responsibility for their action while in non-market settings the responsibility is broadly shared. Thus, in a non-market setting, individuals will tend to take more risk than they would have if they were making a decision under full ownership. Behavior under bureaucratic choice will tend to be less responsive to changes in the underlying conditions than behavior under market choice. A simple cost-benefit matrix is therefore not an appropriate action for bureaucratic choice[2].

When federal subsidies are a factor, additional distortions can be introduced into the bureaucratic system, particularly when they result in undervalued water. Due to federal subsidies, the price of water often does not reflect the cost of production, which leads to over-consumption, lack of motivation for conservation, and freshwater ecosystem decline. This problem is visible particularly in water poor states that use most of its water for production of low-value crops. For example, in Fresno, CA, farmers pay $17 per acre-foot of water while its production cost is $42. As a result, 60% of irrigation projects are ineffective[25, 26].

Another issue with bureaucratic choice is the cost of regulation; in some instances, regulation might be more expensive than the benefits it yields.

For example, a 1985 analysis of the costs of regulating pumping in the High Plains of Texas indicated that it could take 50 years to make the present value of the costs of regulation exceed the present value of the benefits[16]. Texas is a particularly fitting for an analysis of water-usage regulation because it is the only state where a landowner has full ownership of groundwater beneath the land and cannot be sued by an injured neighbor so long as the water is used "on the premises of the owner of such a well" (Texas Water Code, Section 11.205).

Although federal bureaucracy often introduces additional costs, it can also become a part of an effective solution. So far, a combination of government and local cooperation consistently seems to produce the best results.

For example, a combination of water conservation, acreage reduction, and federal salinity control projects was found to be the most efficient solution for the problem of salinity in the Colorado River. While the same level of salinity reduction can be achieved with federal projects alone, the cost would be 18 times higher than a policy that includes acreage reduction[12].

Finally, in some cases the involvement of the broader public may be not only necessary, but also an efficient part of the solution. A case study of New York City's water supply since the 1970s shows that deregulation has led to spiraling socio-economic inequalities in water consumption. To battle the negative effects of deregulation, the most promising solution was found to be the development of a more sophisticated public sphere and new forms of democratic decision-making[6].

Threats to Effective Water Management

When designing appropriate strategies it is crucial to consider potential threats that may dampen or even halt achieving the desired goals. Among the pitfalls for water policies are popular attitudes, lack of consumer information, and the fragmentation of water policy without a central controlling body.

The first potential pitfall involves popular attitudes and the lack of consumer information:

- Popular attitudes to water bills resemble attitudes toward taxes rather than other utility bills such as electricity or gas. People consider water a public good to which they are entitled. Possible solution: policy makers could present water bills as invoices for the on-demand delivery of treated, pressurized tap water[10].

- Most households are not aware of their actual water consumption or its real cost because water is a small budget item for most households. In some areas, water bills are lumped into other utility bills which fails to motivate consumers to pay attention to their water bills[10].

- Another threat for water management is the lack of central control over water policy. Texas provides a telling example. Texas has three major state agencies involved in water policy. The Texas Water Development Board is responsible for water planning and provides loans and grants for water and wastewater treatment plants and for water supply facilities. The Texas Commission on Environmental Quality grants permissions for water use and controls water pollution. Lastly, the Texas Parks and Wildlife Department oversees the enforcement of environmental provisions of the water law[1].

[1] In addition to the three major state agencies, there are hundreds of other agencies with overlapping jurisdictions including the General Land Office, Department of Agriculture, Texas Railroad Commission, Texas State Soil and Conservation Board, local soil conservation districts, 800 rural water supply corporations, 750 investor-owned water supply cooperatives, 230 water control-improvement districts, 18 water improvement districts, 42 freshwater supply districts, 36 levee improvement districts, 44 drainage districts, 19 irrigation districts, 26 navigation districts, 48 water control/underground water conservation districts, 20 river authorities (these authorities control 34 percent of all state surface water rights), 590 municipal utility districts (MUDs), and over 750 cities with populations over 100 people that operate their own water and sewage facilities. Such fragmentation in water management control drastically increases the complexity of the policy making, implementation, and enforcement process (Bath, 1999).

Implementation: Local Control and Delivery System Efficiency

During the past 20 years, great progress has been made in understanding the implementation of public policy and exposing its complexity. Unlike traditional theory, which dates back to the 1960s and studies whether policies are implemented from top to bottom or the other way around, more recent theory exposes much more complexity in implementing public policies. At the forefront of this contemporary thought is the 2009 Nobel Laureate and author, Elinor Ostrom.

Traditional Theory: Top-Down vs. Bottom-Up

Traditional scholarship developed two distinct theories of policy implementation: the top-down approach and the bottom-up approach[24].

The top-down approach to decision making is centralized and implementation is carried out through statutes, executive orders, or court decisions. Successful implementation is achieved by minimizing the deviations from the policy by making policy goals as clear and consistent as possible and by limiting the number of actors. Under this approach, analysts only look at the institutional failures to implement policies.

The bottom-up approach takes into consideration the public perception of a policy and the service deliverers. Successful implementation is achieved by maximizing the freedom to adapt a policy by those at the end of the implementation chain, the "street level bureaucrats" who come into direct contact with the public. Under the bottom-up approach, the central government authorities play only a limited role[24].

To synthesize these two theoretical approaches, analysts have proposed a comprehensive model of implementation: the ambiguity/conflict model. In this model, the success in policy implementation depends on a policy's level of ambiguity and conflict. *Conflict level* refers to the level of agreement on goals among policy makers. *Ambiguity level* refers to both ambiguity in goals and in means of achieving the goals.

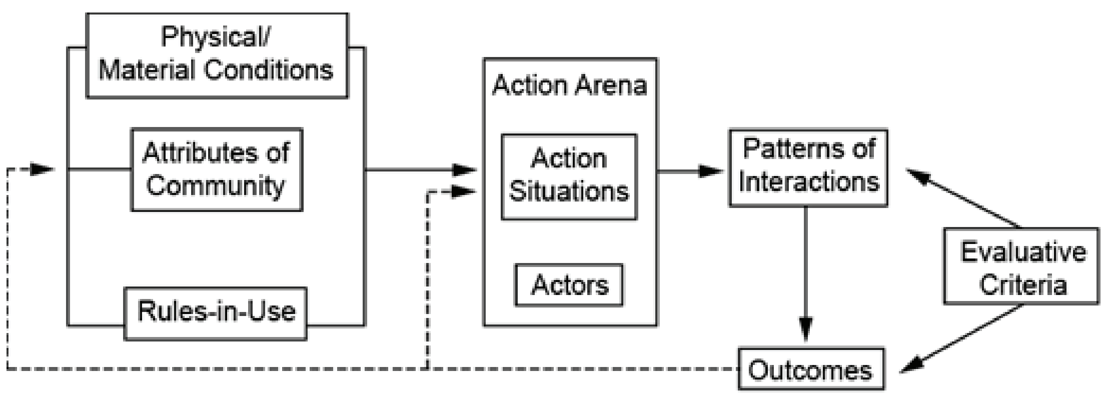
When both conflict and ambiguity in a policy are low, the desired outcome depends only on sufficient funding. An example of successfully implemented policy is small pox eradication. However, if both ambiguity and conflict in policy are high, the success of the implementation of the policy will depend on the strength of the coalition of actors at the local level who control the available resources[14].

Elinor Ostrom: The IAD Framework

Unlike the traditional theories of implementation, Elinor Ostrom and her coauthors offer a more complex framework for understanding the different factors that play a role in policy implementation: the *Institutional Analysis and Development* (IAD) framework. The theory was motivated by the effort to understand collective action in field settings of diverse structures, particularly the complex public economies of U.S. metropolitan areas.

The IAD framework can be described as a conceptual map that identifies the key components of public decision making processes and can be used to analyze, predict, and explain behavior within institutional arrangements. Figure 1 illustrates these components and how they relate.

Figure 1
The IAD Framework



Source: Ostrom et. al., 2010

The key component of the IAD Framework is the *Action Arena*, which refers to the social space where individuals interact, exchange goods and services, solve problems, or dominate one another.

Action Arenas include a set of actors who can be single individuals or groups functioning as corporate actors. Each actor has a different way of acquiring, processing, retaining and using information about contingencies available to them. Each also has different preferences over the available actions and outcomes. One can be influenced by external – conscious or unconscious – processes for selecting a particular course of action. Finally, each actor possesses different resources.

Ostrom, et.al. identified the seven action arena components that affect the preferences, information, strategies, and actions of participants. The Action Arena includes a broad set of variables dependent upon other contextual variables such as the structure of the resource system (size, complexity, predictability); the rules used by participants to order their relationships; and the structure of the community.

7 Components of an Action Arena	**Example of Problem Analysis Using a Common Water Resource**
Participants	Who and how many individuals/businesses withdraw water? In what amount? What are the projections for future use of water, both from individuals (population increase) and businesses? What are the participating regulatory bodies (incl. state and federal agencies)?
Positions	What are the positions regarding water usage of the different participants (incl. individuals, businesses, regulatory bodies)?
Allowable actions	How can participants use water? What are the limitations (e.g. what is the allowed amount of pollution households and businesses can release in water and sewage systems)?
Potential outcomes	What are the risks and costs associated with overusing or polluting water in the area (incl. groundwater and surface water resources)?
Level of control	Do water users take actions on their own initiative or do they confer with others? (e.g., what permits do individuals or businesses need to use water?)
Information available	How much information do water users have about the condition of the resource itself, about other users' cost and benefit functions, and about how their actions cumulate into joint outcomes?
Costs & benefits of actions & outcomes	How costly are various actions to each type of user, and what kinds of benefits can be achieved as a result of various group outcomes? (e.g. can cooperation between water users yield better outcome, such as conservation of water resources or improved infrastructure, than an uncoordinated use? If so, what would be the most effective joint action?)

The IAD framework exposes the complexity of the public decision making process but it also directs attention to actors, positions, sets of possible actions, and the range of potential outcomes and helps reach the optimal solution.

Example: Managing the Commons

Since the 1960s, Ostrom has conducted ground breaking research specifically in the management of common-pool resources, with a focus on the management of irrigation systems, fisheries, and forestry. Her research shows that a sustainable public private partnership can develop in water management and that local irrigators' organizations are likely to be more effective than large bureaucratic organizations in adopting, changing, and enforcing various configurations of operational rules in response to physical diversities[20].

Among the key factors that contribute to the development of cooperation in managing common-pool resources are five mechanisms that help develop trust among participants[18]:

- Communication among participants - by far the most important factor in inducing cooperation.
- Known reputation of participants - particularly if face-to-face communication is limited.
- Sufficient motivation of actors - high marginal returns of cooperation and capability to enter as well as exit cooperation.
- Repeated interaction - enables learning about other actors during a long time horizon.
- Sanctioning mechanism - increases the costs of unilateral defection.

Ostrom's findings have immediate public policy implications. Most importantly, her research shows that the type of ownership, whether public, private, or a combination of the two, is not as crucial for the effective management of resources as is its monitoring.

Monitoring by users, for example by guards recruited from local farmers, yields the best results because individual users are directly accountable to each other. Local irrigators' organizations were found to be more effective than large bureaucratic organizations in adopting, changing, and enforcing various configurations of operational rules in response to physical diversities[20].

While further research may identify additional policy implications, Ostrom's research clearly shows that panaceas are not to be recommended. Each resource exists in unique conditions and is affected by a different mix of factors. Understanding specific local conditions is essential for assessing local risks and determining the most effective public policies.

Lake Conroe

Photo by: Media Point

Implications for the Houston Region

This review of the theoretical and empirical knowledge about water resource management shows that the success of water management has been enormous, leading, at least in the U.S., to almost complete elimination of water related deaths during the past century. However, water quality and supply continue to be important issues on the policy makers' agendas. At the top of the list of water related issues in many parts of the U.S., including the Houston region, is the aging water infrastructure and water contamination. In making decisions about the best strategy to address these issues, policy makers need to properly assess the costs and benefits of any attempt to improve water availability and to carefully weigh the tradeoffs in risks in terms of water quality.

As the reports on water quality, water quantity, and the heath impacts indicate, there is substantial information to start a process of *"take aways"* that can inform the IAD framework and assure successful implementation[2].

The set of participants: The report estimates that during the next 30 years the region will add approximately 3.5 million new persons. This growth could result in the development of an additional 800 square miles of land along with increased contaminants related to that population.

Implication: This increase in scale and scope will be unprecedented in the region.

The positions: As indicated throughout this report, there are numerous actors who have jurisdiction and positions in this process.

Implication: With this fragmentation there is ambiguity in the existing degree of consensus on positions on the forthcoming challenges. In fact, there may be disagreement on the scope and scale of the challenge.

The set of allowable actions: There is a range of possible policy actions, including traditional tools such as tax abatements and bond issues. However, on the demand side, it is unclear that the price of water accurately reflects production costs. There also appears to be a lack of data (and the resources to collect it) to determine future environmental challenges.

Implication: Actions at this point are geared toward expanding water supply, but demand-side concerns (e.g., conservation) exist. This latter challenge is complicated by the fact that the cost of water to the consumer does not reflect the true cost of production.

The potential outcomes: The future quality of place in the greater Houston region is at issue.

Implication: Significant progress has been made on health outcomes and improvements in the quality of place due to investments in public works infrastructure. With additional significant investment, improvements will continue.

The level of control over choice: Various jurisdictional issues need to be addressed so that appropriate and timely action can be taken.

Implication: Continued fragmented responsibility among numerous agencies will likely complicate arriving at cost-effective solutions.

[2] The Green Buildings report also contains important information about specific policy initiatives (e.g., tax abatements) and provides data on the results of the policy interventions that can be traced back to actions by the city of Houston in 2004.

The information available: There is good information on water quantity, but less information on water quality. Cost information appears to be fragmented and may not accurately reflect supply and demand conditions.

Implication: The lack of uniformity in information and data quality poses a threat to an optimal allocation of public resources.

The costs and benefits of actions and outcomes: Little cost-benefit analysis and overall risk assessment have been conducted.

Implication: A failure to provide accurate cost-benefit analysis and risk assessment poses a threat to the optimal allocation of public resources.

Examples show that the best solutions for water management are a blend of policies carefully tailored to local conditions that also consider the opportunity for federal funding. The solutions must carefully weigh all the costs and benefits of all available alternatives, involve the broader public, and take into consideration the interaction of the various agencies controlling water policies. Complex as it is, policy makers in the words of Elinor Ostrom, "must learn to deal with complexity rather than rejecting it."

Harris County Commissioner's Court

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The Indicator Study is a series of peer-reviewed reports produced annually by the Center for Houston's Future in cooperation with local governments, academic and research institutions. It tracks and documents the region's progress on issues critical to the sustainability and future of the Greater Houston region.