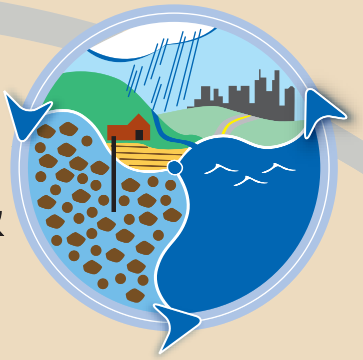
Groundwater & Alternative Water Supplies



Key Message

*M*eeting increasing demands for water is a constant challenge and pressure to find both short-term and long-term water supply solutions has never been as urgent in many regions of the country as it is today. States, tribes, municipalities, industry, and water supply entities are engaged in water resource planning to meet current and future challenges posed by climate extremes (both short and long term), increasing pressures on existing resources from population growth, competition for resources among various industries, and quantity and quality issues associated with current supplies.

Water conservation and repairs to leaky infrastructure are usually the first steps taken to help stretch existing resources; however, the hunt is on to identify new water sources to meet increasing demands. Alternative water resources can be an important part of this strategy. Untapped or underutilized groundwater sources may be available locally to supplement or provide needed capacity to water systems. Switching to sources such as "undesirable" water for industrial and agriculture purposes, brackish groundwater desalination, stormwater harvesting, aquifer storage and recovery, and water reuse are five groundwater-related resources that are either currently used or being considered for development in many areas of the nation.

As water supplies become less reliable, all levels of government will need to evaluate the potential to use alternative water resources and determine if the management of alternative groundwater resources can help meet future demands. Federal, state, tribal, and municipal governments need to encourage and facilitate the use of these unconventional water resources. One of the key challenges to using alternative resources is achieving local-level acceptance that these are viable, long-term water supplies that justify the expense associated with investigation and characterization, as well as development of the infrastructure needed to utilize them.

Source 7/27/2011 Austin American Statesman.

A cow looks for blades of green grass in the bottom of an empty stock tank at a ranch near Manor, Texas on July 2011.

Hurricane Irene produced tremendous rainfall over parts of the State of Vermont on August 28, 2011, creating record flooding of rivers in the state.

Meeting Water Demand in a Climate of Uncertainty

> "As one ponders the escalating water demands of a growing population and the uncertainties of climate extremes, it is apparent that water managers across the nation will be forced to adapt and become increasingly creative in their pursuit of sustainable water supplies. The unfortunate reality is that as more of the water resources customarily used in the U.S. become less reliable, our water supplies will need to be supplemented or replaced by costly alternatives to meet our future requirements"
>
> Jamie Crawford | Office of Land and Water Resources, Mississippi Department of Environmental Quality

why alternative water supplies matter to groundwater?

Water resource planners are facing unprecedented challenges to both maintain current resources and find new ones to meet increasing demands. Groundwater is being tapped more and more for a host of different uses—public and private water supplies, agricultural irrigation, industrial, energy exploration and production, aquaculture, livestock, mining, thermoelectric power, carbon sequestration, and environmental in-stream flows—all vying for what is essentially a static or decreasing resource. Changes in historic rainfall and temperature patterns as well as pressures from increased population growth are adding urgency to the need to find additional water resources. It is important that local and regional governments and water suppliers "be prepared," especially if trends or predictions point to changes that could seriously deplete water supply sources. Being prepared includes identifying alternative water resources.

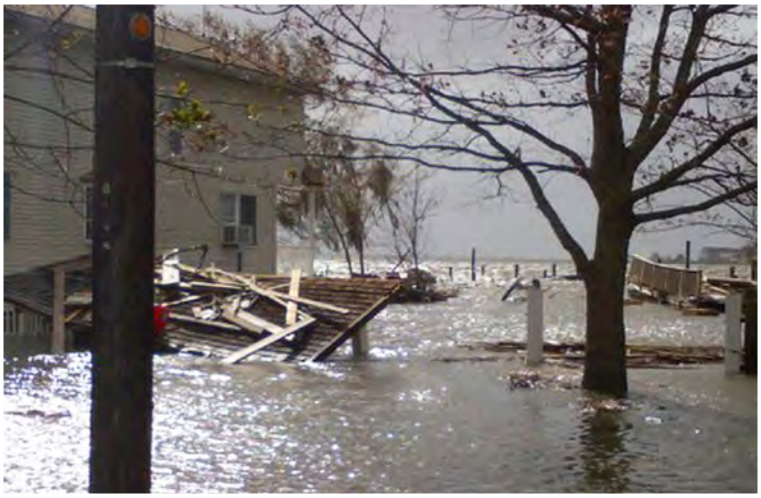


Photo by Lt. Gadomski, NYSDEC Division of Law Enforcement

Damage left behind by Hurricane Sandy in Massapequa, New York, looking toward South Oyster Bay, October 30, 2012. Extreme flooding events are changing ecosystem dynamics. In some coastal areas, potable water has been degraded due to increased salinity.

THAT CLIMATE THING

Climate variability is the glaring wild card in our water resource planning deck. While we may have long-term global climate models, we simply don't have the ability to predict when, how, and where droughts, floods, sea-level changes, and erratic weather events, such as hurricanes and tornadoes, will impact groundwater and surface water resources at a local scale.

Climate extremes are creating uncertainty for water resource planning, not only because they defy predictability for specific localities, but also because they have the potential to disrupt or alter what we currently understand about existing hydrologic systems. Climate extremes include both short- and long-term stresses to water systems such as severe and unseasonable weather; unseasonably heavy precipitation (rain and snowfall); extreme heat and drought; extreme cold; and windstorms such as hurricanes, storm surges, and tornadoes.

For example: In 2011, one of the most severe and costly years from weather events on record, extreme weather hit every region in the United States, resulting in prolonged droughts in the South and the West; deadly floods in the Southeast and Midwest; hundreds of devastating tornadoes across the United States; and Hurricane Irene in the Northeast.

There were many similar extreme weather events in 2012. During the 10-month period ending in October 2012, there were: drought conditions in more than 60 percent of the contiguous United States (at the peak of the drought more than 2,200 counties received disaster designations from the Secretary of Agriculture); deadly floods in Minnesota; Hurricane Sandy in the eastern United States, Hurricane Isaac in Louisiana, and Tropical Storm Debby in Florida; destructive wildfires on more than 9,000,000 acres across 37 states; power outages affecting more than 3,400,000 homes due to severe

Source 7/27/2011 Austin American Statesman.

This corn stalk is typical of the condition of hundreds of acres of corn destroyed by drought near Round Rock, Texas, in July 2011.

Forest fires remove sediment-trapping vegetation and generate a covering of ash. As a result, nearby drinking water utilities may have difficulty treating surface water because of the presence of sediment and ash transported during subsequent rainfall events. In such circumstances, alternative water supplies, including groundwater, may need to be utilized.

storms during the summer; and heat waves, highlighted by July being the warmest month on record for the contiguous United States as well as more than 9,600 daily high temperature records broken during June, July, and August.

Long-Term Climate Variability Predictions

Some predicted long-term climate variability, based on climate models, has been proposed by the United States Global Change Research Program (USGCRP) in their 2009 report Global Climate Change Impacts in the United States – Water Resources Chapter (www.globalchange.gov/usimpacts)*. These models predict that changes on a global scale will affect the overall hydrologic cycle in the U.S., but currently we do not have the ability to predict, on a local scale, specific impacts on surface water and groundwater.

Some efforts to look at long-term climate indicators are being used to predict future potential climate variability and extremes (short and long term). Studies on the cause and effect of the Pacific Ocean La Niña and El Niño weather patterns (El Niño/Southern Oscillation) on shifting rainfall and drought patterns in the U.S. are using indirect indicators such as tree ring growth dating back 1,100 years to determine severity and duration of droughts in the East Coast, South, and Southwest. One unmistakable conclusion that can be drawn from various discussions on historical climate variability and current efforts to predict local climate change is that the hydrologic cycle that has been observed over the past century is no longer a reasonable benchmark on which to base future water management decisions.

USGCRP has concluded that floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change, and rainfall becomes more concentrated into heavy events (with longer, hotter dry periods in between). This climate variability is altering the hydrologic cycle, affecting where, when, and how much water is available for all uses.

Figure 1 illustrates USGCRP's predicted variability in climate in the U.S. Precipitation and runoff are likely to increase in the Northeast and Midwest in winter and spring, and decrease in the West and especially the Southwest, in spring and summer. In areas where snowpack dominates, the timing of melt-water runoff will continue to shift to earlier in the spring, and stream baseflow will be lower in late summer.

> *The hydrologic cycle that has been observed over the past century is no longer a reasonable benchmark on which to base future water management decisions.*

USGCRP has also found that shallow groundwater aquifers that exchange water with streams are likely to be the most sensitive part of the groundwater system to weather change. Reduced summer water levels in streams, lakes, and wetlands are likely to reduce shallow aquifer recharge. This reduced recharge may cause small streams or wetlands to dry up. However, more frequent and larger floods are likely to increase groundwater recharge in semi-arid and arid areas, where most recharge to shallow aquifers occurs through dry streambeds after heavy rainfall and floods.

Variability in rainfall runoff patterns will result in a decreased stream baseflow in the summer. As a consequence, there may be a decrease in the amount of groundwater that is available to be pumped were the groundwater/surface water hydrologic connection is managed through water rights adjudication. Public water supplies that depend on groundwater under the influence of surface water may experience reduced inflow from surface water sources, affecting the volume of water available to be pumped.

Increased evaporation and plant water-loss rates will alter the balance of runoff and groundwater recharge as well as increase the demand for water (USGCRP). Generally, variations in aquifer recharge will not only change aquifer yield or discharge, but also modify the groundwater flow network. As a result, streams that in the past gained base flow from groundwater discharge (springs) may become disconnected from the regional groundwater flow due to a drop in the water table, and instead of gaining flow during dry periods, these streams may lose flow to the shallow groundwater systems.

In areas that already rely on groundwater, increased demand will further stress the available resource.

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* USGCRP expects to release a Third National Climate Assessment Report in early 2014.

PREDICTED VARIABILITY IN CLIMATE IN THE U.S.

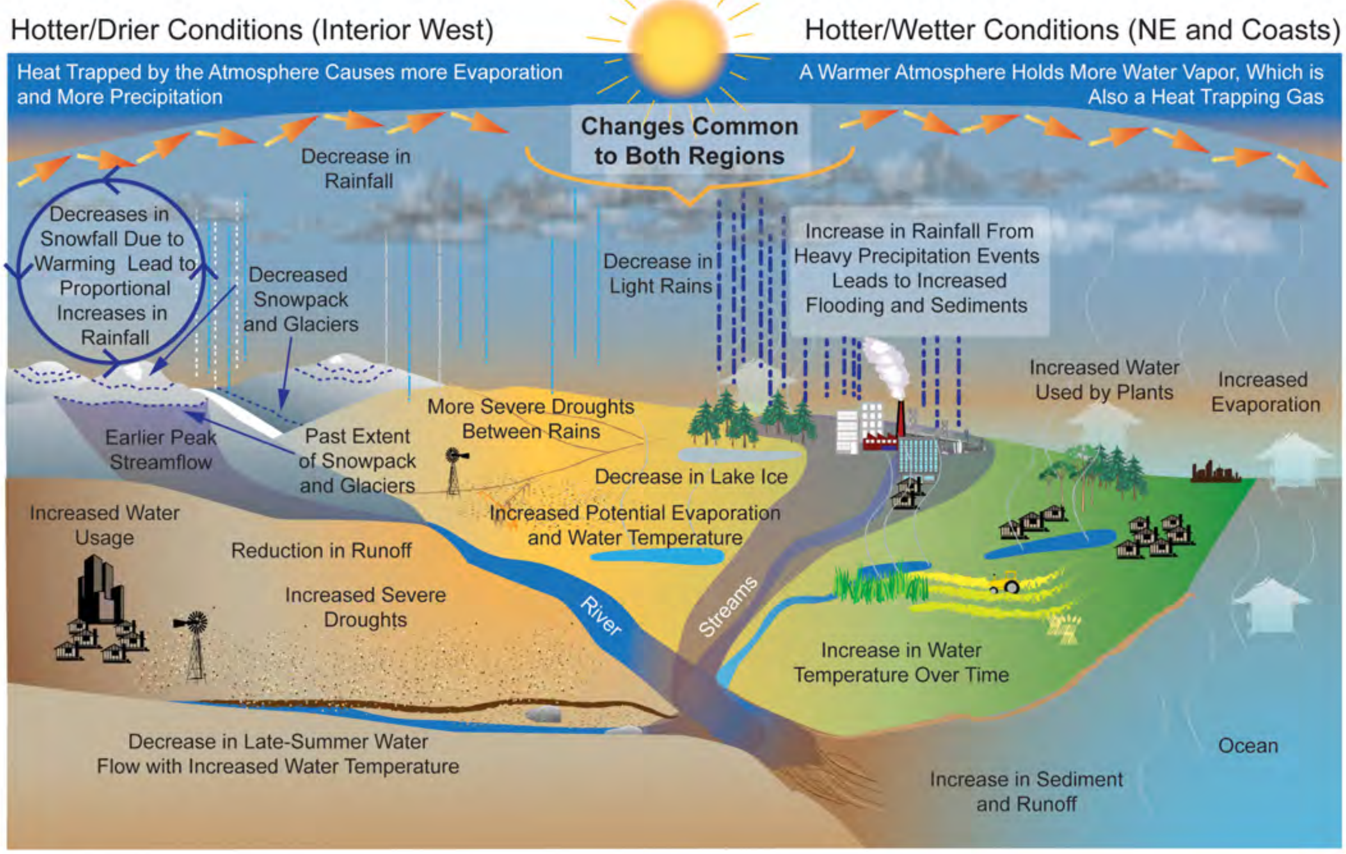


Figure 1. ***General predictions of climate in the U.S. (USGCRP, Water Resources Sector, Global Climate Change Impacts in the United States, 2009 Report.)***

During periods of drought, groundwater recharge will decline. Recharge will decrease as the temperature and spacing between rainfall events increase. Increased groundwater pumping to make up for the rainfall deficit will further stress or deplete aquifers.

Climate variability is predicted to affect not only groundwater input (recharge) and output (discharge) but also groundwater quality (Dragoni and Sukhua, 2008). Water quality degradation may occur in inland aquifers as pumping overstresses the aquifer, resulting in lower quality water from deeper zones or other surrounding formations being drawn into the aquifer to meet demand. These changes in groundwater quality will affect the cost of treatment.

Sea-level rise and aquifer pumping is expected to increase saltwater intrusion into coastal freshwater aquifers, making some water resources unusable without desalination. Freshwater aquifers are also at risk from saline recharge resulting from inundation due to sea level rise and storm surge. Increased evaporation or reduced recharge into coastal aquifers will exacerbate saltwater intrusion.

Research is needed to improve our understanding of climate drivers and variability at multiple geographic and time scales and to evaluate risks to water resources related to climate uncertainty. Improved monitoring, data handling, and evaluation to identify and respond to changing regional and local trends will allow for better early warning systems that:

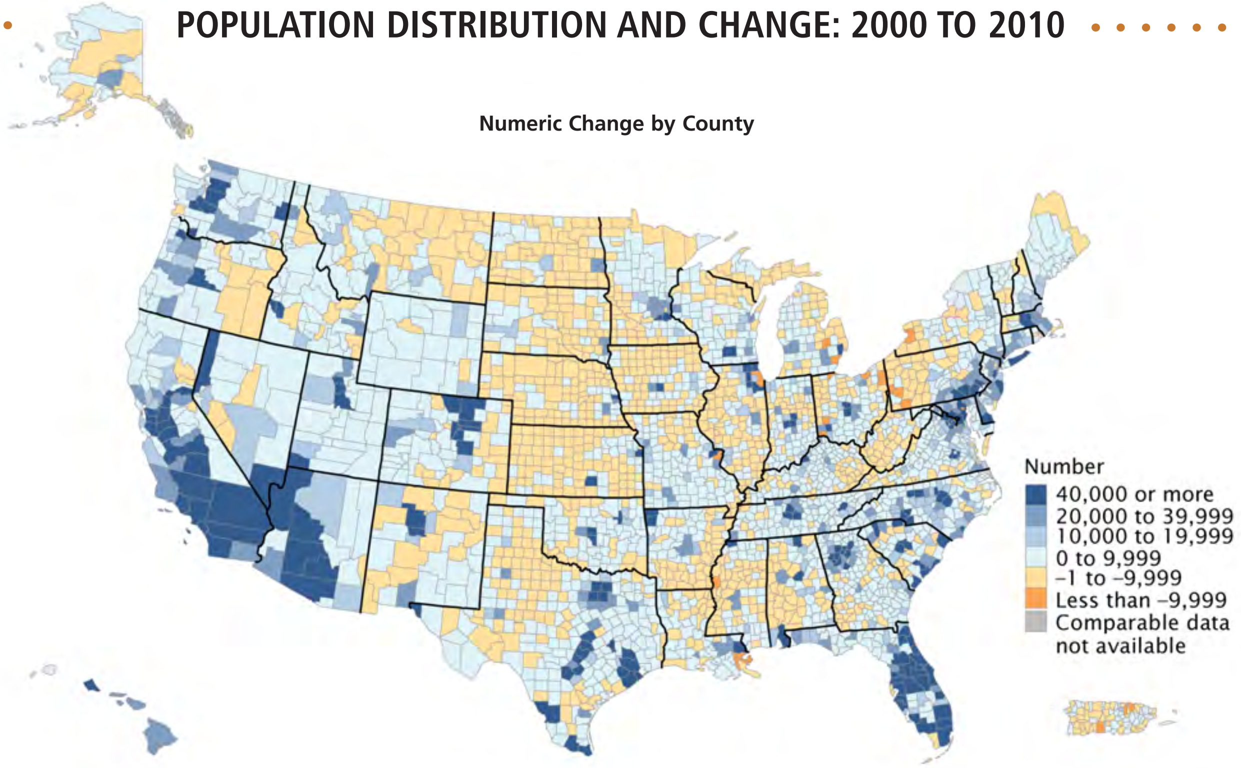
- focus on critical or vulnerable systems
- deliver real-time data
- improve data access, storage and retrieval
- allow for real-time “smart” analysis
- provide feedback and evaluation.

These tools can be used to help manage resource demands for surface and groundwater either by themselves or to help identify potential longer term solutions to shortages such as utilizing alternative groundwater resources.

THE POPULATION GROWTH AND MIGRATION FACTOR

Supplying increasing volumes of water to growing populations has placed additional stress on existing and aging water infrastructure. As demand grows for water resources needed to serve expanding populations, it may well become necessary to tightly manage existing resources as well as tap alternative resources accurately. Predicting population growth is a key component to determining if alternative groundwater resources should be part of a water management plan.

POPULATION DISTRIBUTION AND CHANGE: 2000 TO 2010


Numeric Change by County

Percentage Change by County

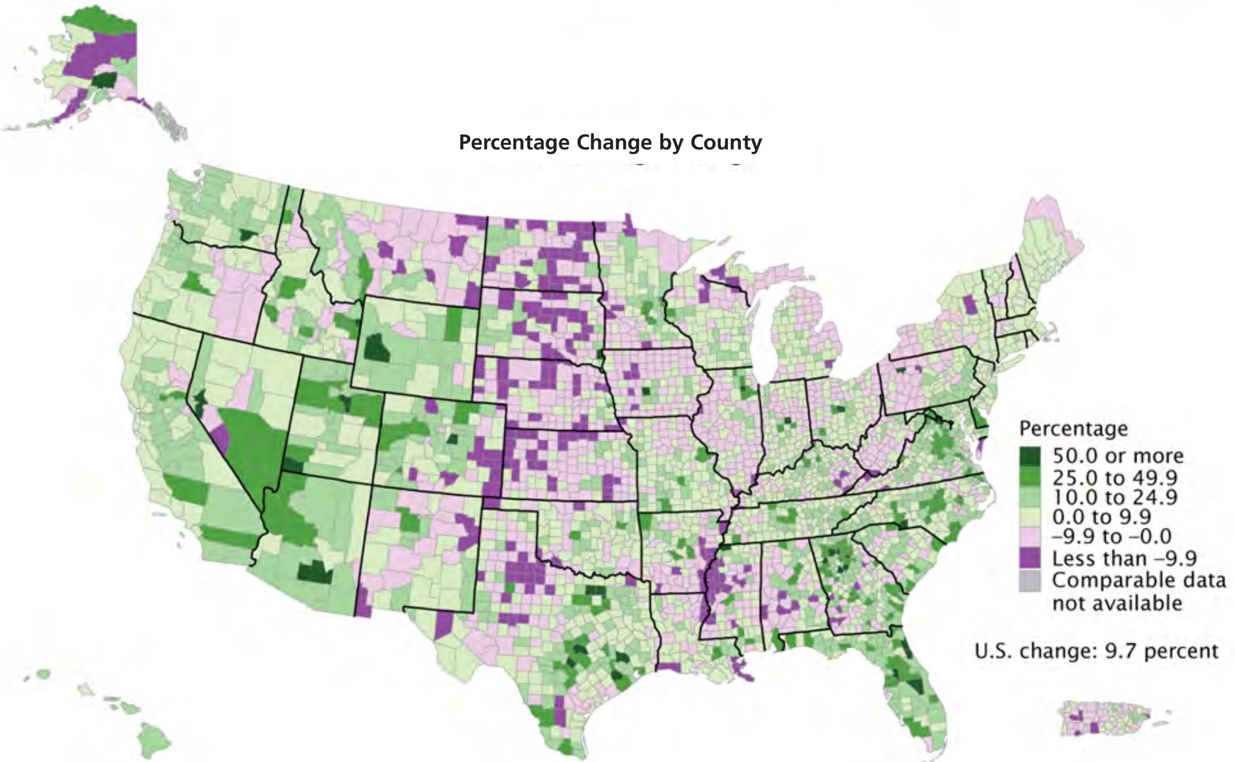
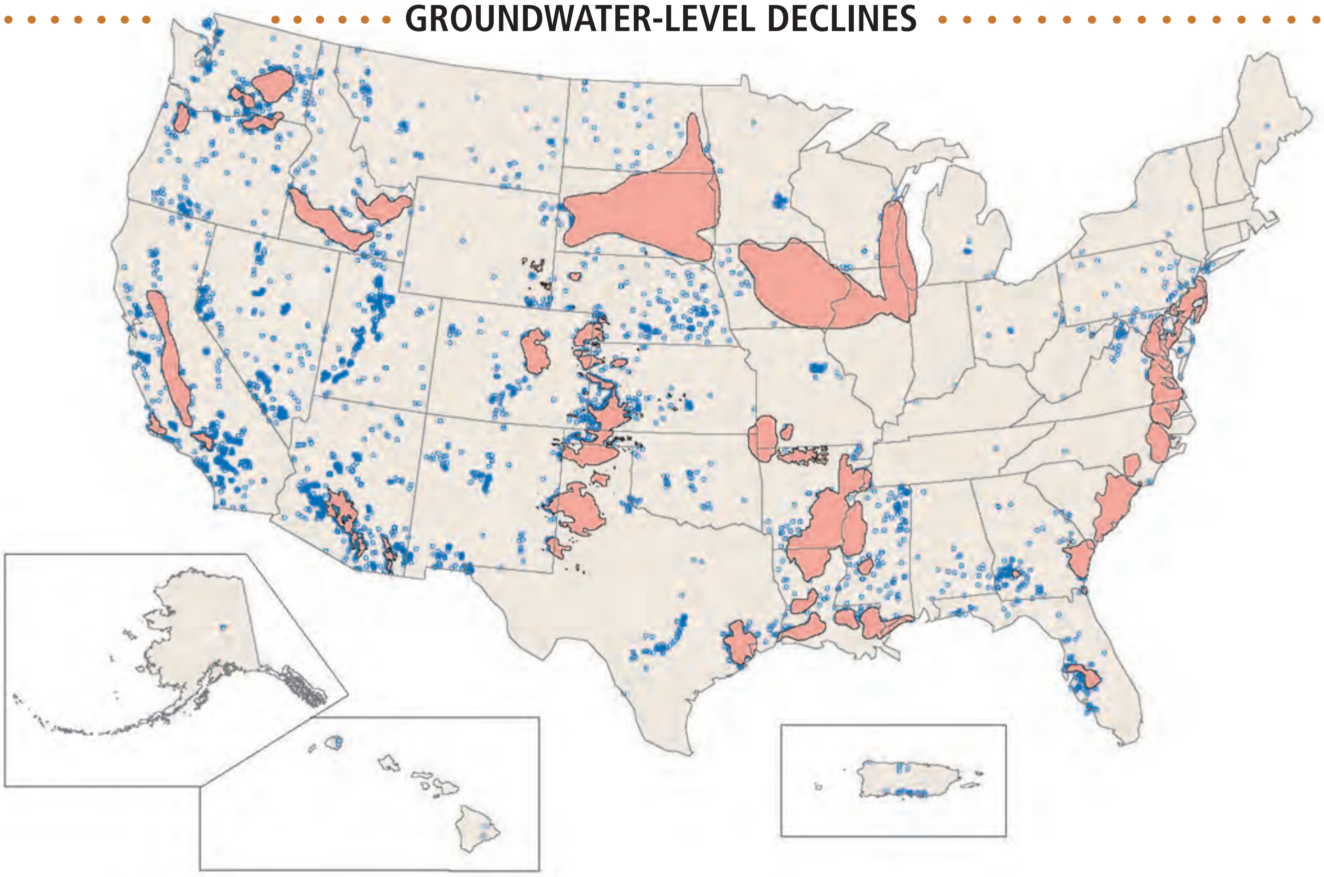


Figure 2: *From US Census Bureau, Census Brief C2010BR-01*

GROUNDWATER-LEVEL DECLINES



🟥 Areas in excess of 500 square miles that have water-level decline in excess of 40 feet in at least one confined aquifer since predevelopment, or in excess of 25 feet of decline in unconfined aquifers since predevelopment.

● Wells in the USGS National Water Information System database where the measured water-level difference over time is equal to or greater than 40 feet.

Figure 3: *Source: Reilly, T.E., Dennehy, K.F., Alley, W.M., and Cunningham, W.L., 2008, Ground-Water Availability in the United States: U.S. Geological Survey Circular 1323.*

The 2010 Census reported 308.7 million people in the United States, a 9.7 percent increase from the Census 2000 population of 281.4 million (US Census Bureau, Population Distribution and Change: 2000 to 2010, 2010 Census Brief C2010BR-01). Over the next three decades, net population increase (births minus deaths plus net migration) will be most evident in three states—California, Texas, and Florida—each projected to gain more than 6 million persons, and will account for 45 percent of the net population change in the U.S.

Coastal areas are also adding population and some water infrastructures in these areas are currently experiencing or are expecting to experience increased salinity issues, with saltwater intrusion into groundwater resources as well as possible costal subsidence. Coastline counties of the U.S., bordering the Atlantic and Pacific Oceans and the Gulf of Mexico, account for 254 of the nation's 3,142 counties yet contain 29 percent of its population, five of its ten most populous cities, and seven of its ten most populous counties. The population in coastline counties has grown steadily in recent decades, increasing from 47 million people in 1960 to 87 million people in 2008.

The concentration of high percentage population changes among the western and southern states continues a trend from recent decades (Figure 2). Nevada is the only state that has maintained a growth rate of 25.0 percent or greater for the last three decades; it has been the fastest-growing state for five straight decades. Six states, including five in the West, grew by 25.0 percent or more between 1990 and 2000. Wyoming, after having lost population between 1980 and 1990, has grown over the past two decades, surpassing the national level between 2000 and 2010.

Population growth and domestic migration within the U.S. has generally been to areas that have a history of groundwater availability and sustainability problems (compare Figure 2 and Figure 3). At a broad geographic level, there has been a net out-migration from the Northeast and the Midwest and net in-migration to the South and West to some of the most arid parts of the country. In addition to Nevada and Arizona, other states with large population growth in areas of low annual rainfall include Utah, Idaho, and Texas. Not only are the states with increasing populations typically arid, many of the southern states experiencing rapid growth are also currently experiencing long-term drought conditions, including Texas, Georgia, Florida, South Carolina, and Arizona.

ADAPTING TO MEET FUTURE DEMANDS

The U.S. Government Accountability Office (GAO) estimates that even under normal conditions, water managers in 36 states anticipate shortages in localities, regions, or statewide in the next 10 years. Groundwater currently provides drinking water for nearly 130 million people each day and approximately 40 percent of water used for irrigation. Models for site-specific effects of climate variability on existing water resources are yet to be developed; however, the anticipated stresses on water resources nationwide and the changes predicted by USGCRP, raise uncertainty as to the availability of future water resources. Water managers should be prepared to review and if necessary adapt planning policies if evidence begins pointing to persistent changes in the recurrence rates and lengths of droughts, the frequency of heavy rains, or the early melting of snow pack.

> *"We know that the way we've been managing water resources for the last hundred years is obsolete."*
>
> Patricia Mulroy, General Manager Southern Nevada Water Authority. Testimony to the U.S. Senate 2009.

> *Water managers should be prepared to review and if necessary adapt planning policies if evidence begins pointing to persistent changes in the recurrence rates and lengths of droughts, the frequency of heavy rains, or the early melting of snow pack.*

Source : Musick Groundwater Consulting.

Low lake level (1117 ft above MSL) at Hoover Dam on Lake Mead on the Colorado River in December, 2012. Water level is 48 feet below the average level for December due to prolonged drought.

Water supply managers must ask themselves about what previously untapped resources are available to meet current and future demands. What kind of adjustments do they need to make to meet future demand? How do they adapt to change? Managers are looking for resources that will allow their systems to be more resilient. What alternative resources will provide them with the ability to prepare and plan for, absorb, recover from, and

HYDRAULIC FRACTURING JOINS THE COMPETITION FOR WATER IN DROUGHT-RIDDEN SOUTH KANSAS

Extreme weather events and ongoing water supply conditions affect multiple users in a given area and can significantly elevate competition for scarce water resources. The use of hydraulic fracturing technology in oil and gas development operations is one of the newer industries that require large amounts of water. Hydraulic fracturing operations require anywhere from two to three million gallons of water (Marcellus Shale) up to 16 million gallons or more (Eagle Ford Shale) per frac job. In drought-stricken areas, companies using this technology are resorting to some extreme measures to obtain the water they need to tap into oil and gas reserves.

Digging to increase pond capacity on a farm in Kansas to supply water for hydraulic fracturing operations. Source – CNN Money, Blake Ellis

In 2012 companies began looking for alternative sources of water in drought-ridden fields of southern Kansas. They gained access to water in a number of ways—paying farmers for any remaining water left in ponds, drilling their own water wells, digging ponds next to existing streams, or trucking in large quantities of water from out-of-state (often the most expensive option). In some cases states have imposed limits to water withdrawals from specific streams to ensure downstream obligations were met. In these situations trucking in water has become almost the only viable option.

Water shortages have the biggest impact on smaller oil and gas producers that are hard-pressed to handle the additional costs or delays. As the drought persists, local farmers and ranchers are less likely to want to sell the water they also need for crops and livestock. However, as long as oil prices remain high, both industry and local governments have an incentive to continue to produce needed water. In Kansas, local governments and industry have worked together to keep the water flowing.

To help deal with these challenges, third-party companies have emerged as water brokers. Instead of locating water themselves, smaller oil and gas producers team up with a third party to meet their water needs. These companies do whatever it takes—contract with local land owners, dig ponds, locate available nearby resources, truck in water—and sell that water to the drilling companies.

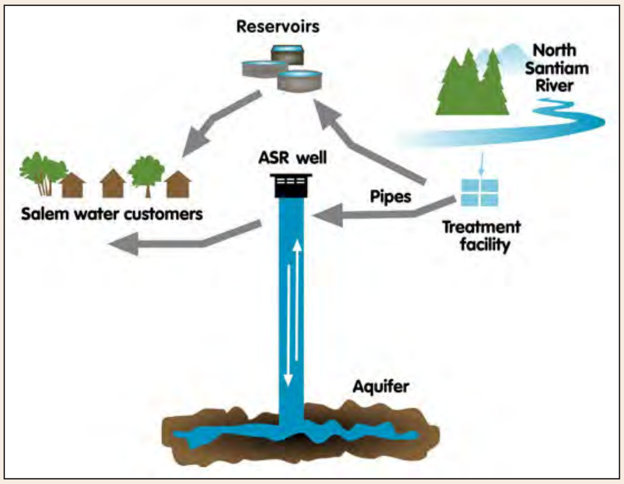
Very often hydraulic fracturing operations are competing with other water-intensive uses, such as farming, irrigation, public and private water supplies, and other industries, for already stressed groundwater resources, especially those in drought-ridden parts of the country such as Colorado, California, Kansas, and Texas. It is essential that water-use planning and management be in place before additional water-intensive activities are introduced to any community, let alone drought-stricken areas.

more successfully adapt to adverse short- and long-term supply changing events in a timely manner?

The key to adapting to weather extremes and managing increased water demand due to population growth, of course, is recognizing that there might actually be a potential cause for concern. This may seem obvious, but according to the U.S. GAO, national water availability and use have not been comprehensively assessed in 25 years. Communities and local water users need to have detailed knowledge of all available water resources. Many states support groundwater quality and water level monitoring, aquifer modeling, and resource planning, at the state, regional, and/or local levels. These tools should be used to help assess water availability trends and conditions and manage demands for groundwater, in and of itself or as a component of the hydrologic cycle. If the potential for a long-term, or even a short-term, water supply shortage is identified, then the business of investigating other options

ANTICIPATING WATER SCARCITY IN OREGON'S WILLAMETTE RIVER BASIN

Oregon State University (OSU), the University of Oregon (UO), and Portland State University (PSU) are collaborating on a comprehensive, highly integrated examination of hydrological, ecological, and socio-economic factors in the Willamette River Basin. The project, dubbed "Willamette Water 2100," is a unique 5-year National Science Foundation (NSF)-funded project involving water resources managers, elected officials, and a growing list of other diverse stakeholders with a strong interest in protecting ecosystems and water resources. Participants will share their needs and perspectives, identify scenarios, and interpret results. Working with these public officials, the project team will help translate the results of the research into the planning and decision making processes. (*http://water.oregonstate.edu/ww2100/*)



City of Salem, Oregon, aquifer storage and recovery (ASR) facility at Woodmansee Park. The ASR well was the first in Oregon to provide municipal water supply.

Six research teams are developing separate model components that will be integrated in an Envision modeling tool. Envision is a theoretical framework developed at OSU to evaluate how climate change, population growth, and economic growth will alter the availability and use of water in the Willamette River Basin. It provides a computing environment in which state-of-the-art models can interact synergistically. It also contains a multi-agent-based modeling component that enables it to represent the impact of human decision-making on landscape change. The team has the following objectives:

- Identify and quantify the linkages and feedbacks among hydrologic, ecological, and socioeconomic dimensions of the water system
- Determine where and when human activities and climate change will create water scarcities
- Evaluate a broad range of strategies that could enable this region to prevent, mitigate, or adapt to water scarcities
- Create a transferable method of predicting where climate change will create water scarcities in other regions and where those scarcities would exert the strongest impact on society

To support the NSF priority of stakeholder involvement, the WW2100 Broader Impacts Research Team initiated development of a "Learning Action Network," including Upper, Middle, and Lower Willamette Basin regions, during the 2011 spring and summer. Three basin-wide field trips were completed in partnership with private, public, and non-profit water and land-use professionals covering a range of Willamette Basin water resources topics. On May 9th, 2012, a full day Learning Action Network workshop was held with elected officials, governmental, private, and non-profit water resources managers resulting in significant research data to inform Envision model development and long term engagement of stakeholders.

Santiam Water Control District fish passage structure near Turner, Oregon; expensive upgrades to comply with current Willamette Basin Biological Opinion requirements will impact industry in the basin.

begins—some options may well take considerable time and money to put in place.

Traditional adaptation strategies generally start with stretching existing resources by repairing leaks in existing infrastructure and adopting water conservation and efficiency measures for all users—industrial, municipal, and agricultural. Conservation is often achieved through public awareness and financial incentives to install conservation devices.

After tightening the existing system, many planners look for other alternatives. While most planning efforts focus on developing traditional water sources, many planners are beginning to consider, or have started to utilize, alternative and sometimes-unconventional water sources to supplement or provide needed peak capacity. These include recycling gray water for irrigation or substituting it for freshwater in landscape and agricultural irrigation and as industrial process water.

Storing excess water in times of plenty through stormwater harvesting and aquifer storage to be used during times of need is another strategy. In some arid areas, treated wastewater effluent is being further treated and reused as drinking water. Some resource managers are directing new non-drinking water users to "undesirable groundwater" that meets their quality and quantity needs but is not considered a drinking water source (i.e., the right water for the right use).

Many water plans identify and meet future demands through long-range projects designed to obtain access to additional freshwater resources (surface or groundwater). Other plans involve changing the end users of existing resources (e.g., agricultural) to municipal use of groundwater or developing conjunctive use of water resources (e.g., using surface water as a primary source and groundwater as an alternative or supplemental source).

SAN ANTONIO WATER SYSTEM (SAWS) REDUCES USE AS THE POPULATION GROWS

SAWS' Recycled Water Program was initiated to reduce the amount of water San Antonio pumps from the Edwards Aquifer. It conserves potable water and protects endangered-species habitats and critical ecosystems.

The system distributing recycled water spans 110 miles and delivers high-quality, treated, recycled water to commercial and industrial customers and to four stream-discharge locations for enhancement and restoration of aquatic ecosystems. Regular water quality sampling at 13 locations has confirmed improvements as seen by lower turbidities, higher clarity, less algal growth, lower bacterial counts, and the return of several species sensitive to water quality and intolerant of pollution. Access to the recycled water has also attracted several businesses to the area.

SAWS also spearheaded several water conservation programs, developing media campaigns and community-based outreach to raise public awareness and participation. The utility focuses on forming partnerships and involving stakeholders to ensure the success of its programs, which yielded more than 1 billion gallons of ongoing water savings since 2009. Activities included 1,842 residential water conservation consultations, resulting in a cumulative drop of more than 80 million gallons in participating household-water consumption. Other activities saved more than 600 million gallons, such as SAWS' Conservation Make Over program, which assists low-income neighborhoods, retrofits older buildings, and conducts other indoor programs.

Conservation has helped drop the system-wide gallons per capita per day (GPCD) from 136 in 2008 to 125 in 2009. SAWS had an average annual GPCD drop of 1.5 between 2000 and 2009. Thanks to conservation programs in place since 1994, the utility is now able to serve twice as many customers using the same amount of water. Even during very dry conditions in 2011, the system had a surplus of 8,416 acre-feet and additional storage of approximately 90,000 acre-feet.

SAWS plans to select a contractor for the first phase of a brackish groundwater desalination project. The proposed system is expected to supply 30,525 acre-feet of water by 2026.

Source: http://www.tceq.texas.gov/publications/pd/020/2013-NaturalOutlook/texans-take-action-addressing-future-water-supplies

STATE CLIMATE ADAPTATION PLANNING

Where does groundwater fit into a state climate-resilient water program? The use of alternative or unconventional water resources to supplement or provide needed capacity is one piece of the supply puzzle. The Federal American Clean Energy and Security Act, Subtitle E—Adapting to Climate Change suggests including the following key elements in State Climate Adaptation Plans:

- Assess and prioritize water supply vulnerability to a broad range of climate change impacts
- Identify and prioritize projects, programs, and measures to build resilience to current and predicted impacts of climate change
- Fully consider and undertake initiatives that protect or enhance natural ecosystem functions, including maintaining water quality and groundwater recharge
- Research and collect data on saltwater intrusion into coastal rivers and aquifers

Planning for anticipated water demands should be undertaken at all levels, from federal, state, and local governments to private and public water utilities, with participation from consuming stakeholders. Stakeholders at all levels should work together to integrate long-term planning, including addressing climate variability, population increase, land use changes, water supply, flood control, and water quality. As part of this planning process, assumptions regarding the potential for more extreme events, larger floods, and longer droughts should be reevaluated given that future climate variability may be outside the range of our past experience.

ALTERNATIVE GROUNDWATER RESOURCES

Stresses on traditional freshwater supplies have prompted a search for additional sustainable and affordable supplies. To even begin to meet this considerable challenge, planners need to balance water demands with available water resources and use a combination of alternative “new” water sources along with conserving existing sources.

> *As the competition among water users becomes more pronounced, all available management options will need to be considered to meet the growing demand.”*

As the competition among water users becomes more pronounced, all available management options will need to be considered to meet the growing demand. The future may dictate an increasingly more creative management approach that looks beyond just quantity issues and incorporates the specific water quality needs of users. In other words, target potential water resources based on the quality of water needed for a specific use.

Unconventional alternative water sources that are either used or being considered for development in many areas of the nation include “undesirable” groundwater, desalinized brackish or saline groundwater, stormwater runoff harvested for later use, available water stored in aquifers for later use or to help manage aquifer quality and quantity, and wastewater treated for reuse.

Before investing in these technologies, however, extensive risk and cost-benefit analysis, together with an analysis of the potential for reducing demand and increasing water use efficiency should be conducted. In addition, the process should include an education component to provide for widespread acceptance of alternative water resources. State and federal water management agencies should evaluate the potential for integrating “undesirable” groundwater, aquifer storage and recovery, wastewater reuse, desalination, and stormwater harvesting opportunities with existing and future water project operations, new construction and rehabilitation, and infrastructure improvement work.

Redirecting Use to “Undesirable” Groundwater

As a result of pumping water at an unsustainable rate, aquifers in many areas are being depleted, resulting in water level declines, saltwater intrusion into freshwater resources, and occasional land surface subsidence. Brackish and saline sources of groundwater, while undesirable for drinking water unless treated, are frequently overlooked as an alternative resource. The direct (untreated) use of groundwater with objectionable drinking water quality (e.g., taste, odor, color, pH, TDS) can supply other beneficial uses such as agricultural and industrial supply. This option has the distinct economic advantage of using poorer quality water without incurring significant treatment and disposal costs.

For example, such sources may be perfectly acceptable for some agricultural applications, supplies for some industries, cooling water for power generating facilities, and energy-related operations that require large volumes of water for cooling and related processes.

The availability of multiple-layered aquifers with varying quality and yield potential is indicative of the hydrogeologic setting in most East and Gulf Coast regions, Midwest plains, and Western Basin and Range areas. These assets can provide state resource managers with options to steer major water users to otherwise objectionable groundwater sources (assuming they are deemed suitable for specific quantity and quality needs). Such action would reserve higher quality resources for potable uses, especially in water stressed areas. One example is the successful use of aquifers with lesser quality as sources for several large water supply projects related to leaching salt domes at several new natural gas storage facilities in Mississippi.

Groundwater Desalination

With the ever-growing demand for water, planners are turning to abundant saline groundwater supplies as an alternative resource. The USGS found that in 2005 about 20 percent (82,600 million gallons per day (Mgal/d)) of total national water withdrawals (about 410,000 Mgal/d) came from groundwater sources. Relatively little untreated saline groundwater was used in 2005. However, desalination treatment can be used to tap a vast, underutilized groundwater resource (Figure 4).

In 2002, Sandia National Laboratories projected that more than 70 billion dollars will be spent worldwide

LOCATION AND DEPTH OF SALINE GROUNDWATER RESOURCES

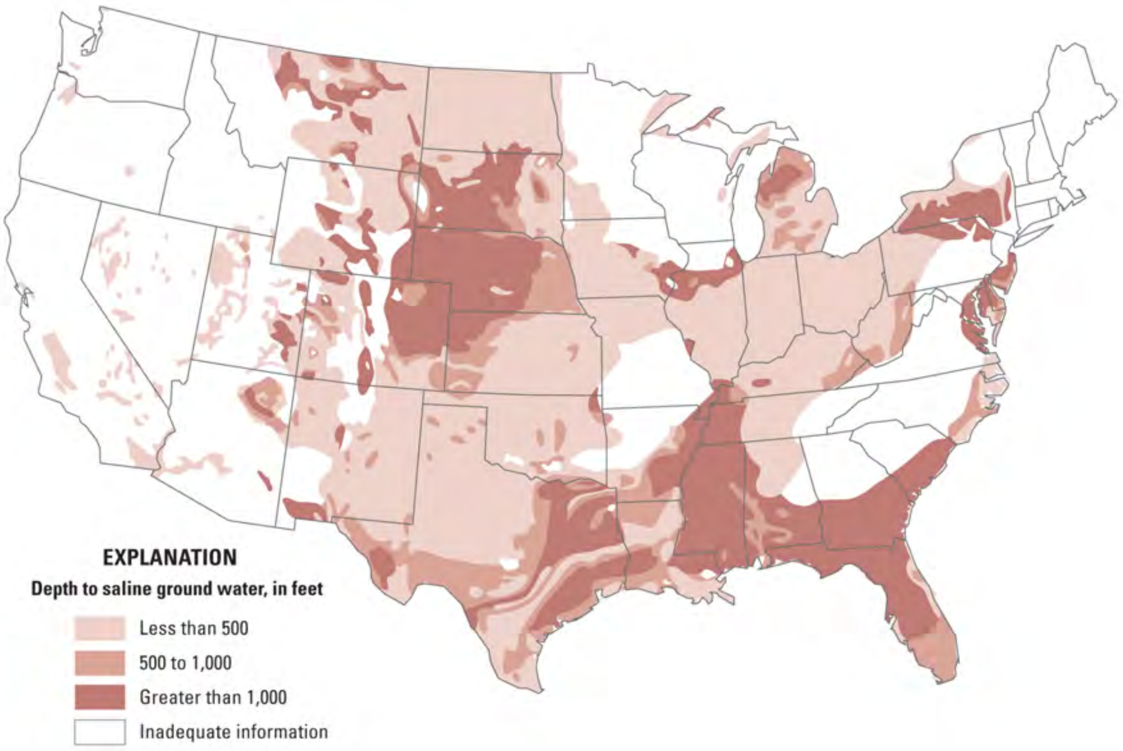


Figure 4: *Depth to Saline Groundwaterfrom USGS "Desalination of Ground Water: Earth Science Perspectives," Fact Sheet 075–0 October 2003*

BRACKISH GROUNDWATER DESALINATION IN TEXAS

Once only a potential resource, brackish groundwater is now becoming an important source of new water supply. Texas has an abundance of brackish groundwater, estimated at more than 2.7 billion acre-feet.

Brackish groundwater contains dissolved minerals measured in units of milligrams per liter and can be classified as fresh (0–1,000 milligrams per liter), brackish (1,000–10,000 milligrams per liter), and saline (greater than 10,000 milligrams per liter). For comparison, seawater contains approximately 35,000 milligrams per liter of total dissolved solids.

Source: http://www.jsg.utexas.edu/news/2008/01/salt-water-goes-fresh-in-el-paso/

El Paso, Texas is the site of the world's largest inland desalination plant. This plant represents a forward-looking strategy in water supply—not only for a region but also for a world that is increasingly challenged by short supplies of fresh water.

If used for potable purposes, brackish groundwater needs to be desalinated. Otherwise it can cause scaling and corrosion problems in water wells and treatment equipment and cannot be used in many industrial processes. The Texas Commission on Environmental Quality has established a primary standard of 500 milligrams per liter of total dissolved solids and a secondary standard of 1,000 milligrams per liter for public water supply systems. Groundwater above that concentration can be used for irrigation; however, a total dissolved solids concentration greater than 3,000 milligrams per liter is not usable for irrigation without dilution or desalination and, although considered satisfactory for most poultry and livestock watering, can cause health problems at increasingly higher concentrations.

Desalination Stats

Currently, there are 44 municipal brackish water desalination facilities in Texas. Twelve of these facilities use brackish surface water as a source of raw water, which accounts for a design capacity of 50 million gallons per day (56,000 acre-feet per year). Thirty-two facilities use brackish groundwater as a raw water source, which accounts for a design capacity of 70 million gallons per day (78,400 acre-feet per year). In total, the state has a desalination design capacity of 120 million gallons per day.

Reverse osmosis is the predominant desalination technology; 42 of 44 desalination facilities use this technology. To track the growth of desalination in Texas, the Texas Water Development Board (TWDB) operates and manages a desalination database for Texas (*http://www.twdb.state.tx.us/apps/desal/ChoosePlant.aspx).*

Desalination in Regional Water Plans

In the 2011 Regional Water Plans, 5 of the 16 regional water planning groups recommended brackish groundwater desalination as a water management strategy to meet at least some of their projected water needs. In total, the regional water planning groups project that desalting brackish groundwater can create about 181,568 acre-feet of new water per year by 2060.

Desalination Demonstration Projects

To encourage and facilitate the development of brackish groundwater in the state, the TWDB proposed the Brackish Groundwater Desalination Initiative in 2004. The goal of the initiative was to develop models of brackish groundwater desalination that illustrate the use of innovative, cost-effective technologies and offer practical solutions to key challenges to implementing desalination projects.

Source: www.twdb.state.tx.us/publications/shells/Desal_Brackish.pdf

Key Term

DESALINATION

Removal of salt (sodium chloride) and other minerals from water to make it suitable for human consumption and/or industrial use.

over the next 20 years to design and build new desalination plants and facilities (USGS Fact Sheet 075–03, 2003). The ability to utilize local brackish or saline aquifers (either along the cost or inland) can reduce the costs of treatment and transporting the water long distances.

A report by the National Research Council Committee on Advancing Desalination Technology (NRCCADT) points out that water scarcity in some regions of the U.S. will intensify over the coming decades, and desalination, using both brackish and seawater sources, will likely be part of water management strategic planning. The committee suggests that the theoretical potential for desalination is effectively unlimited because large quantities of inland brackish groundwater appear to be available for development and that the costs of producing desalinated water is no longer the primary barrier to implementing this technology.

As shown in Figure 4, much of the U.S. is underlain by brackish or saline groundwater resources. Since much of this supply is beneath easily accessible and higher quality fresh water resources, it has remained virtually untapped. One of the major hurdles in pursuing a desalination project is the need for detailed characterization of the hydrologic proprieties of the saline aquifer.

To develop a saline water resource, knowledge of aquifer yield and water quality is necessary. Basic water quality information needed to understand the ease of treatment (e.g., amount of total dissolved solids and metals) and potential treatment problems (e.g., amount of silica or iron present in the water) is generally lacking.

To facilitate the use of saline resources, both state and the federal governments (USGS) are conducting saline aquifer studies to determine the characteristics and availability of groundwater for desalination. This information can be used to target specific sites for more detailed investigation to determine development cost.

One site-specific unknown is whether or not the use of brackish/saline aquifers will have unintended impacts on freshwater aquifers that are in direct hydrologic connection. Could withdrawal of saline water affect water levels in hydrologically connected fresh water aquifers? Could potential fresh water/salt water interactions lead to expanding saltwater zones or the upwelling of saline water, resulting in freshwater aquifer degradation?

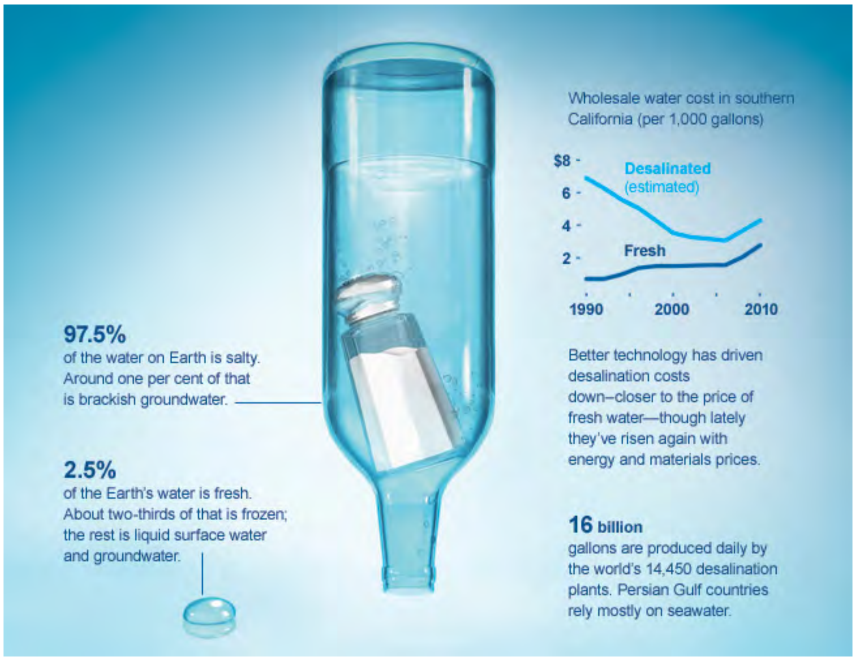


Illustration by Bryan Christie Design

Desalination of brackish and saline water is becomming an affordable means to meet growing water demands.

Beyond traditional saline aquifer sources, other sources of groundwater that may be amenable to desalination need to be quantified. These include treating water co-produced with oil and conventional and unconventional natural gas production and water co-produced with coal-bed methane. Many oil- and gas-producing formations have associated water that is only slightly saline (less than 10,000 mg/L), notably in the intermountain basins of the western U.S. Water produced as part of coal-bed methane production in the Powder River Basin of Wyoming is generally less than 3,000 mg/L TDS. However, the likely presence of organic compounds in this water complicates treatment (USGS Fact Sheet 075–03, 2003).

Desalination is energy intensive and is therefore vulnerable to the rising cost of energy, possibly preventing its wide-scale use (NRCCADT). In general, the treatment technology that is used to remove the solids will determine the potential cost of a project. Currently, evaporation, reverse osmosis, and microfiltration are commonly utilized. The blending of treated water with fresher sources may be used to extend the resource at a lower cost. Brackish groundwater is less expensive to treat than more saline resources. With lower total dissolved solids in the feed water, less energy is required and treatment costs to develop and treat the resource are generally lower.

Another frequently cited problem that may be limiting the development of in-land brackish groundwater desalination is the cost of concentrate residual disposal (NRCCADT). Site-specific information is necessary to evaluate potential environmental impacts of disposal and the most cost-effective method. Management of the concentrated saline waste residual can be costly, and methods used vary widely depending on local regulations and site-specific conditions.

Some currently used concentrate-residual disposal methods include direct discharge to surface water, discharge to a publicly owned wastewater treatment facility, surface evaporation from ponds, or underground injection. Some of these disposal methods require the time and expense of acquiring a permit, which must be considered in the lead-time and the overall cost of desalination. NRCCADT concluded that the high cost of environmentally sustainable concentrate management at some inland locations ultimately offsets the cost advantage that can be obtained from utilizing feed water with lower salinity.

Stormwater Harvesting

Stormwater "harvesting" is defined as the collection, storage, treatment, distribution, and use of stormwater runoff for beneficial purposes. Harvesting projects can occur over a wide range of scales, from small-scale rainwater harvesting projects, where water is collected from rooftops, to large-scale diversion and use of stormwater from streams and reservoirs (Alan Plummer and Associates, 2010).

Many water resource managers are looking at holistically managing the hydrologic cycle (including stormwater harvesting) to address competing and increased demands from agriculture, environmental flows,

Key Term

STORMWATER HARVESTING

Collection, storage, treatment, distribution, and use of stormwater runoff for beneficial purposes.

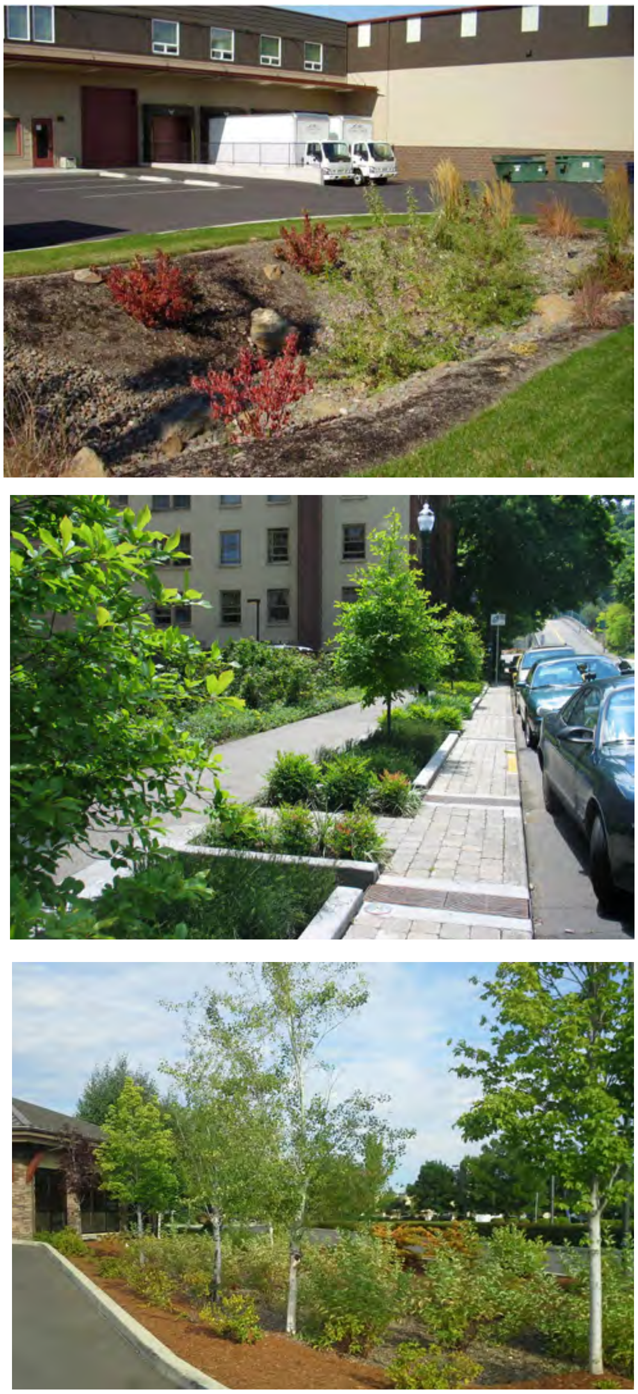


Photo courtesy of David Cole, UIC Hydrogeologist, Oregon Department of Environmental Quality

Photo courtesy of EPA

Photo courtesy of Lori Tella, Jackson Soil and Water Conservation District, Medford, OR

Three examples of Green Infrastructure used to direct recharge to the shallow subsurface. Top: Bioswale; Middle; Green Street Planters; Bottom: Rain Garden.

municipalities, and industry. Climate extremes may alter the timing and peak volume of precipitation. This change to the hydrologic cycle can be partially mitigated through stormwater infiltration to shallow groundwater—ideally, capturing rapid runoff from early spring melts and intensive storm events for later use when rainfall is less abundant. Stormwater harvesting can help store water so it can be used to meet some of the peak water demands or environmental surface water quality and quantity needs during low-flow conditions.

Another benefit from enhanced stormwater recharge, which would have otherwise been rejected aquifer recharge, is redirecting runoff to the shallow subsurface to prevent flooding and erosion while, at the same time, supplementing stream base flow from shallow groundwater discharge. This redirection helps smooth the hydrograph of a stream and maintain in-stream flows. In other words, it lessens the amount of overland flow, reducing the potential for contamination and stream erosion.

Redirection to shallow groundwater also slows floodwater movement; delaying discharge to streams and enhancing stream base flow during dry periods. Enhanced base flow, in turn, can provide water for both aquatic habitats and surface-water-dependent utilities.

If stormwater harvesting is used to recharge shallow aquifers, best management practices that do not transfer pollution from surface water to groundwater resources must be used. Methods utilized to capture stormwater at the local level and prevent high peak flows in surface water drainages during storm events are discussed in Section 6 of *The Groundwater Report to the Nation—Groundwater and Stormwater Management*, and are not repeated here.

Stormwater recharge to shallow aquifers can be accomplished through the use of many different infiltration techniques such as rain gardens, recharge ponds, infiltration structures, and injection wells. However, some steps should be taken to protect the quality of groundwater during stormwater harvesting. In a study on Managed Underground Storage of Recoverable Water (2007), the National Academy of Sciences cautioned that “Urban stormwater….is highly variable in quality; for this reason, caution is needed in determining whether stormwater is of acceptable quality for recharge.”

> *Urban stormwater...*
> *is highly variable in quality; ...*
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> *whether stormwater is of acceptable*
> *quality for recharge. (National*
> *Academy of Sciences, 2007)*

Alan Plummer and Associates (2010) discussed the variability of stormwater quality from one watershed to another and between different storm events. Stormwater quality depends on watershed characteristics, pollutant sources, and watershed infrastructure. Unexpected events, such as chemical spills, can also have a significant impact on stormwater quality. They provide examples of different land uses and the potential impact on stormwater quality:

- The presence of industrial land uses and paved roads with high traffic volumes increases the likelihood of chemical pollution of the stormwater.
- Stormwater from commercial and industrial watersheds generally has lower concentrations of nutrients and higher concentrations of heavy metals than stormwater from residential watersheds.
- High volumes/frequencies of sewer overflows increase the likelihood of pathogens in stormwater runoff.
- Stormwater from residential watersheds tends to have greater coliform levels by one order of magnitude than stormwater from commercial and industrial watersheds, due to the presence of domestic animals.
- Stormwater from totally urbanized watersheds is likely to have higher chemical concentrations than stormwater from partially urbanized watersheds.

The Clean Water Act vs. the Safe Drinking Water Act

USEPA’s new stormwater initiative encourages the infiltration of stormwater to the subsurface. It is intended to control stormwater volume and prevent the contamination of surface water. It also allows for no net increase in stormwater runoff volume from preconstruction conditions. However, there may be some incompatibility between the goals of the Clean Water Act to remove stormwater pollutants from surface water by directing it to the shallow groundwater system and the goals of the Underground Injection Control (UIC) program under the Safe Drinking Water Act.

The Safe Drinking Water Act requires that USEPA and delegated authorities protect underground sources of drinking water (USDWs) from injection activities that would cause contamination and USEPA has set minimum standards to address the threats posed by all injection wells, including stormwater drainage wells. Under the UIC program, stormwater injection is a concern because (as discussed previously) stormwater may contain sediment, nutrients, metals, salts, microorganisms, fertilizers, pesticides, petroleum, industrial spills, and other organic compounds that could harm USDWs.

The National Academy of Sciences (2007) cautioned that this potentially conflicting regulatory approach may undermine the UIC program by putting contaminants underground without appropriate controls.

> *We will need to change the way stormwater is regarded; from being a nuisance that needs to be quickly disposed of, to being a valuable resource.*

The types of stormwater harvesting structures regulated under the UIC Class V program are limited. USEPA defines Class V stormwater drainage wells as structures that manage surface water runoff (rainwater or snow melt) by placing it below the ground surface. Class V wells are typically shallow disposal systems designed to infiltrate stormwater runoff. Stormwater drainage wells may have a variety of designs and may be referred to by other names including dry wells, bored wells, and infiltration galleries. The use of the term "well" may be misleading—it is important to note that a Class V well by definition is 1) any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or 2) an improved sinkhole, or 3) a subsurface fluid distribution system (an infiltration system with piping to enhance infiltration capabilities). The third part of the definition includes both horizontal and vertical emplaced distribution systems.

Some types of stormwater infiltration systems do not meet the definition of a Class V stormwater drainage well. For example, projects that infiltrate water through recharge basins, without a subsurface fluid distribution system, are not regulated under the Class V program. Infiltration trenches are generally larger at their widest surface point than they are deep, and they do not contain any perforated pipes or drain tiles to distribute and/or facilitate subsurface fluid infiltration. These types of structures, if regulated at all to protect groundwater quality, would be subject to standards at the state and local level.

Photo courtesy of David Cole, UIC Hydrogeologist, Oregon Department of Environmental Quality

Typical dry well used to direct stormwater to the subsurface in Oregon.

Challenges facing states and local governments are to find ways to harvest stormwater as an alternative source of water, store it for later use, integrate new stormwater regulations and innovative technologies to address surface water problems, and prevent the contamination of groundwater. To accomplish this, we will need to change the way stormwater is regarded; from being a nuisance that needs to be quickly disposed of, to being a valuable resource. Best management practices that do not transfer pollution from surface water to groundwater resources need to be identified and encouraged as part of this initiative. To successfully utilize stormwater harvesting as an alternative water resource, this non-transference concept will need to be addressed in the federal-state-local partnership in several different program areas:

- USEPA NPDES and MS4 programs
- USEPA Drinking Water and UIC programs
- Department of Agriculture and Bureau of Land Management BMPs and Stormwater Management programs, and
- USGS Water Census Initiative.

HAWAII AND THE BUREAU OF RECLAMATION TEAM UP TO STUDY THE CAPTURE AND REUSE OF STORMWATER

Groundwater is the principal source of potable water in Hawaii. As sugar cane and pineapple production has declined over the past decade, prime agricultural land is being opened for new residential and commercial development. Between 2000 and 2010, the state's population increased by 12.8 percent with an associated increase in residential construction.

Development has two impacts on Hawaii's groundwater supply: (1) it increases potable water demand; and (2) it decreases groundwater recharge from rainfall, which is critical for sustaining aquifer levels.

The state's 2004 Water Reuse Survey and Report explained that on the more populated islands existing water sources were being "stretched to the limits of their sustainable yields." The report noted that water reuse is a key component of sustainable resource management. The report was created to provide an overview of the current status of water reuse in Hawaii and to assist the State of Hawaii Commission on Water Resources Management (CWRM) in assessing the potential for using recycled water to meet non-potable water demands across the state. It provides a comprehensive inventory of wastewater reclamation facilities and existing users of treated effluent statewide. It also examines future opportunities for reuse projects and any obstacles to expanded utilization of recycled water.

In 2008, the U.S. Department of the Interior Bureau of Reclamation, in partnership with the CWRM, conducted an appraisal of stormwater reclamation and reuse in Hawaii (http://state.hi.us/dlnr/cwrm/planning_alternative.htm). Unlike most stormwater management approaches, this appraisal explored opportunities to capture and reuse stormwater to augment potable supplies, rather than to simply improve water quality for continued discharge to streams and near-shore coastal waters.

The appraisal consists of three study elements:

- **Element 1** - (1) develop a state-wide framework for identifying and resolving institutional barriers to stormwater reclamation and reuse, and (2) develop a handbook for reclamation and reuse technologies and best management practices for existing and new developments.
- **Element 2** - an appraisal of opportunities for groundwater recharge of stormwater over a brackish water (caprock) aquifer in a dry but rapidly developing area on Oahu called the Ewa Plain.
- **Element 3** - an appraisal of statewide opportunities for augmenting groundwater supplies with stormwater, including groundwater recharge.

Out of this effort, in 2008, the state also produced *A Handbook for Stormwater Reclamation and Reuse Best Management Practices in Hawaii.*

A Handbook for Stormwater Reclamation and Reuse Best Management Practices in Hawaii

AQUIFER STORAGE AND RECOVERY

Storing plentiful water resources underground to use either at a later date or to manage the water quality of an aquifer can be attractive to planners as part of their alternative water resource toolbox. Aquifer Storage and Recovery (ASR) projects are both scalable and flexible—wells can be added as needed to provide for additional storage. The use of ASR can also avoid the potential political, environmental, and economic impacts from the construction and flooding of new surface water reservoirs. Water stored underground is not as susceptible to contamination from surface sources or evaporation as are surface reservoirs. The overlying formations provide a layer of protection from spills or stormwater runoff containing nutrients or pesticides.

Key Term

AQUIFER STORAGE AND RECOVERY

Storage of water underground in times of plenty to be used in times of need.

Currently, many different types of water sources are being stored underground. Some systems store treated drinking water processed in low-water-demand periods (during winter months or at night) for use during high-demand periods in the summer. Others store stormwater, treated wastewater, or treated surface and groundwater from other aquifers when it is available. The aquifer into which the water is injected can be either fresh or saline.

ASR systems are complex projects utilizing sophisticated technologies for characterizing the subsurface environment, predicting hydraulic and geochemical behavior of groundwater, and conveying and treating water for injection and retrieval for ultimate use. To fully utilize this technology, collaboration is needed between all levels of government (e.g., local, state, tribal, and federal USGS, USEPA, BLM) to conduct research that will provide additional information for planners to consider.

Before injection, potential sources of recharge water and treatment requirements must be identified. The hydrogeologic characteristics and the chemical composition of potential receiving aquifers must be identified, and the chemical interaction between the recharge water and the aquifer matrix must be understood.

Sometimes injected water, when recovered, will contain metals and disinfection by-products that were not present in the water before injection. While both groundwater in the aquifer and injected water are potable, the mixing of the two waters may trigger reactions with the rock matrix that causes the retrieved water to exceed a drinking water Maximum Contaminant Level (MCL).

USEPA or states and tribes that have delegated authority to regulate the Underground Injection Control (UIC) program need to examine and address this problem in their permitting process by balancing the use of ASR for drinking water management with the potential for contamination of underground sources of drinking water. USEPA suggests that permits issued to public water system operators should require operational practices that reduce mobilization and minimize the area within which potential mobilization could occur. They recommend that this should be coupled with controls that would prevent a groundwater user, other than the public water system operating the injection well, to have access to the impacted area of the aquifer.

To encourage ASR at the local level, there is a need for educational materials on topics such as potential injection water sources and their ability to interact with receiving aquifers. Additionally, there is a need for research on practices that can minimize the extent of potential contaminate mobilization as well as information on receiving aquifer composition and hydrogeologic characteristics, such as porosity and permeability (which influence the recovery of injected water); aquifer material interaction with injected water; and receiving aquifer water quality to pinpoint areas where ASR can be used.

WATER REUSE

In areas already suffering from water scarcity and where rainfall volume is predicted to decrease, wastewater reuse can stretch existing potable surface and groundwater supplies. Direct reuse of wastewater and indirect reuse through recharge of aquifers using lower-quality reclaimed water can provide an alternative resource to meet demands. With proper treat-

ORANGE COUNTY'S GROUNDWATER REPLENISHMENT SYSTEM

In the mid-1990s, California's Orange County Sanitation District (OCSD) faced the possibility of having to build a second ocean outfall that would have cost approximately $200 million. At the same time, the Orange County Water District (OCWD) was dealing with ongoing seawater intrusion problems and the need to expand its Water Factory 21 (WF 21) from 22.6 million gallons per day to 35 million gallons per day.

California had been—and continues to be—undergoing a severe drought, not to mention increasing water demand due to population growth and the growing need for and cost of imported water supplies. OCWD chose to build upon its long-history of successfully treating wastewater at WF-21. Here they employed advanced processes to purify the wastewater and send it to groundwater recharge basins, where it would ultimately become part of north and central Orange County's drinking water supply. The result was the Groundwater Replenishment System (GWRS).

The GWRS takes highly treated wastewater that would have previously been discharged into the Pacific Ocean and purifies it using a three-step advanced treatment process consisting of microfiltration, reverse osmosis, and the use of ultraviolet light along with hydrogen peroxide. The process produces high-quality water that exceeds all state and federal drinking water standards. OCWD then replenishes the groundwater in the basin with water from the Santa Ana River, recycled water, and imported water (when available).

OCWD has one of the most sophisticated groundwater monitoring programs in the country. The District runs more than 350,000 analyses of water from more than 650 wells every year. OCWD performs nearly 50 percent more water quality tests than is required in order to ensure the highest water quality possible.

This state-of-the-art water purification process can produce up to 70 million gallons of high-quality water every day, enough to meet the needs of nearly 600,000 residents. Planned upgrades will create an additional 30 million gallons per day increasing capacity to serve 850,000 people.

The design and construction of the GWRS was funded jointly by the OCWD and the OCSD. These two agencies have worked together for more than 30 years, leading the way in water recycling and providing a locally controlled, drought-proof, and reliable supply of high-quality water in an environmentally sensitive and economic manner.

Source: OWCD Fact Sheet

Three-step advanced treatment process consisting of microfiltration (top photo), reverse osmosis (middle photo), and ultraviolet light with hydrogen peroxide (bottom photo).

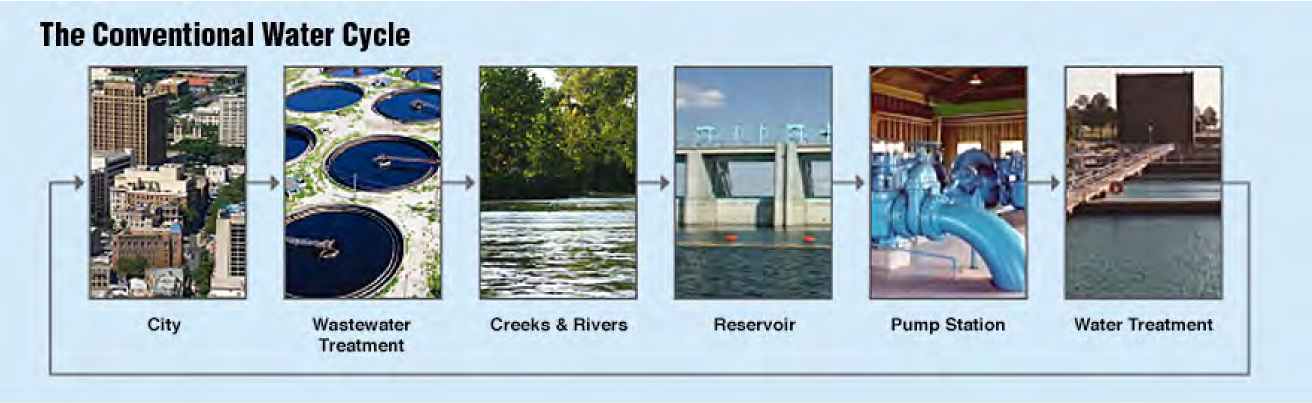
Water is then sent to groundwater recharge basins, where it ultimately becomes part of north and central Orange County's drinking water supply.

ment, direct water reuse can augment water sources and provide an alternative source of supply for non-potable purposes, such as agriculture, landscape, public parks, and golf course irrigation. Other non-potable applications include cooling water for power plants and oil refineries, industrial process water for facilities such as paper mills and carpet dyers, toilet flushing, dust control, construction activities, concrete mixing, and artificial lakes. Although feasible and used in many arid locations, direct reuse of wastewater, treated to drinking water standards, is not well accepted by the public as a drinking water supply.

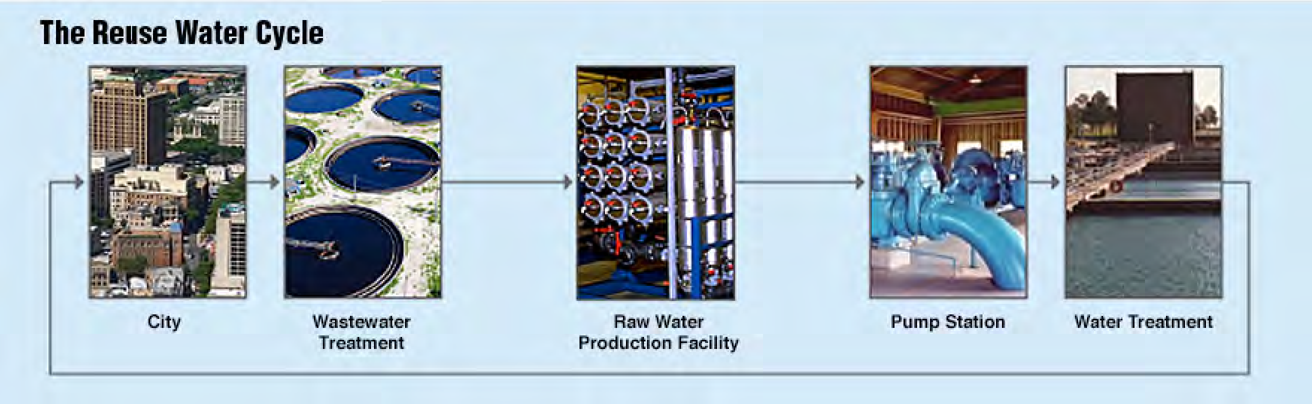
A USEPA study in 1999 found that communities, especially those in arid regions of the U.S., are trying to derive some secondary benefits from treated wastewater effluent through aquifer recharge, subsidence control, or maintenance of a salt water intrusion barrier. The indirect reuse of wastewater to control saline water movement into freshwater aquifers has been used successfully both in California and Florida. Wastewater barriers have been introduced into aquifers through recharge from detention/retention basins and aquifer recharge wells. States with primacy for the Underground Injection Control Class V Well program have developed and implemented regulatory programs to permit these wells.

When examining the reuse of treated wastewater, unintended consequences from removing the wastewater from the volume of water discharged to surface water from public and privately owned wastewater treatment works need to be studied. Reducing the volume of wastewater discharged back to surface water as return flow will have negative impacts on dry period baseflow or low-flow conditions in streams—potentially affecting downstream users and environmental flows and reducing the ability to attain water quality standards in surface streams.

Educational materials and outreach to local communities are needed to aid in 1) selecting a proper technology to treat wastewater to a level where it can be reused, 2) understanding costs to produce reclaimed water, and 3) understanding the costs to develop/finance delivery infrastructure. To facilitate wastewater reuse and aquifer replenishment, collaboration between Clean Water Act programs and Safe Drinking Water programs at USEPA, USGS, USFWS, BLM, states and tribes will be needed to identify areas were reuse is feasible.



The Conventional Water Cycle



The Reuse Water Cycle

http://www.tceq.texas.gov/publications/pd/020/2013-NaturalOutlook/texans-take-action-addressing-future-water-supplies

COLORADO RIVER MUNICIPAL WATER DISTRICT USES MULTIPLE APPROACHES TO SECURE SUPPLIES

Water is always a chief concern to people in west Texas, no more so than during extended drought. The Colorado River Municipal Water District supplies water to member cities Big Spring, Odessa, and Snyder, and sells water to Midland, San Angelo, Abilene, Stanton, Robert Lee, Grandfalls, Ballinger, and Pyote.

Surface water supplies are at historic lows in Lake J.B. Thomas, E.V. Spence Reservoir, and O.H. Ivie Reservoir, the district's three repositories of surface water. Evaporation and extended drought have rendered spillways useless artifacts sitting on dry land. In 2009, a barge was built to capture water from a deeper portion of Lake Thomas. A second barge was built and moved to deeper water in March 2011 to tap a shrinking supply.

New wells have been drilled in Ward County, some 60 miles from the nearest reservoir. A pump station and a 45-mile pipeline have been constructed, connecting to existing storage in Odessa to deliver this groundwater to the system. These new wells will supply 30 million gallons per day.

In Big Spring, a direct reuse facility, scheduled to come on line in 2014, will treat wastewater and blend it with raw water from the lakes to supply customers in Big Spring, Stanton, Midland, and Odessa. When fully operational, this $14 million plant should supply two million gallons per day. Other projects of the district include:

- refurbishing existing wells, pipelines and pump stations
- reversing the direction of a pipeline
- two additional reuse facilities
- brackish-water desalination
- channel dredging in O.H. Ivie Reservoir

Sources: http://www.tceq.texas.gov/publications/pd/020/2013-NaturalOutlook/texans-take-action-addressing-future-water-supplies and Water-Reuse Projects Move Forward, Despite Concerns by Audrey White*, Texas Tribune, Feb. 8, 2013 http://www.texastribune.org/2013/02/08/cities-pursue-treated-wastewater-ease-water-shorta/*

Photo courtesy of CRMWD

Barges are used to move intakes to deeper water when levels decline. This barge on Lake Thomas was moved twice—in Jan. 2009 and again in Mar. 2011. This picture was taken in Sep. 2012.

Recommended Actions

Legislation and Regulatory Programs

- Congress should support research and development of innovative water conservation and supply augmentation strategies, including groundwater recharge and recovery, desalination, and wastewater reuse.
- States should examine their existing water laws and long standing practices and procedures to determine if they have the flexibility to address potential long-term drought or climate variability impacts. This examination should focus on water initiatives and programs associated with demand management, efforts to "stretch" existing supplies, water banking, and water transfers.
- States and local governments should implement new stormwater regulations and innovative technologies to address surface water quality problems while at the same time preventing contamination of groundwater. Stormwater should be viewed as a potential source of groundwater recharge.
- USEPA and states/tribes that administer the Underground Injection Control (UIC) Program should examine and address problems that are preventing the use of aquifer storage and recovery and desalination technology.
- States should balance the rights to water and acceptable uses of wastewater effluent to promote recycling, while meeting in-stream flow obligations and protecting surface water rights dependent on return flows. State and local regulatory entities should cooperate in permitting reuse projects while requiring wastewater treatment suited to the proposed water use.
- Congress should fund groundwater-related information collection required to implement national initiatives and legislation (such as the SECURE Water Act).

Education

- Public education programs should be developed at all levels of government to help increase the understanding that many alternative water sources are not "wastes" and to also understand the value of these resources.
- Realistic data should be developed at the federal and state level to help water planners evaluate the lead time and monies needed to investigate the cost/benefit of various alternative resource including: the potential benefit and downside to each alternative water option; what will be needed to adequately characterize the resources and selecting a treatment technology; and understanding costs to produce, develop, and provide delivery infrastructure.

Recommended Actions continued

Research

- USGS and states should continue to develop brackish and saline water resource information such as identifying the characteristics and the availability of aquifers for desalination. This information should be shared with water resource planners to help target sites for more detailed investigations and to allow planners to determine the cost to develop the saline groundwater.
- Low cost and more energy efficient treatment options for undesirable fresh water that contains high iron or exceeds other secondary drinking water standards related to taste and color need to be developed.
- Additional research should be conducted to evaluate the chemical and microbial constituents in urban stormwater and their behavior during infiltration and subsurface storage.
- To fully utilize aquifer storage and recovery technology, all levels of government (local, state, tribal, and federal) and academia should collaborate to conduct research that will identify potential receiving aquifer reservoirs, provide information on water quality changes that can occur between the reservoir matrix and the injected water, and treatment needs either before injection or after production of stored water.
- The Bureau of Reclamation, USEPA, USDOE, and USGS should continue to support research into the benefits and obstacles to implementation of wastewater reuse, as well as define and study effects of emerging contaminants on drinking water. Cooperative research at all levels of government is needed to identify areas were reuse is feasible through collaboration of the Clean Water Act and Safe Drinking Water Act programs.
- Climate models that help predict extreme weather and provide better information at a local or regional scale need to be developed at the federal and state level to facilitate state and local planning.

Resource Planning

- To foster sustainable growth policies, states should identify water requirements needed for future growth, and develop integrated growth and water supply impact scenarios that anticipate an increased need, taking into account the potential effects of population growth and climate variability and extremes in administrative, regulatory, and legal agreements involving water resources.
- All levels of government should evaluate current and future capacity for using alternative water resources as part of their water management planning process and provide funding to address management at the local level.

Section 11 References: Alternate Water Supplies

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