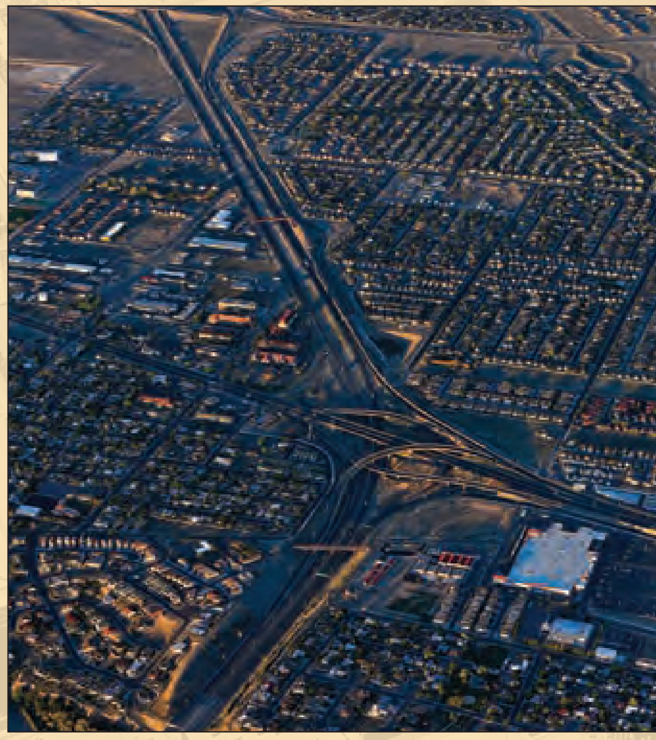
A LOOK TO THE FUTURE

DECISION-MAKERS
FIELD CONFERENCE 2009
The Albuquerque Region



The Coors Interchange on I–40.

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Water Supply Strategies Identified in New Mexico Water Plans

Joanne Hilton, P. G. and Dominique Cartron, J. D., *Daniel B. Stephens & Associates, Inc.*

New Mexico relies on limited surface and ground water resources to meet competing demands for water. Interstate compacts, endangered species issues, and intermittent drought can place further constraints on the amount of water that can be used for agriculture, drinking water, commercial, and industrial uses. Riparian vegetation needs and open water evaporation further deplete our limited water supplies. To address these shortages, a variety of water planning efforts have been initiated in New Mexico.

NEW MEXICO WATER PLANNING INITIATIVES

Many planning efforts are underway in New Mexico to assess water supply availability, institutional constraints, projected demands, and strategies for meeting future demands. These planning efforts take place at the regional, county and municipal, and state levels and generally have the common objective of ensuring a high-quality, sustainable water supply for the future. Other goals include infrastructure planning, drought planning, and protection of water rights or water quality.

Regional Water Planning

Water planning has evolved from several different legislative initiatives, beginning with the regional water planning program in the mid-1980s. After the U.S. Supreme Court ruled that New Mexico's ban on out-of-state water transfers was unconstitutional, the legislature acted quickly to set up a framework for long-term water supply planning, to demonstrate the need for water resources and to ensure an adequate supply for the future. The regional water planning statute provided general guidance, and some regions began organizing to develop a plan, but the program wasn't fully implemented until the Regional Water Planning Template was drafted in 1994 and additional funding was made available.

As the first formal water planning program in the state, regional water planning evolved according to the planning template and with input from the stakeholders in the planning regions. At the outset, New Mexico was divided into 16 regions, and as the program received more funding, each region assessed its water supplies and future demands for water.

Municipal and County Water Planning

Water planning at the municipal and county level has been done for many years in the form of water master plans for utilities. These plans allow water suppliers to ensure that their infrastructure is adequate to meet demand within the service area, but they do not generally include a hydrologic study or address water rights issues.

Water development planning for water suppliers arises out of the state engineer's obligation to ensure that water rights applications are consistent with public welfare and conservation of water within the state. To allow municipalities and other water suppliers to acquire water rights without putting them to immediate beneficial use, New Mexico water law allows a 40-year water planning period "to plan for the reasonable development and use of water resources" to meet "reasonably projected additional needs" within the planning period. The state engineer also requires these entities to include water conservation in evaluating the need for additional water rights.

State Water Planning

State water planning emerged in 2003 as a "strategic management tool" to protect the state's resources. The legislature set out an ambitious program to address all aspects of water supply planning, from public participation to the development of technical resources as the basis of the plans. Statutory objectives include:

- Promote stewardship of the state's water resources
- Protect and maintain water rights and their priority status
- Protect the diverse customs, culture, environment, and economic stability of the state
- Protect both the water supply and water quality

- Promote cooperative strategies, based on concern for meeting the basic needs of all New Mexicans
- Meet the state's interstate compact obligations
- Provide a basis for prioritizing infrastructure investment
- Provide statewide continuity of policy and management with regard to our water resources

The state water plan was published in 2003 and was followed by an implementation report in 2004, a progress report in 2006, and a review and proposed update in 2008. The state water plan builds on the regional plans, yet addresses water issues from the perspective of the state in accordance with the different legal obligations the state must fulfill as it manages New Mexico's water resources.

The 12.8-mile-long concrete-lined Azotea Tunnel conveys San Juan–Chama water from Navajo River to Azotea Creek in the Rio Grande basin. These imported waters flow down Azotea and Willow Creeks 11.8 river miles to Heron Reservoir.

STRATEGIES FOR MEETING FUTURE WATER DEMANDS

Water supplies in many parts of New Mexico are already over-appropriated, and during drought years, not all demands can be met, or they are met through non-sustainable ground water mining. Expected population growth, along with associated economic activity, suggests larger projected shortfalls between supplies and demands in the future. (The difference between the legally available water supply and the projected demand is referred to herein as the supply–demand gap.) Accordingly, through the New Mexico Regional Water Planning Program, each region has identified strategies for reducing the gap between supply and demand in the region overall, and additional strategies have been identified by local water providers through their individual planning processes.

The types of strategies outlined in various water plans can be segregated into four main categories:

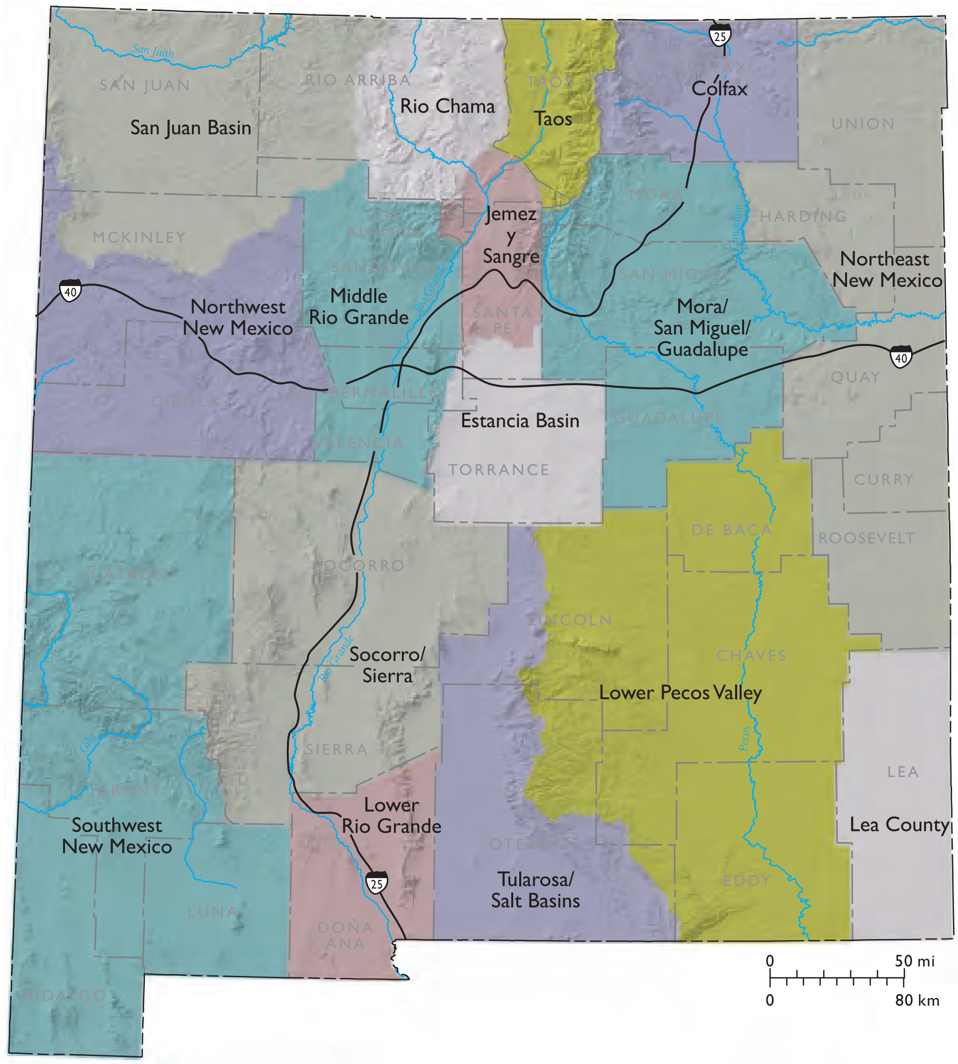
- Reduce demand
- Develop new sources of supply
- Improve water management
- Protect water quality

Reduce Demand

Strategies that are intended to reduce demand for water through conservation measures or other means are included in this category. Water conservation is often, at least initially, the lowest-cost and most practical method of reducing the supply–demand gap. In relation to uncertainties in availability and costs for acquiring water rights and building new infrastructure for water projects, the costs for conservation programs are relatively low. Conservation strategies generally fall in the realm of either municipal or agricultural conservation.

Most municipalities in New Mexico are trying to reduce both indoor and outdoor water use in their communities. A recent analysis in California identified indoor water conservation as the most viable conservation method and further identified urban conservation (both indoor and outdoor) as producing the highest estimated quantitative change in the supply–demand gap (in comparison to aquifer storage and recovery, wastewater reuse, new surface storage, agricultural water conservation, desalination, and cloud seeding). Indoor water conservation programs include measures such as replacing high-water-use toilets and appliances with lower-water-use fixtures, detecting and preventing leaks, and educating consumers in the need for and measures to minimize water waste. Outdoor water conservation programs include education or incentives for xeriscaping and restrictions on days of the week or time of day when landscape irrigation can occur. Reductions in outdoor water use usually provide for more significant savings in consumptive use, because return flows are generally higher for indoor uses. Many municipalities are also implementing strategies to maximize wastewater reuse and thereby reduce the demand for potable water.

Agriculture remains the largest water use sector in New Mexico. Even in areas such as the Middle Rio Grande, which hosts the largest urban population in the state, agriculture water use still represents more than half of the total withdrawals (excluding natural riparian and open water evaporation losses) in the area. Agricultural water conservation includes measures such as lining ditches to reduce leakage, implementing more efficient irrigation technologies (i.e., drip irrigation or low energy precision application), or switching to lower-water-use crops.



New Mexico's sixteen water-planning regions.

In New Mexico much of our agricultural water is used for flood irrigation of alfalfa or other hay crops. The same field of hay can be harvested 3 to 6 times per year without replanting, making this a relatively high-value crop in relation to the labor expended. Many alfalfa growers farm on a part-time basis while maintaining other employment. While switching to lower-water-use crops and more efficient irrigation methods is technically feasible, one of the key obstacles to that change is the economic and practical feasibility of growing more labor-intensive crops.

Determining the exact amount of reduction in demand that can result from conservation programs is often complex. For example, improved efficiencies in agricultural delivery systems may result in better water deliveries and higher crop yields, having value to farmers, but may not necessarily make additional water available to support other water uses. Similarly, savings in municipal conservation may be complicated by reductions in return flows. If conservation programs are intended to make water available to supply the growing demands in New Mexico, they must be specifically designed for that purpose.

The biggest gains in water conservation are often realized at the beginning of a water conservation program, when water users move from highly inefficient water use to lower-water-use technologies. As more conservation measures are introduced and enforced, there is a diminishing return on how

The Strategic Water Reserve

With the passage of the Strategic Water Reserve Act in 2005 and the adoption of implementing regulations, the New Mexico Interstate Stream Commission (ISC) is developing a basin-specific water management program "to assist with interstate compact compliance; and to assist the state and water users in efforts to benefit threatened and endangered species," which are the two authorized purposes for the reserve.

The act allows the ISC to acquire water rights for the reserve through sale, lease, or donation. By providing the ISC with a means to acquire water rights for these purposes, the act provides a tool to help reduce potential conflicts related to the delivery of water for interstate compacts or water needed for endangered species. Some types of projects that could be considered for implementing the reserve are:

- Restoring river habitat
- Augmenting flows in specific locations at specific times of the year
- Supporting delivery of water for interstate stream compacts

In 2008 the ISC designated the Middle Rio Grande and Lower Rio Grande as priority areas for the program. The state has already acquired water rights in the Pecos River Basin for the Strategic Water Reserve.

Implementation of this program in river basins with complex water management issues requires an incremental process to ensure success. Factors such as the availability of funds to purchase water rights and a limited water market must also be considered. In the Middle Rio Grande, through a series of listening sessions held in the summer of 2008, the ISC brought together stakeholders from the public, local governments, Indian tribes, water planning regions, and major water providers to gather input for moving the program forward, and to ensure that the general public understands the purposes of the program and the legal protections afforded to water rights holders.

The statute and regulations carefully lay out the legal requirements regarding acquisition of the water rights for the reserve. Export of water is not allowed, so any water acquired for the reserve must remain within the river or ground water basin where it was acquired. Acquisitions or transfers of water rights for the reserve must comply with the state engineer's transfer process, must not impair existing users, and may not result in new depletions. Acequia water rights are excluded, and water may not be acquired through condemnation. One important legal protection for water rights holders who are willing to lease but not sell water rights is the provision that water rights leased to the reserve are not subject to forfeiture. Successful implementation of the Strategic Water Reserve will allow the ISC to protect New Mexico's water resources and reduce potential conflicts in priority river basins.

much water can be saved. For example, the city of Santa Fe has had a program that allows developers to receive city water for new development by paying for the replacement of older toilets with newer lower-use models. However, the city estimates that most older homes have been retrofitted, with only 25 percent remaining to be retrofitted, indicating that this program cannot indefinitely provide a supply for new housing.

Conservation alone will not save enough water to meet all of the growing demands in New Mexico. Nonetheless, by lessening water demand, efforts to conserve water in both the agriculture and municipal sectors are seen as important strategies for closing the gap between supply and demand.

New Sources of Supply

Strategies in this category include projects that will result in additional physical water supply with associated water rights to address future needs of the region such as the development of additional ground water supplies or, where legally allowable, surface water storage. In many cases, the development of a new supply for one geographic area is actually based on movement of water from another area, such as the construction of pipelines to import water. Nonetheless, these projects can be very important in providing a new source to the region receiving the water. The Ute and Navajo pipelines are important strategies in this category and will supply water to communities in eastern and northwestern New Mexico, respectively, that are in need of viable renewable resources to support water demands and replace non-renewable ground water use.

Along the Rio Grande, numerous contractors have the right to develop and use water allocated to them from the San Juan–Chama Project (imported from the Colorado River basin). Many of these contractors—including the City of Albuquerque, City of Santa Fe, and County of Santa Fe—now have drinking water projects under construction to allow the use of this water. Los Alamos County and the city of Española have plans to begin using their San Juan–Chama project allocations as well. Though the full contracted allotment of San Juan–Chama project water may not be available to all contractors during drought years, the use of this water will nonetheless replace non-sustainable ground water mining with a renewable source in many years. Conjunctive management of surface and ground water supplies is an important strategy for most of the San Juan–Chama contractors.

Some of the regional water plans, and many municipal forty-year water development plans, have identified transfers of water from agriculture as a means to meet their growing demands. In regions such as the Middle Rio Grande, the Pecos, and other stream-connected basins in New Mexico, water rights are a limiting factor—that is, any new use must be offset by a transfer from an existing use. In the more densely populated areas, multiple water providers may be competing to purchase the same water rights, while at the same time such purchases are limited because transfers are only for consumptive uses and are not allowed in all cases. Additionally, many regional water plans and other stakeholders (e.g., New Mexico Acequia Association) have expressed strong support for conserving water for agricultural use. Thus, while transfers of water from agricultural to municipal uses are expected to continue, transfers alone cannot be expected to meet all the water needs.

One potential new source of water that has elicited considerable recent interest is the development of deep brackish ground water supplies. The relative merits and issues with brackish water development are discussed in Bruce Thomson's paper, in this volume.

Water Management

This category includes projects that have the potential to improve management or provide for more efficient use of water resources, but do not result in a new water right that can be applied to new growth in the region. Strategies in this category would include improved watershed management, funding, education, development of policies or programs to address issues such as water availability for growth, domestic wells, and other water management functions.

One example of a water management strategy is riparian restoration. In the last decade New Mexico has devoted considerable resources to efforts to eradicate salt cedar. Whether those programs result in measurable changes to water supplies in the long term depends on the extent of removal and post-removal conditions (i.e., whether the salt cedar evapotranspiration that was occurring is replaced by bare soil, open water evaporation, or evapotranspiration by other vegetation). Projects in areas with shallow water tables or where vegetation rapidly regrows may have only minimal benefits. Therefore, continued monitoring and optimally designed programs are key to evaluating and optimizing benefits. Similar issues occur with higher-elevation forest thinning and cloud-seeding programs. Scientific evidence of the value of these programs is varied, and results are dependent on site-specific conditions.

Statewide efforts at salt cedar eradication have had varying results, depending upon site-specific conditions. Whether these programs result in measurable, long-term changes to water supplies depends on the extent of removal and on post-removal conditions.

Special legislation has given the Interstate Stream Commission a flexible water management tool through the Strategic Water Reserve, which allows the state to purchase water rights to be used either to benefit endangered species or assist with interstate river compact compliance.

Water Quality

Strategies in this category include policies or programs that will protect or improve water quality (e.g., developing wellhead protection programs or providing alternatives to septic tanks), thereby preserving the usability of the region's water supplies. Treating poor-quality water is an added expense, and in most cases water quality does not completely constrain the use of the supply. Nonetheless, programs to protect or improve water quality are important for providing safe drinking water supplies for the future of New Mexico. Water quality protection was identified as a key strategy in many of the New Mexico water planning efforts.

STEPS FOR GOING FORWARD

New Mexico remains a water-short state with many users competing for our limited water resources. While some development of new sources of water for a given area is possible, overall we will need to find ways to live within our means. No single water project or program will easily solve our water problems, and continued implementation of a variety of strategies will be necessary for New Mexico to close the gap between water supply and demand and to prepare for times of drought. Some key steps for moving forward to address water shortages are:

- Continue to support municipal, commercial, and industrial water conservation programs
- Support research on and implementation of agricultural conservation programs that are specifically designed to reduce losses and consumptive uses, and to maximize benefits to farmers and partners that can work cooperatively with farmers
- Support policies that provide for the protection of water quality
- Support ongoing efforts for scientific study of water supplies and metering, monitoring, and public reporting of water uses
- Support research and implementation of programs focusing on innovative strategies for reducing demand and efficiently developing new supplies and/or improving water management
- Support initiatives for addressing drought and climate change
- Support ongoing planning efforts to better understand physical and legal limitations and to develop cooperative strategies for meeting future demands

Implementing strategies to address protection of the quantity and quality of our water supplies is critically important for the continued prosperity of New Mexico.

The Middle Rio Grande Water Right Market

Kyle S. Harwood, *Harwood Consulting, PC*

The water right market in the Middle Rio Grande is an amalgam of historic practices and laws that have been adapted to the increasing stress on and uncertainty of water supply, increasing regulation, and increasing public interest in water use. The prior appropriation doctrine and the regulations of the Office of the State Engineer are used to manage the state's watersheds (surface water) and aquifers (ground water), and they must address a tremendous variety of goals and functions. The New Mexico Constitution declares that the waters of the state belong to the public, and that water may be subject to appropriation (a right to beneficially use the water). The tension between the public interest and a private property right to water is what defines the legal and economic dimensions of the Middle Rio Grande water right market. Water supply stress is the primary motivation for the water right market, because of uncertainty in water supply resulting from drought and climate change, the long-standing requirements of interstate water agreements, the unknown water demands for endangered species, the un-quantified senior water rights for Native American claims, and the increasing diversions by water utilities in the Middle Rio Grande basin.

DEVELOPMENT OF THE MIDDLE RIO GRANDE WATER RIGHT MARKET

In the Middle Rio Grande, the water right market consists primarily of acquisitions, by or for the water utilities, of the most senior rights (pre-1907) that have been used for surface irrigation of agriculture, and the transfer of that right to a utility in order to offset ground water depletion. In order to keep the surface water system whole, or undiminished, a ground water depletion offset is quantified using a scientific model that estimates the effect on the surface water system that results from ground water pumping. The majority of the senior rights are supplied from surface water, and most ground water rights are junior to these surface rights. This acquisition and transfer is required to maintain the legal principle of prior appropriation. The prior appropriation system recognizes the earliest or most senior use of water within a hydrologic system. It was adopted in the western United States in the late 1800s as the legal principle by which relative property rights in water use would be determined. The interrelationship between ground water and surface water and the early adoption of the legal principle of prior appropriation are the two most basic elements of the water right market.

The declaration of the Rio Grande Underground Water Basin on November 29, 1956, by the state engineer was triggered by a regional drought and the need to comply with the Rio Grande Compact, which allocated the river between Texas, New Mexico, and Colorado. The declaration of a basin brings the drilling and diversion of ground water within the jurisdiction of the state engineer. About a year later, the state engineer held a hearing on an application by the City of Albuquerque to drill new wells in which he imposed conditions that would avoid impairment of senior surface water users. Albuquerque appealed the qualified approval of their application, and in 1962 the New Mexico Supreme Court issued a decision in *City of Albuquerque v. Reynolds*. The opinion affirmed the state engineer's authority to impose offset requirements on junior ground water pumping in order to protect senior water rights from impairment.

In the forty-five years that have passed since that decision, a great deal of effort and expense have been directed at both the scientific principle (ground and surface water interaction) and the legal/regulatory principle (acquisition and transfer of senior surface water to offset junior ground water depletions) that provide the foundation of the water right market. The water right market has evolved particularly in the past ten years with changes to the formal and informal rules used by the state engineer to review water right validity and the potential for impairment when water rights are proposed for transfer. At the same time, local governments and water providers have increasingly assigned the cost (and in some cases, the responsibility) of the needed water supply to the proponent of new demand. These trends, and others discussed below, have precipitated a steep increase in water right pricing and a public interest in the water right market.

Perhaps the single most salient fact in the development of the water right market over the past five decades has been the increase in price for an acre-foot per year of water right that is transferred to a new point of diversion, otherwise known as consumptive use. Using approximate numbers, and drawing upon the expertise of my colleague Dr. F. Lee Brown (H_2O Economics), the market price quadrupled in thirty-five years from the 1960s to early 1990s, to approximately $1,000 to $1,200 per acre-foot per year consumptive use. The price quadrupled again in only 8 years to approximately $4,400 per acre-foot per year consumptive use in 2003. The price quadrupled again in only 4 years to the $15,000 to $20,000 range per acre-foot per year consumptive use in 2007, with some water right transactions in specific circumstances priced at twice that amount. Few professionals, even those intimately involved with current transactions, are willing to venture an opinion about the future trend of water right prices in the Middle Rio Grande.

WATER RIGHT MARKET MECHANICS

Two very different relationships, a private property transaction and a public regulatory process, define the water right market. The private transaction is typically a contract in which a buyer and a seller exchange money for title to real property. It usually includes mutual commitments to cooperate in the public process that requires compliance with a variety of rules and regulations to change the use, user, or location. In this context, a private transaction also applies to public entities (such as cities or counties), because the negotiation, review, and enforcement of the transaction is managed by the parties to the contract. By contrast, the public process is managed by the state engineer in accordance with statute and regulation. The public process requires an application, legal notice, an opportunity for protest, and the application of the rules and regulations to the resulting transfer or denial.

The characteristics of a water right that may change during a transaction include ownership, volume, priority date, place of use, purpose of use, point of diversion, and the economic value or price of a water right. Only when the proposed water right market transaction involves a change in the point of diversion, place of use, or purpose of use does it become a regulatory matter in which legal notice and an opportunity for protest is provided to the public. This is the water right market that is most commonly discussed. By contrast, a simple change of ownership, in which no other attribute of the water right is changing, is handled administratively by the state engineer and does not involve a public process. A change in ownership often occurs with a change in point of diversion, place or purpose of use, and the quantity and priority date can become issues in the state engineer's review of a water right transfer.

The private transaction process is one that involves water right brokers and other water resource specialists finding each other through referral and advertising. Negotiations typically result in custom contracts depending on the nature of the water rights, their intended use, and the particular constraints or preferences of the parties. The complexity and cost of the water right purchase agreement has grown over time as parties anticipate, negotiate, and draft provisions to address different scenarios that may occur in the transfer proceeding.

From an economic perspective, a market works best with abundant data regarding water supplies necessary to meet short- and long-term demand, pricing information across a spectrum of volume and timing scenarios, and regulations that incorporate social equity and public policy. From a legal perspective, a market works best with certainty of title (or the adjudication of water right characteristics), standard business practices for transactions, and consistent precedent in court decisions that interpret contracts and regulations. By any measure, the water right market in New Mexico is a long way from being efficient and effective, from either an economic or legal perspective.

THE EVOLUTION OF THE WATER RIGHT MARKET

The water right market operates within a context of law, economics, and regulation. In the Middle Rio Grande the nature of these factors creates an extremely complex and uncertain environment. This basin has the greatest population and projected population change in the state, the greatest rate of change in water right prices, the highest prices in the state, significant and un-quantified water right claims for Native American and endangered species, and an interstate compact in which New Mexico is both an upstream and downstream state.

The practice of water right dedication (identification of an offset without transfer) was the subject of a negative Attorney General Opinion in 1994. The opinion concluded that the dedication process was unlawful and that statutorily mandated procedures, especially those related to notice, should be followed. At this point, there were four major factors affecting the water right market: the Attorney General Opinion, sharp increases in water right pricing, growing urban demand, and the mandate of federally protected endangered species. These continue to be the most tangible constraints on creative solutions to the challenge of balancing the policies and water budget in the basin. With these sobering thoughts in mind, it is perhaps mindful to recount the 2003 New Mexico State Water Plan statement regarding the water right market:

> *Consider water rights transfer policies that balance the need to protect the customs, culture, environment and economic health and stability of the state's diverse communities while providing for timely and efficient transfers of water between uses to meet both short-term shortages and long-term economic development needs.*

The water right market has become a tool to meet all of these equal and conflicting public policies. Water right transfers are one significant mechanism for urban growth, along with conservation, importation, and treatment. It is also the required process used to acquire water rights for the Strategic Water Reserve to assist the state with compact and endangered species goals (see sidebar on the Strategic Water Reserve in this volume). On the other hand, a protest in the state engineer transfer process has become a common way for some residents to seek protection of their customs and culture.

THE FUTURE OF THE WATER RIGHT MARKET

No matter what assumptions or vision you hold for the future of New Mexico water, any changes to the current pattern of water use and ownership will require a market.

It is likely that the future evolution of the water right market will be incremental, and will take one of two forms. Either the rules (regulations, statutes, and litigation) will ease and become more regular, and the water right market will become a more typical economic model, or the rules will become tighter and more specific, and the water right market will become a more typical regulatory model. The state government sits at the crossroads of federal, local, and Native American governments with respect to balancing water use and changes to water use. The ability to craft and impose new solutions at the state level is tempered first by interstate and international imperatives, and then always by the judiciary and the electorate.

The current system within which the market operates is like an old rubber band—useful and functioning, although brittle, and with an uncertain future. There are a number of ideas that might improve efficiency or equity, but it is not clear how we would get there from here. Executive and legislative leadership will be indispensable in defining the future of the water right market in the Middle Rio Grande.

Suggested Reading

Evaluating the costs of desalination and water transport, Y. Zhou, & R. S. J. Tol, Water Resources Research, 41 (3), W03002, 2005.

Saline Water—Considerations for Future Supply in New Mexico

Bruce Thomson and Kerry Howe, *University of New Mexico*

As the demands on existing water supplies intensify, increasing attention is focused on the search alternate means of meeting the increasing demand for water. These may include diversion of water from other basins, purchase of water from agricultural owners by municipal and industrial users, implementation of aggressive conservation methods to extend existing resources, and development of low-quality water supplies by use of advanced treatment to render the water suitable for appropriate use. Low-quality water supplies that are under consideration include treated wastewater and brackish and saline ground waters.

In recent years, brackish and saline ground water resources have received much attention as a potential new source of water. There are three reasons for this: First, as communities recognize the constraints imposed on them by impending water shortages, they are willing to pay more for water. Second, advances in high-performance water treatment technologies and associated reductions in the costs of these technologies have increased the viability of using low-quality water as a source of supply. Third, New Mexico regulations regarding jurisdiction of deep and salty ground water sources lead to the conclusion that these supplies are not currently owned and/or not subject to administration by the New Mexico State Engineer. The convergence of these three factors has led to consideration of brackish and saline water supplies as a source of water to support municipal development in several communities in New Mexico.

BRACKISH AND SALINE WATER RESOURCES IN NEW MEXICO

Most commonly, salinity is measured as the concentration of total dissolved solids (TDS) in water. This is determined by taking a measured volume of water, filtering it, evaporating it to dryness, and weighing the remaining residue. TDS can be inferred by measuring the electrical conductivity of the water. The dissolved ions in salty water render it more electrically conductive, thus, electrical conductivity is a frequently used cheap and rapid method of estimating the salinity of water. Regulations under the federal Safe Drinking Water Act recommend (but do not require) that public water supplies have a TDS of less than 500 mg/L.

There are many communities in New Mexico and elsewhere that supply drinking water to their customers with TDS levels greater than 500 mg/L and a few that provide water with TDS greater than 1,000 mg/L. Above 1,000 mg/L, however, most customers object to the taste of the water, and some may experience gastrointestinal upset.

It has been estimated that 75 percent of New Mexico's ground water resources have a TDS greater than 1,000 mg/L; however, because this water has little value, there has been little work to quantify and characterize this resource. The New Mexico Office of the State Engineer, the New Mexico Water Resources Research Institute, and the U.S. Bureau of Reclamation sponsored a workshop in 2004 to develop programs to quantify the resources and identify strategies to manage them.

CLASSIFICATION	TDS (mg/L)
Fresh water	< 1,000
Mildly brackish	1,000–5,000
Moderately brackish	5,000–15,000
Heavily brackish	15,000–35,000
Seawater and brine	> 35,000

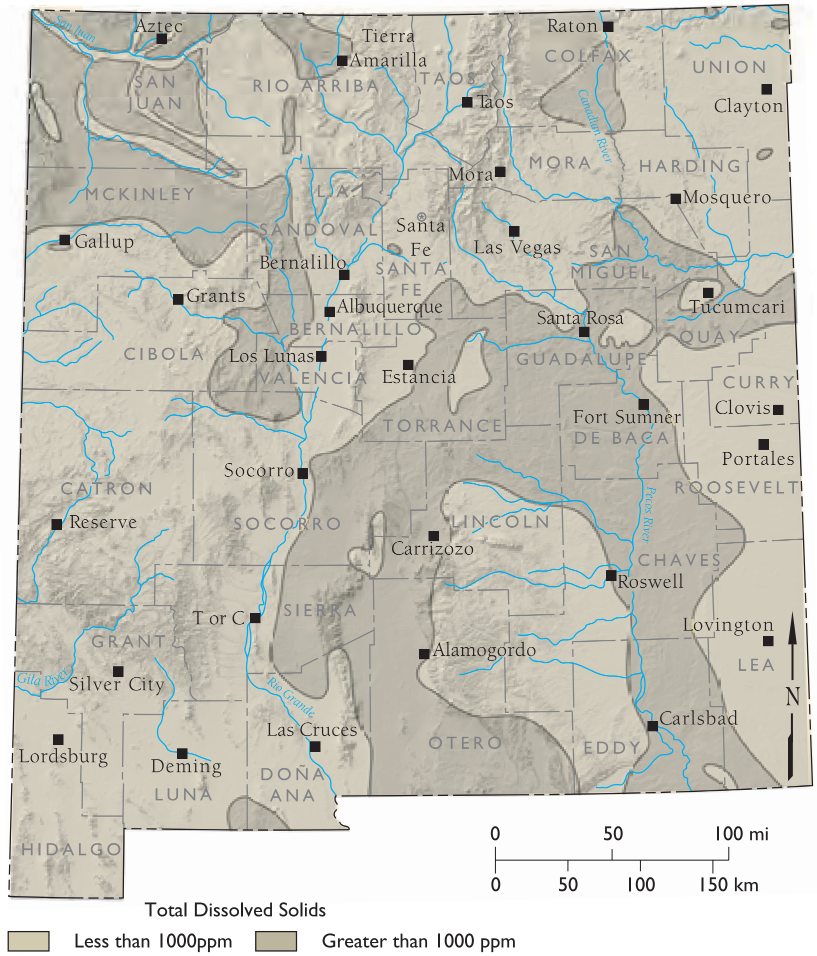
Classification of brackish and saline water according to concentration of total dissolved solids.

As this document goes to press, the state engineer does not have jurisdiction over ground water if (1) the TDS of the water is greater than 1,000 mg/L and (2) the top of the water-bearing formation is at least 2,500 feet underground. This leads some water resource managers and developers in need of water resources to consider ground water meeting these criteria as "new" water, in that it is not subject to state laws or regulations that govern water rights. Recognizing the potential magnitude of these resources and the fact that they may be a "new" resource has led to many proposed projects to tap them.

In New Mexico, notable proposed projects include development of deep saline ground water for the city of Gallup, development of the Salt Basin in Otero County, and use of brackish water in the Tularosa

Basin. Closer to Albuquerque, two proposals have been made in the past ten years to extract 7,200 and 25,000 acre-feet per year from the Estancia Basin, desalinate it, and sell it to Santa Fe to augment their water supply. More recently, in 2007, Sandoval County began a project to characterize a deep saline aquifer in the Rio Puerco basin of western Sandoval County to support new municipal development. And in 2008 the Atrisco Oil and Gas Corporation announced discovery of a deep saline aquifer in western Bernalillo and Sandoval Counties that could support land development of the Albuquerque area. As of February 20, 2009, the Office of the State Engineer has received over 250 notices of intent to appropriate deep brackish or saline ground water resources in New Mexico, totaling approximately 550,000 acre-feet of water.

Another large source of saline ground water in New Mexico is associated with oil and gas development. Although it varies widely depending on location, well, and length of service, oil wells in New Mexico pump about 10 gallons of salt water (so-called "produced water") for every gallon of oil. This water generally has little or no value as a potential water resource for three reasons:



Generalized map of ground water quality in New Mexico, according to total dissolved solids.

- Oil and gas fields are located far from potential water markets so that water transport costs would be prohibitive
- Oil and gas wells have short life spans, which is not conducive to installation of expensive water transport and treatment infrastructure
- Produced water is frequently of very poor quality with very high concentrations of TDS and petroleum hydrocarbons making desalination difficult. The authors know of no projects in which produced water is being considered as a source of municipal water supply.

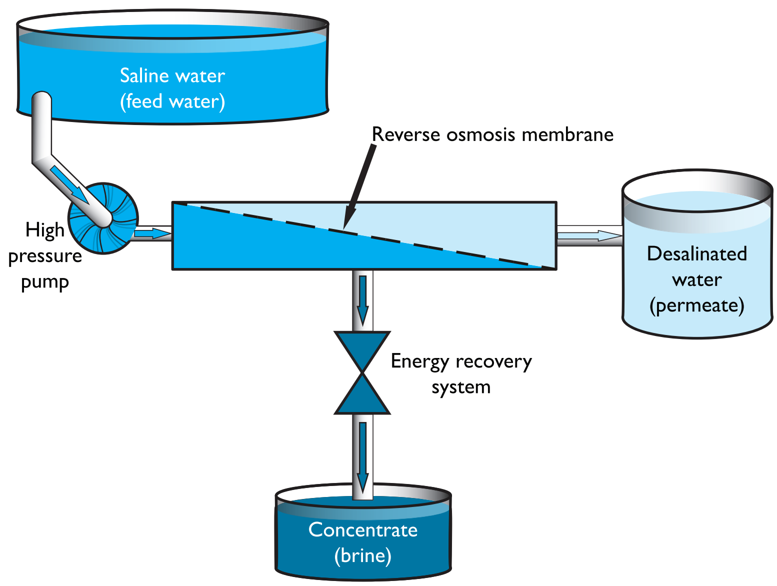
There are two notable hydrologic challenges associated with deep saline water sources. The first is to determine if they meet the criteria of the definition limiting the state engineer's jurisdiction over the resource according to its depth and quality. If pumping of the deep saline source affects overlying water resources, this is an indication that the two aquifers are hydraulically connected and therefore subject to administration by the state engineer. The second challenge is to determine the size of the resource, and specifically, whether it is being replenished by fresh water sources or is simply ancient water trapped in the formation by geologic processes. These two challenges are clearly related and point to the need for extensive characterization of these resources before they can be developed.

When evaluating a deep saline ground water source for potential municipal supply the sustainability of the resource must be considered. The term *sustainability* has many different definitions. One appropriate definition is that developed by the American Society of Civil Engineers Committee on Sustainability, which states that "sustainable water resources systems contribute to objectives of society now and in the future while maintaining ecological, environmental, and hydrological integrity." It is important to consider whether a deep saline ground water resource meets these criteria of sustainability. Ground water becomes saline through concentration of dissolved salts by evaporation and/or by dissolution of soluble minerals present in subsurface formations. The presence of high TDS may indicate that the ground water is not being replenished, but instead accumulated in the formation during the geologic past. For ground water that is not currently under the jurisdiction of the state engineer, the statutory definition stating that the top of the formation is at least 2,500 feet deep implies that many of these formations likely do not have an active source of recharge. Therefore, any decision regarding whether to develop a deep brackish-water aquifer should be based on a determination of whether the resource is sustainable as well as how the water will be used. If the water is to be used for industrial or agricultural supply perhaps the community can accept development of a non-sustainable water supply, provided that it does not impair fresh water aquifers or cause physical problems such as subsidence. However, if the brackish water is intended for municipal or residential supply, a reasonable plan should be required describing how a sustainable source of water will be provided before the brackish resource is allowed to be developed.

DESALINATION TECHNOLOGY

Desalination involves removal of dissolved constituents from water. There are two classes of desalination technologies that are commercially viable: phase transfer technologies and membrane technologies. Phase transfer technologies involve conversion of water from liquid to vapor, followed by condensation of the vapor back to liquid water. The most familiar form of this technology is thermal distillation, but there are several variations of the distillation processes including multistage flash distillation, multiple effect distillation, vapor compression, and others. Although phase transfer technologies are used in the Middle East for seawater distillation and for some small home or laboratory units, they are not used for inland desalination plants in the U.S. because membrane processes offer a less-expensive alternative. Membrane processes are based on diffusion of water molecules through a semi-permeable membrane in response to a large pressure gradient (reverse osmosis or RO) or diffusion of ionic constituents through a semi-permeable membrane in response to a voltage gradient (electrodialysis reversal or EDR). Almost without exception desalination of high TDS ground water is accomplished using RO.

A solution of salts dissolved in water has a characteristic osmotic pressure that represents the difference in chemical potential between the high TDS water and pure water. If salt water and fresh water are separated by a semi-permeable membrane such as a biological cell wall or RO membrane, the osmotic pressure difference determines the direction that water will flow through the membrane. If the hydrostatic pressure on the salt water side of the membrane is less than the osmotic pressure, pure water will pass through the membrane to dilute the salt water. If the hydrostatic pressure on the salt water side of the membrane is greater than the osmotic pressure, pure water will leave the salt water and diffuse through the membrane into the fresh water side. This is the principle behind the RO process; high pressure on the salt water forces pure water through the membrane. Dissolved constituents including salts and organic molecules remain in the salt water.



Schematic diagram of the reverse osmosis (RO) process.

Three criteria are especially relevant to the performance of an RO system. The first pertains to rejection of the dissolved constituents in the feed water. RO

A large commercial reverse osmosis plant illustrating use of banks of reverse osmosis membranes to achieve desalination.

membranes will remove greater than 90 percent of virtually all dissolved constituents so that the quality of the permeate approaches that of distilled water. Rejection depends on molecular properties such as size, charge, and polarity. In particular, rejection increases with molecular size so that removal of large molecules such as pesticides and pharmaceuticals approaches 100 percent. The second factor is the fraction of feed water that is recovered as permeate. The fractional recovery depends on the pressure applied to the system, but even more importantly, by the tendency for minerals in the concentrate to form precipitates that plug the RO membrane. Most inland desalination plants are able to operate at fractional recoveries between 50 and 75 percent. The last criterion is the pump power. The required pressure is determined by the TDS concentration of the concentrate stream and the power depends on both flow rate and pressure. A fundamental requirement of the RO process is that the feed pressure be greater than the osmotic pressure, or water will not flow through the membrane. Most seawater desalination plants operate at pressures near 1,200 psi.

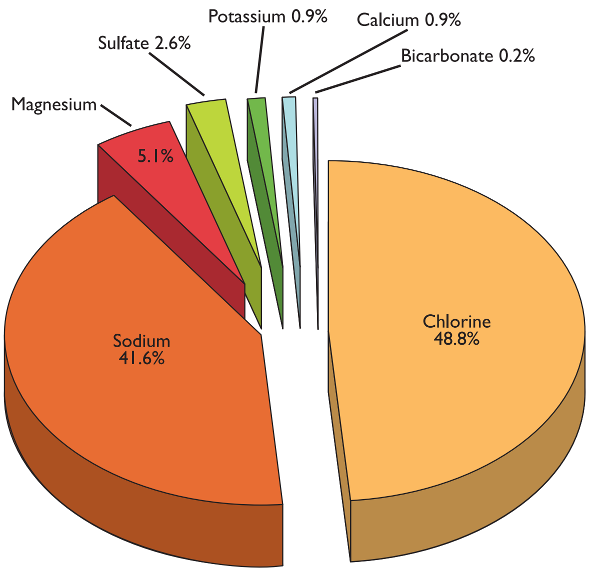
There has been exponential growth in worldwide desalination projects since 1960 to a current installed capacity of 11 billion gallons per day. Worldwide, 60 percent of this capacity is for seawater desalination. However, there are three important differences between seawater desalination and inland desalination: (1) magnitude of the water supply, (2) chemistry of the water, and (3) concentrate disposal options.

A community using seawater as their source of supply has an unlimited water resource to draw upon. Therefore, the fractional feed water recovery does not affect the availability of water. Most seawater desalination plants operate at recoveries of 35 to 60 percent, the exact amount is determined by process design considerations and economics, not the cost of the water resource. In contrast, an inland community must maximize feed water recovery because the water is expensive and the supply is limited. But high recoveries lead to problems with fouling (plugging) of the membranes because of the difference in the chemistry of seawater and ground water, which is the second difference.

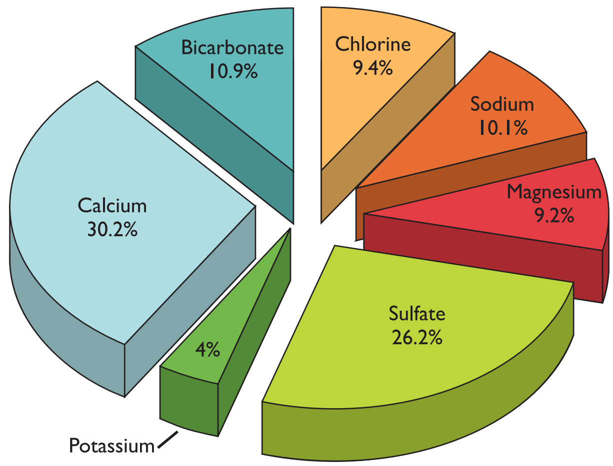
The chemistry of seawater is dominated by sodium and chloride ions. These are the constituents in table salt. In contrast, ground water will have ions that reflect the local geology and will include not only sodium and chloride but also high concentrations of calcium, magnesium, bicarbonate, silica, and sulfate. The distinction is important because many of the ions in ground water will form precipitates when concentrated by the RO process.

An RO treatment process operated at 75 percent recovery will concentrate the salts in the feed water by a factor of four. Because many of the minerals in inland saline waters are already at or near their solubility limits, the process of concentrating the minerals will cause precipitation on the membrane surface resulting in fouling. Minerals that frequently cause fouling include calcite ($CaCO_3$), gypsum ($CaSO_4$), and silica (SiO_2). Their presence dramatically reduces the flux of pure water through the membrane, thereby requiring frequent membrane cleaning. Cleaning is not totally effective, is costly, and may reduce the life of the membrane.

The third important difference between seawater and inland desalination is concentrate disposal. An RO plant located on the coast can discharge the RO concentrate in the ocean, usually through a pipe with diffuser nozzles to dilute the concentrate and minimize high salinity impacts on the marine environment. This option is not available to inland communities. Their options are primarily limited to disposal in evaporation ponds or deep well injection. Although the arid Southwest would seem to be an ideal location for evaporation ponds, experience with wastewater sludge drying beds has shown that they do not work well. A design study for a 100 million-gallons-per-day desalination plant in Phoenix found that 10 square



The chemistry of seawater.



The chemistry of ground water from the Tularosa basin.

miles of evaporation ponds would be required for concentrate disposal, at a cost of $410 million. The new Kay Bailey Hutchison desalination plant operated by the El Paso Water Utilities, which produces 27.5 million gallons per day of drinking water, uses deep well injection for concentrate disposal. This option has also been suggested for the proposed Sandoval County desalination plant. Deep well injection is expensive and complicated. The disposal wells must be constructed to strict requirements. Further, the RO concentrate is corrosive and may cause aquifer plugging. Technologies to improve fractional feed water recovery, minimize scaling, and develop alternative concentrate management strategies have been an active area of research in recent years.

Inland desalination has challenges besides the technical ones. The process is very expensive. One cannot directly compare the costs of seawater and inland desalination processes because they are affected by so many variables, especially the feed water salinity and chemistry, concentrate disposal options, and which factors are included in the cost estimate. Large seawater desalination plants are estimated to be able to produce fresh water at a cost of approximately $2.30 per thousand gallons. However, because of the differences between seawater and inland desalination projects discussed above, desalination of ground water is more expensive, perhaps as much as four times this cost. The actual cost of water delivered to the customer will depend on several factors including:

- the cost of purchasing fresh water supplies
- the costs of pumping, storing, and delivering treated water
- the fraction of water that is treated by desalination

This last point means that if the feed water is not too saline, it may be blended with the desalinated water to avoid having to treat all of the water entering the distribution system.

Discussions of desalination often include the assumption that future technologies will solve the problems of high energy demand and operational challenges such as scale formation and concentrate disposal. In 2008 the National Resource Council published a report that considered many of the factors that contribute to the high cost and technical challenges of desalination. They noted that the largest two major components affecting the cost are the annualized capital costs (i.e., the cost of construction) and the energy costs, and that the process is especially vulnerable to rising energy costs. For inland desalination plants, the cost of concentrate management becomes a major factor in the total costs. Power is dependent on feed pressure, and pressure must be greater than the concentrate stream osmotic pressure; future technology advances cannot violate these fundamental thermodynamic limitations. The National Resource Council study noted that current membrane technology is approaching these fundamental limits of energy efficiency and that further improvements may result in only 5 to 10 percent reduction in the annual desalination costs.

The Kay Bailey Hutchison Desalination Plant in El Paso, Texas

William R. Hutchison, *El Paso Water Utilities*

On August 8, 2007, the El Paso Water Utilities officially opened the Kay Bailey Hutchison Desalination Plant in El Paso, Texas. The plant is supplied by 32 production wells that pump brackish ground water (total dissolved solids between 2,000 and 2,500 mg/L) from a local aquifer (the Hueco Bolson). Two unique aspects of the plant are its large capacity (27.5 million gallons per day) and the use of deep injection wells for the disposal of as much as 3 million gallons per day (mgd) of concentrate, the byproduct of the reverse osmosis process.

Municipal water supplies for the city of El Paso include both surface water and ground water. Ground water from the Hueco Bolson was first used as a municipal water source in 1903. Ground water pumping from the Hueco Bolson increased from the early part of the twentieth century until 1989. As a result of increased pumping, ground water levels in the Hueco declined, and brackish ground water intruded into areas that historically yielded fresh ground water. El Paso Water Utilities began reducing its Hueco pumping after 1989. This action was made possible by a variety of water management initiatives, including water conservation, surface water diversions, and reclaimed water use. The reduction in pumping resulted in stabilized ground water levels in many areas but did not directly address the brackish ground water intrusion problem.

As a result of the increased surface water diversions that began in the early 1990s, El Paso Water Utilities began to conjunctively manage the surface water and ground water: when surface water supplies are reduced due to drought conditions, ground water pumping is increased to meet demands. Due to the location of the feed wells that supply the plant, brackish ground water is intercepted before it reaches fresh ground water wells. From a ground water management perspective, the interception of brackish ground water will protect the fresh ground water west and south of the brackish supply wells for use during droughts. The desalination plant will not result in a net increase in ground water pumping in the Hueco Bolson; pumping will simply be redistributed.

Concentrate Disposal

The concentrate is disposed of via three deep injection wells located 22 miles northeast of the plant. The three injection wells were constructed to depths of 3,700 to 4,400 feet and can inject more than 3 mgd of concentrate into deep Paleozoic formations.

Three methods of concentrate disposal were considered: passive evaporation, enhanced evaporation, and deep well injection. Passive evaporation for 3 mgd of concentrate would have required a 700-acre double-lined pond. Enhanced evaporation would have required a smaller pond and mechanical sprayers to enhance the evaporation rate. An economic analysis of the three alternatives completed in 2002 showed that deep well injection would be significantly less expensive than either of the evaporation alternatives, if a suitable site was located.

An investigation of the deep well disposal option was completed in 2004 that consisted of geologic and geophysical investigations, test drilling, and preliminary modeling and culminated in the construction and testing of a pilot well in 2004. In July 2005 the Texas Commission on Environmental Quality granted authorization to inject concentrate in up to five wells based on the results of the studies and pilot well.

Several studies were completed related to the potential for mineral precipitation in the well and formations. Of notable concern were calcite, barite, and silica. Mitigation strategies were identified (e.g., lowering the pH of the concentrate), and a plan was developed to further test the potential for mineral precipitation during initial operation.

The second and third injection wells were constructed in 2006 and 2007. The wells are 3,720 and 4,030 feet deep and include open-hole completions in the injection zone (below 2,900 feet).

Initial testing of the wells began in May 2007 and involved injecting fresh water in order to develop well performance data without concern of mineral precipitation. At the beginning of plant operations, the concentrate was diluted, thus continuing baseline data collection. After baseline data were collected, the dilution of the concentrate was reduced and finally eliminated, with no observable change in well performance (i.e., injection rate and ground water level buildup).

Based on initial testing and the initial year of operation, there appear to be no operational constraints with respect to reservoir boundaries or precipitation of supersaturated minerals. Currently, the concentrate has a TDS of about 6,000 mg/L; native ground water in the injection zone had nearly 9,000 mg/L.

Total capital cost was about $91 million, and annual operating costs are projected to be about $4.8 million per year. The concentrate disposal capital costs were about $19 million, and the operating costs are expected to be about $200,000 per year. Amortizing the capital and operating costs yields an estimated cost for desalination at about $534 per acre-foot ($1.64 per 1,000 gallons). The concentrate disposal component of the total cost is about $49 per acre-foot ($0.15 per 1,000 gallons).

CONCLUSIONS

Development of brackish and saline ground water resources in New Mexico appears, at first consideration, to offer many benefits to communities facing increased demand for water. The most obvious are that there are large volumes of water that may not be subject to jurisdiction by the Office of the State Engineer. The attractiveness of the resource is enhanced by recognition that advances in desalination technologies over the past two decades have improved its performance and lowered its cost.

However, it is vitally important that water planners recognize that there are fundamental challenges involved with the development of this resource. The first issue is that brackish and saline ground water supplies may have insufficient recharge rates, particularly if they are from geologic formations that are outside the jurisdiction of the state engineer. In other words, they may not in fact be replenished from atmospheric or surface water sources. Therefore, although the magnitude of the resource may be large, it is finite. Planners should explicitly consider whether the resource is sustainable and recognize the consequences if water used to support municipal development is exhausted. Developers cannot prudently rely on water resources that are not demonstrably sustainable. It is not proper to compare development of non-sustainable ground water resources with other resources such as oil or natural gas. Alternative sources of energy can be used instead of oil or natural gas, though they may be expensive. Water is essential for all living organisms; there is no alternative.

Water planners must also recognize that there are fundamental differences between seawater desalination at a coastal location and desalination of ground water in New Mexico. These differences relate to the chemistry of the water being desalinated, and concentrate disposal options. These introduce substantial complexity and cost to the desalination process. Furthermore, the process is energy intensive, and costs will rise in direct proportion to the cost of power. Although improvements in energy efficiency are limited by thermodynamic principles, research is needed in the areas of scaling control, increasing feed water recovery, and concentrate management options. Planners should be aware of these challenges and allow implementation of technical and management advances as they become available. In addition, policy makers should support research to make advancements in these areas.

Suggested Reading

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The Energy/Water Connection

Peter A. Scholle, *New Mexico Bureau of Geology and Mineral Resources*

> *Water promises to be in the 21st century what oil was to the 20th century: the precious commodity that determines the wealth of nations.*
> —*The Nation*, September 2002

Water and energy are directly related in very many ways. On the positive side, water can contribute to our useable energy. Perhaps the most obvious way is in direct energy production via hydroelectric facilities, but water is also critical to large-scale geothermal development (as the heat exchange fluid), and in thermal electric power generation, whether fueled by coal, oil, natural gas, or nuclear power, because all those facilities require massive amounts of cooling water to recondense the generated steam. Water is also an essential ingredient in biofuels production; indeed, high water usage is one of several reasons why corn-based ethanol production is an economically marginal undertaking.

At a global scale water is fundamental to the redistribution of heat energy from equator to poles via ocean circulation. Many of our concerns about global climate change are really related to possible changes in worldwide temperature distributions controlled either by oceanic circulation or by reflection of solar energy from frozen water (ice or snow on land or oceans). However, large-scale surface ocean circulation not only cools the tropics and warms higher latitudes, it can also yield energy in a variety of ways. Temperature variations in ocean water can be used to generate electricity (using Ocean Thermal Energy Conversion or OTEC systems), and energy stored in moving water (waves, currents, and tides) is already being used, at a few sites, to generate electric power.

ENERGY CAN "PRODUCE" WATER

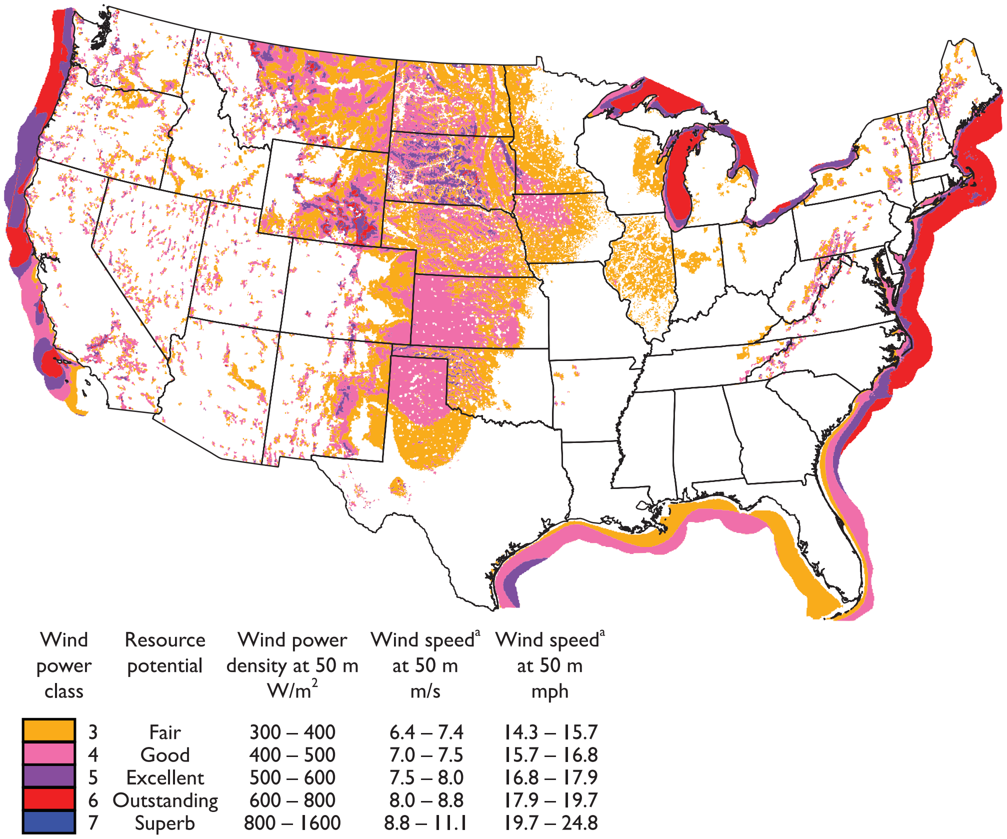
Water can also be a byproduct of energy generation. For example, water is co-produced during petroleum production (oil and especially coalbed methane). A typical oil well in the U.S. produces about eight barrels of water for every barrel of oil, and in economically marginal wells that ratio can be as high as 100:1. Currently produced waters are largely a problem, requiring subsurface disposal or having the potential to cause moderate to severe environmental problems if they are disposed of at the surface. However, such waters could be a resource if they can be adequately cleaned for a variety of uses: agriculture, power plant cooling, geothermal circulation, or even algal biodiesel aquaculture.

ENERGY IS REQUIRED TO TRANSPORT OR PURIFY WATER

Although 97 percent of near-surface water on Earth is in the oceans, the remaining 3 percent in icecaps and glaciers, rivers and streams, and in ground water is more than enough to meet all human needs—if it were distributed where human needs are concentrated. Unfortunately, human needs outstrip water supply in many areas, including in semiarid regions of New Mexico. Water needs in such areas, if they cannotbe reduced by conservation, must be handled through transportation of water from distant sources, multiple-stage reuse of existing water, or desalination of "impaired" waters (saline or otherwise contaminated waters).

Each these three processes can consume large amounts of energy. Energy is a necessary component in water transport in any system where gravity alone does not suffice (i.e., where pumping of surface or ground water is necessary). Energy consumption is especially high if water must be lifted in the process—a 100 m lift consumes as much energy as about 100 km of horizontal transport (Zhou and Tol 2005). Water desalination and waste-water cleanup also have very substantial energy requirements.

Desalination of seawater can be conducted along ocean coasts where brine disposal is relatively uncomplicated, although water salinity is quite high; with unlimited energy one can then pump it anywhere. This model is used today in parts of the Middle East, where energy is plentiful and potable water is very scarce. Indeed 50 percent of the world's desalination output is in the Middle East, with 24 percent from Saudi Arabia alone. Inland desalination incurs some additional costs because of the need to dispose of concentrated residual brines, generally by underground injection of water. Those added costs are more than counterbalanced, however, by lower costs of desalinating terrestrial ground waters that generally have salinities well below



Map of the 48 contiguous United States showing annual average wind resources. Wind power class is based on typical wind speeds and classes of 4 and higher can be useful for generating power with large wind turbines. Wind power and wind speed data are annual averages at 50 meters above ground level. Data is based on historical weather records and detailed surface wind measurements. Map produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.

those of seawater. Thus, typical inland desalination costs are nearly 40 percent lower than for coastal desalination (Zhou and Tol 2005).

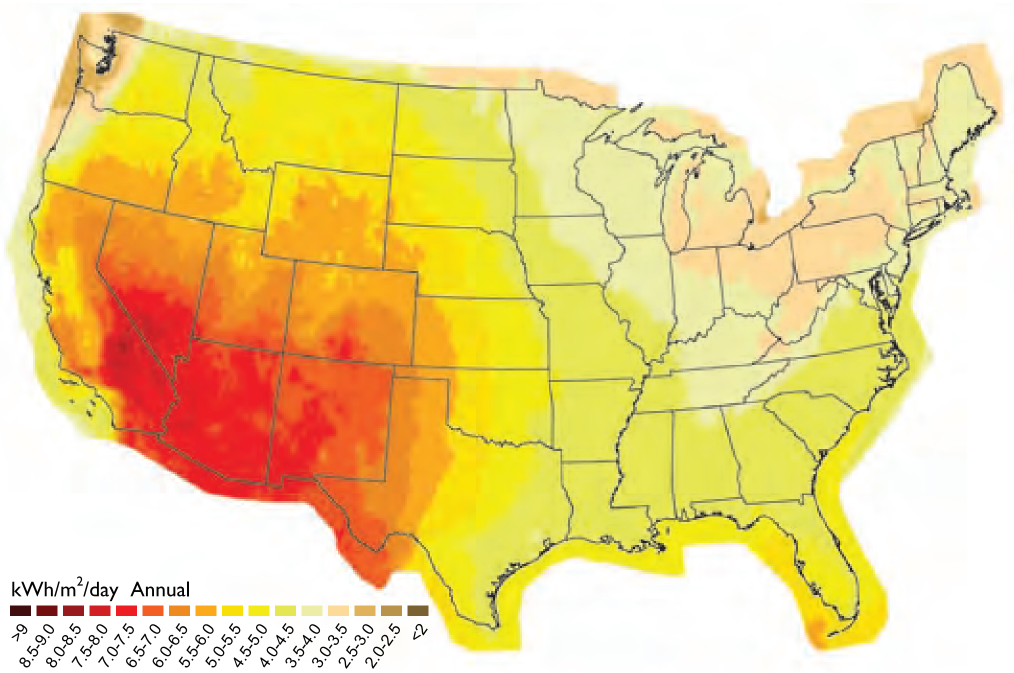
It also should be noted that the energy needed for desalination, and thus the cost of desalinated water, has steadily decreased with time because of technology improvements. Thermal desalination costs have dropped by a factor of 9 from 1955 to 2004 and reverse osmosis desalination costs have dropped by a factor of 5 in the same time period desalination (Zhou and Tol 2005). In some areas, the cost of potable water from desalination now is coming close to the cost of water from natural sources, especially where natural water must be transported over considerable distances, thereby incurring significant additional energy costs.

Energy/water tradeoffs are made every day, and in arid or semiarid regions water commonly is the scarcer resource. El Paso, for example, has spent millions of dollars paying its residents to exchange swamp coolers, which are energy efficient but water consumptive, for refrigerated air systems that use little or no water but do consume large amounts of energy. El Paso also produces about 25 percent of it public water supply through desalination of shallow, saline ground water.

Energy and water both are critical commodities, even though we typically only talk about energy dependencies. And each will require extensive research to achieve improvements in efficiency of use that will extend supplies of both resources. But the key point is this: There are many energy alternatives available to society, but for most uses there is no alternative that can substitute for potable water.

THE FUTURE ENERGY–WATER BALANCE IN NEW MEXICO

Whereas water supplies are scarce in this state (and may become more so as a result of climate change and population growth), New Mexico's energy outlook is far better. Currently New Mexico is a net energy exporter, meaning that we as a state produce more energy than we consume. This is mainly via electricity



Map of the 48 contiguous United States showing annual average direct normal solar input measured in kilowatt hours per square meter per day. Information is derived from a satellite modeled data set (SUNY/NREL 2007) representing information from 1998–2005 with 10 km data cells. Map produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.

from our coal-fired plants in the Farmington area, and our oil and natural gas exports. New Mexico's energy future will also be very robust if we tap the diverse range of potential energy sources. Although our oil and natural gas reserves are declining and will probably continue to decrease, we have enormous solar energy potential and substantial potential for wind (in the eastern half of the state), uranium (we are second only to Wyoming in known reserves), coal (ranked thirteenth in production in the U.S.), algal biodiesel, and low-temperature or closed-system geothermal energy production. Conservation and efficiency can further stretch those supplies, allowing New Mexico to remain an important energy exporter into the future. The fact that solar and wind energy production require virtually no water will certainly favor their use in New Mexico in the future. But we also have substantial uranium resources (second only to Wyoming in the U.S.) and the nation's only active nuclear waste repository, making nuclear energy a potentially viable part of a future energy mix. We also have potential CO_2 sequestration sites and potential hydrogen, compressed air, and other fuel-storage sites in the salt deposits of the Carlsbad–Hobbs area and other areas of eastern New Mexico.

Clearly, New Mexico's water future will benefit from a healthy and diversified energy portfolio. That will allow desalination of impaired waters, potential long-distance transport of water from other areas, and increased efficiency of water use through technologies that reduce evaporative/transpiration losses. Despite those potentials, however, water will remain the limiting commodity in New Mexico's future. We understand little about the hydrology and recharge rates of the deeper, saline waters in this state, but it is unlikely that we will find large supplies of saline water that can provide a sustainable water source for large communities.

For New Mexico to be economically viable, managing our energy/water balance is critical. Water will remain scarce and grow increasingly more expensive as we move to deeper or more distant water sources. Energy exports have been the mainstay of New Mexico's economy for the past half century and will have to remain so in the future. But those energy exports will have to come from far more diversified and more environmentally benign sources than our current natural gas, oil, and coal mix. To maximize energy exports, we'll also need to minimize internal consumption through efficiency.

Most of the controls on energy generation and consumption come at state, regional, national, and even international scales. Is there a policy role for cities in energy? Cities like Albuquerque play a big role in water policy (including water diversions, water reuse and conservation, desalination projects, and the like). It should be in a city's interest to also take on energy policy—to remain or become more economically competitive by fostering viable, efficient, and inexpensive energy systems. That can be done at both the production and consumption ends of the spectrum. Because solar and wind energy systems can be installed by individual homeowners, subsidies and favorable electric grid-interchange contracts can have a major impact on both energy supply and use. Cities could encourage rooftop solar hot water and solar photovoltaic installations (or passive solar home designs) by supplementing existing state or federal tax rebate programs and through building codes. Cities could further encourage such technologies by using them in their own building programs, especially in schools and community centers. Finally, cities and/or local electric utilities could buy solar or wind installations in bulk, or even manufacture them locally (generating jobs) and then sell them at or below cost to citizens. Standardized designs of local manufacture, advice or assistance with installation and maintenance, and even slightly subsidized costs would lead to more rapid and widespread adoption of such systems. On the energy consumption end, improved building standards and tax incentives related to insulation, requirements for double and triple-pane windows, and similar conservation measures could help as well. Some of this is already being undertaken, but much, much more could be done.

Cities, including Albuquerque, could also provide a more energy-efficient transportation infrastructure including bike and motor scooter trails, loaner bikes in downtown areas, high-occupancy vehicle (HOV) lanes, smaller but more frequent bus or van rides, and similar programs. The Rail Runner is a great start, but it will make a real impact only if it is connected to a pervasive, energy-saving local transport system. "Sin taxes"—fees on parking spaces, higher gas taxes, higher automobile license fees—could be used to offset the costs of subsidies for desired behaviors.

It is worth remembering that we are a country that really has never before been fundamentally pushed to conserve. We have only 5 percent of the world's population yet use 25 percent of the world's energy resources and generate more than 30 percent of the world's waste. That means that we have much to gain from pushing efficiency and localized energy generation programs.

It is also worth noting that the two cultures that have a long history of successful adaptation to life in New Mexico, the Native American and Hispanic communities, both thrived in this region precisely because they learned to use energy (and water) wisely and conservatively. The Spanish brought over many of the architectural and agricultural developments of the desert-dwelling Moorish (Arabic) culture, and the Puebloan groups developed similar styles and techniques on their own. The combination of these practices led to energy-efficient houses—thick stone or adobe walls with great thermal mass, enclosed and shaded courtyards, or underground structures that made life in a hot climate possible without energy-consumptive cooling systems. Both cultures developed relatively efficient use of water as well. We have lost much of that efficiency in our current society. We kept the form while ignoring the function. We have retained the adobe architectural style while gaining none of the energy advantages by plastering stucco over flimsy and poorly insulated structural framing. Let's keep the form but get back the function by requiring new buildings to be energy efficient, either by generating energy or by conserving it (or both).

Similar local programs could be instituted for water conservation and could extend far beyond what is done now. Subsidized gray-water systems or xeriscaping (through lawn buybacks), along with incentives to buy water- and energy-saving appliances, have brought about substantial usage changes in many places where they have been seriously adopted. On a larger scale, we need to encourage more efficient use of water in agriculture, and research ways to reduce non-productive water loss at both state and local levels. A simplified water budget for New Mexico shows that annually we lose almost as much water to evaporation (82 million acre-feet) as we gain from rainfall (85.2 million acre-feet). Clearly, exploring more effective ways to store water—selective renegotiation of interstate compacts to allow upstream storage of waters in cooler areas, or developing aquifer storage and recovery—is critical for our future.

In summary, how we handle energy and water policy, on both local and state levels, will make an enormous difference to the future economic viability of New Mexico. Our water resources will always be finite and are already stretched thin. We either rely on rainfall, which is dependent on climate change, or we "mine" ground water resources that cannot be replenished in our lifetimes. Conservation certainly can help, as can a shift of water from low-value uses to higher-value ones. But we would be deluding ourselves to think that measures to reduce evaporative losses or exploitation of cleaned-up saline waters are going to provide sufficient water for vast numbers of new residents. Saline waters are our last savings account for un-rainy days (i.e., drought periods). They are expensive to pump, expensive to clean, and residual brine disposal will be an ever-increasing issue. But more importantly, using saline waters for non-emergency purposes simply puts us closer to the brink of a future catastrophic shortfall of water. We must, in the long run, find a way to balance population, water use, and water supply.

On the positive side, New Mexico has enormous potential for energy development from the state level right down to the level of the individual homeowner. Wise energy policy, with incentives for efficiency and localized generation and disincentives for inefficiency, can offset the costs of water supply and keep New Mexico's economy strong well into the future. Energy has been New Mexico's economic flagship for decades, and although the nature of the energy sources will change, that is likely to remain the case well into the future.

Suggested Reading

Evaluating the costs of desalination and water transport, Y. Zhou & R. S. J. Tol, Water Resources Research, 41 (3), W03002, 2005.

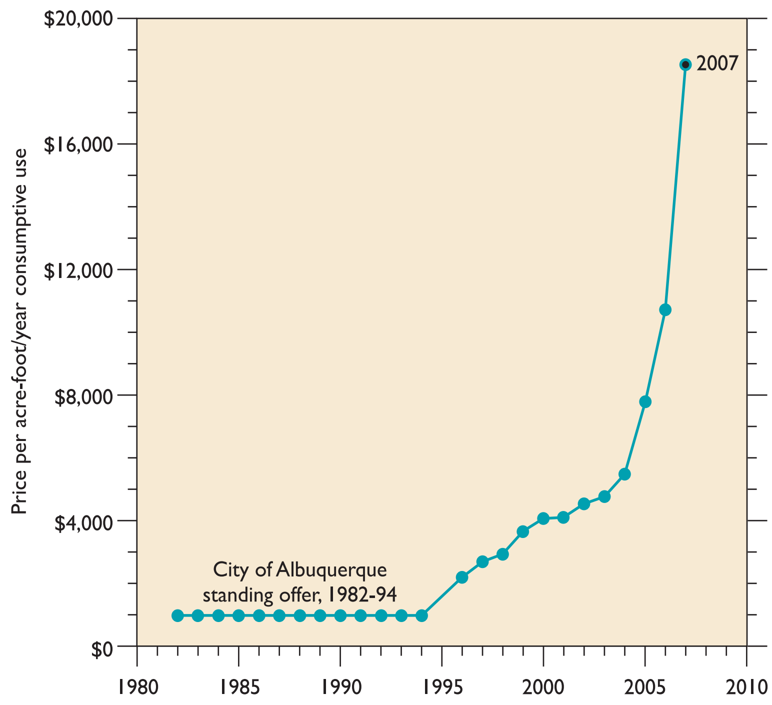
Is Ground Water Really a Resource in the Albuquerque–Belen Basin?

John Shomaker, *John Shomaker and Associates, Inc.*

Much of the recent geologic study in the Middle Rio Grande has focused on ground water. Part of the reason has been the perceived pending shortage of water, which is reflected in many ways but perhaps most strikingly in the rapidly rising trend of Rio Grande water-right prices. If one assumes that an investment in a recurring acre-foot per year should yield "water interest" at, say, 5 percent per year, a price of $20,000 per acre-foot per year (and prices have been significantly higher) would yield a constant supply at $3.07 per thousand gallons. That is more than the incremental cost of the same water delivered by the glassful at a kitchen sink in Albuquerque or Las Cruces, and almost as much as in Santa Fe. It is similar to, or more than, the cost of desalination (if one already had the water).

In 15 years or so, our paradigm relating to water supply has changed dramatically, from one that regarded the ground water stored in the Albuquerque–Belen Basin aquifer as a useful resource, to a new one that rejects it as a water supply, and emphasizes "living within our means," and therefore, reliance entirely on renewable water. Under the old paradigm, we asked "How much water is there in the aquifer?" and "How much do we need each year?" and decided we were in no jeopardy because dividing the one number into the other led to an answer of hundreds or even thousands of years. But then we learned about the effects of overpumping the aquifer, in the form of diminished flow of the Rio Grande, which would preclude making our legally required deliveries to others downstream, and to subsidence problems here, and we adopted a new paradigm. Now we ask "How much water will the river bring us?" and expect (or at least hope) to leave the river-connected ground water more-or-less intact. We are also looking again at "mining" the non-renewable ground water in deep, non-river-related aquifers.

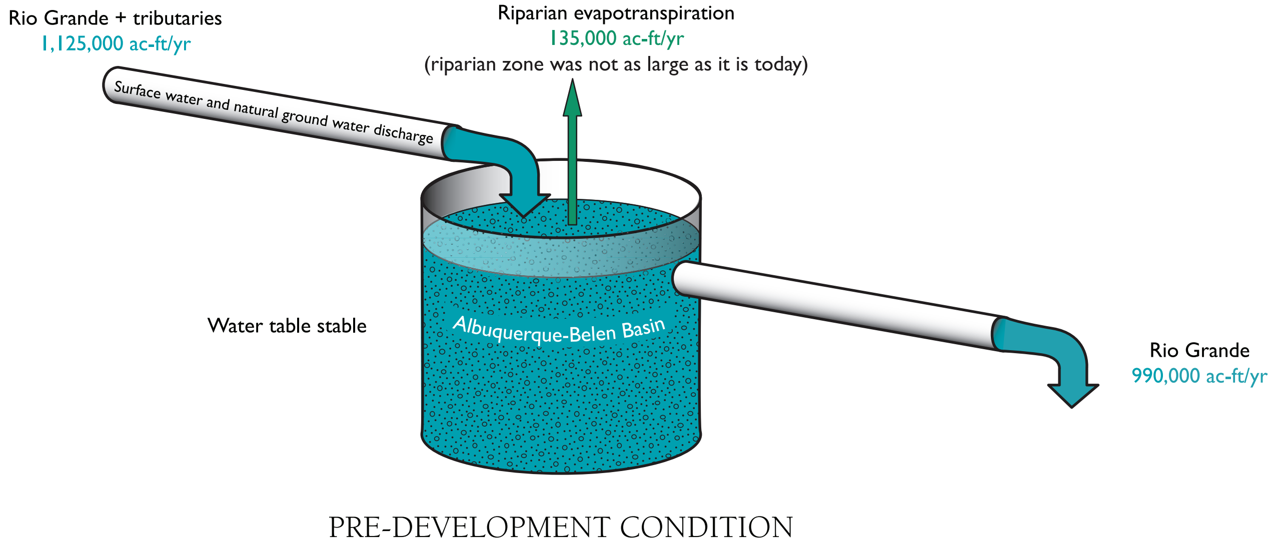
If shortage does loom, and the price of water does continue to rise, we may be tempted by the old paradigm. This paper will explore several ways of making use of the great volume of stored ground water, but may in the end persuade you that it shouldn't be thought of as a resource, even though to leave it just out of reach may be somewhat annoying.



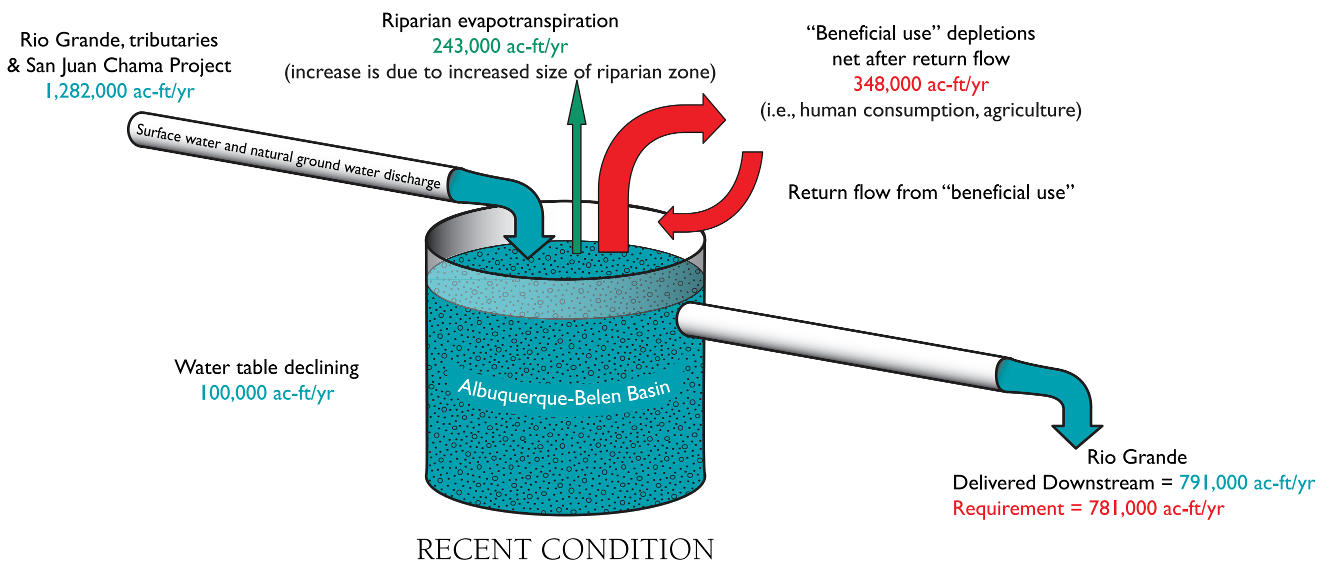
The average annual price of water rights in the Middle Rio Grande since 1982, per acre-foot per year consumptive use (annual average, weighted by transaction size). Data from F. Lee Brown, H_2O Economics.

How much water, of usable quality, is stored in the valley-fill aquifer of the Albuquerque–Belen Basin? Bob Grant, one of Albuquerque's leading geologists and a careful thinker about water issues, in 1977 estimated the volume in the aquifer as about 2.3 billion acre-feet—equivalent to around 70 percent of the contents of Lake Michigan. More recent ground water studies, including computer modeling of the aquifer by the U.S. Geological Survey (USGS) and the Office of the State Engineer, have led to implied estimates of about 1.1 billion acre-feet down to 5,000 feet, which is still far from the base of the valley fill in some places. Deep drilling has confirmed the presence of the water to some degree; the City of Albuquerque drilled three deep tests in 1988, in the near-northeast heights, to depths of more than 3,000 feet, and did not reach the bottom of usable ground water. Until the mid-1990s, with the new calculations by USGS, and change in City of Albuquerque policy, the paradigm of the time allowed us to think of all of this as a resource that the Albuquerque area could and would rely on for the future.

In contrast with the estimated 1.1 billion acre-feet of ground water to a depth of 5,000 feet, to be a little conservative, the annual renewable supply—the water brought to the Albuquerque–Belen Basin by the Rio Grande and its tributaries—is miniscule. The average yearly inflow under natural, "pre-development" conditions has been estimated at 1,125,000 acre-feet, about a tenth of one percent of the volume of ground water, and the only loss in the Albuquerque–Belen reach of the valley under natural conditions was about 135,000 acre-feet per year consumed by riparian



Water balance in the Middle Rio Grande basin prior to development. Under this condition, the water table was stable.



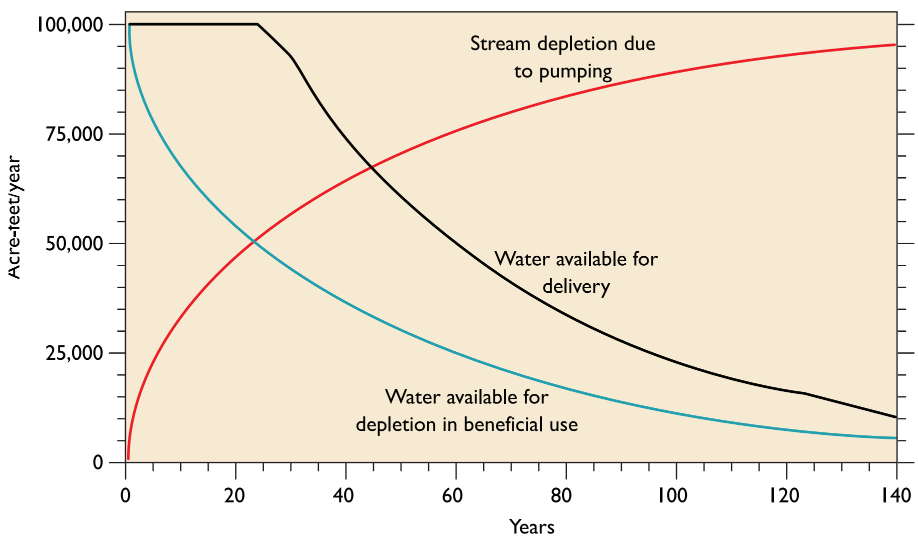
Recent water balance in the Middle Rio Grande basin. Under these conditions, the water table is declining, reflecting an average loss of 100,000 acre-feet per year.

vegetation. The difference, around 990,000 acre-feet per year, moved on downstream. The volume of stored ground water remained essentially constant—the vessel was full, and excess recharge simply spilled into the river.

By about 2000, after the paradigm-shift had occurred but before much had actually been done to implement the new one, the water budget for the part of the valley between Cochiti and San Acacia was roughly as shown in the "Recent Condition" figure. Of the total "beneficial-use depletions," about 248,000 acre-feet per year is depleted by crops (net after return flows), and about 100,000 is ground water depletion for municipal and industrial use. Even after 50 years of heavy pumping, we have probably withdrawn only a million or two acre-feet from storage, leaving perhaps 1.099 billion acre-feet in the aquifer (not that we know the amount with any such degree of precision).

The important message of that figure is the difference between the roughly 791,000 acre-feet that actually flowed out of the basin, and the 781,000-acre-feet delivery requirement under the Rio Grande Compact—a small margin for error—and the fact that it took 100,000 acre-feet of ground water from storage to meet all of the demands, and to provide even that margin.

Under today's policy the stored ground water will not contribute to the water supply at all. Our water use and our obligations to deliver water downstream are balanced by inflow, and the role of the ground water reservoir is limited to that of a short-term drought reserve, expected to be replenished when renewable supplies are ample. The volume of ground water we expect to use has dropped from around a billion acre-feet to almost nothing, even though almost all of the water is still there, and we are more-or-less in equilibrium with the renewable supply. But can that happy state be sustained indefinitely? The price-signal being issued by the water-rights market may be saying no. Of course, the market may be wrong. It may be reflecting only a temporary stress, but if the signal is real, there are at least four ways that we might proceed as demand continues.



Water available from a hypothetical well field, assuming 100,000 acre-feet per year of constant pumping with a 50% return flow from consumptive use.

(1) The price will become high enough to force large amounts of the 248,000 acre-feet per year of water out of agriculture and into municipal supply. This is already happening, of course, and it is accelerating. And the price may become high enough to justify expensive changes in the management of riparian vegetation along the river—salt cedar, Russian olive, and even our beloved cottonwoods—to decrease those depletions, although it can't eliminate them. Transfers of existing Rio Grande water rights only reallocate the renewable supply, and the stored ground water can remain in place as a non-resource. But the rising price also encourages people to look at the ground water again. There are, of course, significant consequences to the reduction of land that is in agricultural use statewide, in terms of the economy and lifestyle, and the effects on largely rural communities.

(2) A second way to make ends meet in the future would be to throw up our hands a few decades from now and go back to drawing down the ground water in storage as we had done under the old paradigm. This would result in the loss of much of the river and the ecosystem associated with it, and also get New Mexico into serious trouble, because of the reduction in natural discharge from the ground water system, and then the loss from the river to ground water, as the stored volume is drawn down. The tank in the "recent condition" illustration wouldn't spill, river flow would diminish, and we would not be able to meet downstream obligations. So this couldn't go on for long, and the implications of failing to meet downstream obligations, even for a short time, may be costly. Even this scheme actually makes very little use of the stored ground water—a withdrawal of only a few million acre-feet would lead to big trouble—so the stored ground water is not really a resource in this context, because we can't pump it without affecting the discharge of the Rio Grande.

The Los Angeles River. A vision for Albuquerque?

(3) A third way to deal with the problem, *and* make use of the ground water in storage, would be to disconnect the river from the aquifer, by lining the channel or by conveying part or all of the river's flow down the valley in a canal. This allows the downstream obligation to be served independently of the uses in the Middle Rio Grande. Downstream rights can be supplied as needed by a combination of inflow from upstream and pumping from ground water storage. This does allow the stored ground water to be a resource, but it has some unpleasant consequences.

A lined channel destroys any natural aspect of the river, and isn't a very attractive sight. Witness the concrete-lined Los Angeles River, through the great city. And there are other large disadvantages. Tens of miles of lining through the high-drawdown part of the valley would be required, and costs would be substantial, to say the least. Subsidence of the land surface, as pore water is withdrawn and the aquifer compacts, is likely to bring serious problems for foundations, pipelines, and roads beyond a threshold of 250 to 300 feet of water-table drawdown. There would be far less riparian vegetation, as the water table drops below the root zone. That would save a lot of water but lead to loss of a lot of habitat. Stored ground water is an enormous resource in this scenario but a non-renewable one. Should we become dependent on it?

The aquifer could also be disconnected from the river, to some degree, by selectively pumping from deep in the aquifer, and close to the river, so that part of the strata beneath the river become less-than-saturated, and thus become much less permeable. I don't think anyone has examined this approach closely, but it is likely to lead to all of the undesirable consequences just described. We may not know enough about the aquifers to predict these effects in detail.

(4) There is another theoretical approach, a clever scheme I first heard put forward by Charles T. DuMars, one of New Mexico's leading water lawyers. Recognizing that the impact on the flow of the river is zero on the first day of pumping from a well far from the river, and rises over time (depending on the hydraulic properties of the aquifer, the distance from well to river, and time), the idea is to pump a constant amount of water from wells, and always return enough of it to offset the effect on the river, even though that amount will eventually come to equal the full pumping rate. If pumping ever stops, the great cone of depression in the water table that has been created would begin to refill at the expense of surface water flow—which would no longer be augmented because pumping would have ceased.

So don't stop pumping. The part of the pumping that comes from ground water storage can be used and depleted until the proportion eventually reaches zero; thereafter, all of the water pumped must go to the river to balance the depletion caused by the pumping. The basic proposition is to sell the water that can be depleted, while it is available, for enough to establish a fund such that income from it will pay for pumping, ad infinitum.

Could such a plan work, in terms of realistic hydrologic and financial projections? The effects of pumping 100,000 acre-feet per year from a large hypothetical well field in the Albuquerque–Belen Basin have been calculated, and that analysis led to the curve labeled "stream depletion due to pumping" on the figure shown here. If it is assumed that the water is used for municipal supply with 50 percent being returned to the river as treated wastewater, then the amount of water available for depletion each year, and the amount of water available for delivery to customers, would be as shown by the two other curves.

In the first year, of the 100,000 acre-feet pumped, there would be 50,000 acre-feet of depletions by evaporation in various uses, and 50,000 acre-feet of return flow from those uses. No water need be bypassed to augment the river. In year 40, there would be 38,850 acre-feet of depletions, 38,850 acre-feet return flow, and 22,300 acre-feet sent directly to the river. By year 100, the numbers would be 15,300 of depletions, 15,300 return flow, and 69,400 to bypass. Ultimately, of course, there would be no water to deplete, and as no water would be delivered for use, there would be no return flow; all of the 100,000 acre-feet would be pumped directly into the river.

A financial analysis based on costs as of about 2000, assuming a range of interest rates for the loans necessary to finance the project, and the income to the perpetual fund, led to the water-sales prices necessary to establish the fund over a period of 30 years. The costs covered by the fund include wells, tanks, pipelines (to carry bypassed water to the river), energy, maintenance, periodic replacement, and management. It was assumed that pumps would be replaced every 20 years, wells after 50 years, and the entire system each 100 years.

The required sales rate is never more than $1.20 per thousand gallons (based on year-2000 costs), which is less than large-scale desalination. This would not be the total price of water delivered to customers, but would replace a part of the costs of supply as they are now.

The total amount of water made available for sale over 100 years would have been about 6.8 million acre-feet, assuming 50 percent return flow in municipal or industrial use. This is still less than one percent of the 1.1 billion acre-feet in storage in the aquifer.

Now to the original question: Should the stored ground water be considered a resource? The fourth scheme presented here has the advantage of "keeping the river whole" and protecting much of the ecosystem, but it also suffers from the disadvantages related to land-surface subsidence, and to the dependence on a non-renewable resource, discussed with the "line the channel" approach. It *further* requires highly reliable ground water studies and modeling, to set the bypass amounts correctly; appropriately conservative financial projections; a trustworthy operator that can be relied upon into the indefinite future; and a commitment of future energy resources, even though the money would, at least in theory, be there to pay for the energy when it is needed. Prediction of either long-term financial conditions or energy costs seems dangerous. Our successors would always face a choice we imposed on them: continue to pump, and pump forever, or give up the river. It's worth the time to think this through, but we may well come to the conclusion that our billion or so acre-feet of ground water in the Albuquerque–Belen Basin is not a resource at all.

Urban Planning in an Era of Diminishing Resources

Phyllis Taylor, *Sites Southwest, Ltd. Co.*

New Mexico's growth and related demand for the state's resources, particularly water, have been the subject of heated debate. Central to this debate is our ability to grow, given resource limitations. The region's population in 2007 was more than double its population in 1970. Projections indicate that the population will pass one million by 2020. Individual jurisdictions in the region have taken steps to tie their land use plans and policies to efficient use of resources, but there is room, and a compelling need, to do more to prepare for the needs and realities of the twenty-first century.

Local governments must balance competing goals and interests—economic vitality and opportunities for our children versus growth limits, local agriculture versus reduced water use, agricultural land preservation versus suburban expansion, water-based recreation versus evaporative losses from open water. Land use policies and regulation, water resource management, and growth management can help provide balance and protect the region's water and energy resources through efficient, resource-conserving urban development. The discussion below is focused on water resources, but the approaches described, with appropriate modification, could apply equally well to energy and other resources in the region.

LAND USE POLICIES AND REGULATION

Land use policies and regulations may mandate or provide incentives for land use patterns that use resources efficiently. Favorable zoning and subdivision ordinances encourage development density and infill. Streamlined development review, density bonuses, variable impact fees, redevelopment incentives, and direct project participation in desirable development are incentives for desired land use patterns. The goal of these policies and regulations is to achieve a development pattern that reduces demand for water, energy, and other resources.

The city of Albuquerque has used standard zoning, special neighborhood zoning, and the authority granted to municipalities by the New Mexico Metropolitan Redevelopment Code to accomplish higher density and infill. The Planned Growth Strategy, elements of which were adopted by the Albuquerque City Council in 2002, identifies additional techniques, including new mixed-use zoning categories, variable fees, and utility services areas to encourage compact development. Even without proactive policies, increasing land prices have resulted in smaller residential lots in Albuquerque.

In rural communities, compact town centers can increase densities in a manner that is consistent with rural character. Los Lunas and Bernalillo are pursuing new types of development in conjunction with Rail Runner commuter transit. Both communities are planning mixed-use development within walking distance of Rail Runner stations, with pedestrian and bike routes that will link neighborhoods, schools, and businesses to the stations. The new Los Lunas Transportation Center with village offices, retail space, and an indoor amphitheater, and the new Bernalillo Flying Star with associated retail space are examples of early projects that bring development to the transit stations. New housing and additional businesses are proposed within walking distance of each station.

Effect of Land Use Policies and Regulations on Water Demand

A change in land use policy affects new development but does not change existing neighborhoods, resulting in a lag time between policy implementation and a noticeable change in water demand. Although reduced water demand as a result of land use change is an incremental process, decisions made today will have a significant impact on water demand in twenty or fifty years.

Residential land use is approximately 56 percent of urban land in the Middle Rio Grande region. From 2004 to 2030, the number of housing units in the region is expected to increase by 46 percent. In the long term, land use policies that encourage more compact development, with smaller irrigated yards, could make a significant difference in residential outdoor water demand.

Reducing the average lot size from the current 6,500 square feet to 5,000 square feet could reduce outdoor water usage in new subdivisions to less than 40 gallons per capita per day (gpcd), making Albuquerque's per capita water use closer to those of Santa Fe, Tucson, and El Paso.

WATER RESOURCE MANAGEMENT

Water resource management links development approvals directly to water availability rather than indirectly affecting water use through land use patterns. Demand management approaches reduce the demand for water directly by changing water use practices (timing and frequency of outdoor irrigation), improve efficiency in water use, reduce water losses, reduce water waste, and/or alter land management practices. Within the region, the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) and Rio Rancho have developed water resources management plans, and Valencia County is evaluating a regional approach to water management. Several municipalities have water conservation ordinances that set standards for outdoor irrigation, restaurants, and hotels. Los Lunas requires new subdivisions to transfer water rights to the village and offers incentives for water conservation. All communities recognize the need to conserve water and the need for additional water rights to support new households and businesses.

Linking Development Projects to Water Supply

The New Mexico Subdivision Act, passed in 1973 and amended in 1995, requires counties to adopt regulations that set forth the county's requirements for water conservation measures, quantifying the maximum water requirements for subdivisions, assessing water availability and water quality. Counties are required to consult with representatives of the Office of the State Engineer prior to adopting, amending or repealing these regulations and to request an opinion from the state as to "(1) whether the subdivider can furnish water sufficient in quantity to fulfill the maximum annual water requirements of the subdivision, including water for indoor and outdoor domestic uses; and (2) whether the subdivider can fulfill the proposals in his disclosure statement concerning water, excepting water quality" as part of the subdivision approval process. Counties are not bound by the state engineer's opinion, although counties may require a permit from the state engineer for subdivision approval. The requirements of county subdivision ordinance vary regarding maximum annual household water use, water conservation measures to be considered, and the number of years for which the subdivider must demonstrate an adequate continuous supply of water. Water supply is only one criterion that counties consider in reviewing subdivisions, and local governments may make decisions that are contrary to long-term sustainability.

A municipality can consider water system capacity in its land use regulations. The city of Albuquerque requires a written statement of water and sewer availability from the ABCWUA for building permits, site plans, and subdivision approval. Other jurisdictions have similar requirements. Major new planned communities like Mesa del Sol in Albuquerque, SunCal's projects in Bernalillo County, and Quail Ranch in Rio Rancho have been required to pay for major infrastructure expansion, including water rights.

New development in a municipality's extraterritorial jurisdiction is often subject to municipal rather than county subdivision regulations. In that case, the New Mexico Subdivision Act does not apply, and there is no state mandated requirement to demonstrate a sufficient water supply. This is a major regulatory gap if new development is not tied to a municipal system.

Water Conservation in New Construction

Best management practices in site and building design, landscape, and interior fixtures can reduce water use in new buildings and subdivisions. The ABCWUA is considering mandatory water conservation measures, offering a range of options and requiring a set of options that reduces annual water use by 20,000 gallons indoors and 20,000 gallons outdoors for new single family homes, or an average of about 45 gpcd. Both Albuquerque and Bernalillo County have in place and/or are planning additional water conservation measures that will include areas not served by the ABCWUA.

Incentives to Retrofit Existing Buildings

The ABCWUA established a voluntary water conservation program in 1995 and has implemented financial incentives for retrofits of landscaping and fixtures. Through these measures, coupled with requirements of new construction, water utility customers have reduced water use 34 percent, from 250 gpcd to a 165 gpcd, saving 100 billion gallons of water since 1994. The authority's goal is to reach 150 gpcd. Rio Rancho's water use was approximately 150 gpcd in 2007, with a goal of 135 gpcd by 2017.

The High Desert community in northeast Albuquerque emphasizes xeric landscapes to beautify public spaces while reducing the need for landscape irrigation.

In Valencia County, current demand in existing water systems varies from less than 100 gpcd to 226 gpcd, with municipal systems having the highest use and rural systems the lowest. The greatest differences appear to be in the percentage of non-residential use and the level of outdoor use.

It is possible to reduce per capita use further through a comprehensive set of water conservation ordinances and financial incentives. As an example, Sangre de Cristo Water customers (Santa Fe) reduced their water use by 40 percent between 1995 and 2007, with per capita use dropping from 168 gpcd in 1995 to 101 gpcd by the end of 2007. From 1995 to 2000, water use was reduced to 143 gpcd using voluntary conservation measures, but severe drought in 2000 pushed the city to implement mandatory requirements scaled to drought stages. The city has continued to refine its requirements, with a Comprehensive Water Conservation Requirements Ordinance going into effect on January 1, 2007. Santa Fe's requirement that approval of new development be tied to offsets created by retrofits of existing fixtures has accelerated the reduction in per capita water use.

Effect of Water Resources Management on Water Demand

Measures that can be implemented in both existing and new development can have an immediate impact on water use. A rigorous residential conservation program similar to Santa Fe's could make possible the 46 percent increase in the number of households that is projected in the Albuquerque region with an increase in total water use in the range of 10 percent.

TYPE OF USE	INDOOR USE	OUTDOOR USE
Commercial	75%	25%
Industrial	95%	5%
Institutional	80%	20%

Typical breakdown of indoor vs. outdoor non-residential water use, by non-residential development type.

Water savings by commercial and industrial users will come from all facets of business operations—processes, domestic plumbing fixtures, heating and cooling systems, and landscaping. The Office of the

TYPE OF USE	PROJECTED SAVINGS BY NEW DEVELOPMENT SERVED BY URBAN WATER SYSYEMS	
	LOW ESTIMATE	HIGH ESTIMATE
Commercial	7.5% indoor/25% outdoor	10% indoor/35% outdoor
Industrial	20% indoor/50% outdoor	70% indoor/60% outdoor
Institutional	7.5% indoor/25% outdoor	10% indoor/35% outdoor

Estimate of potential water savings with implementation of conservation measures, by type of urban development.

State Engineer has documented significant reductions in water use by businesses and institutions that have implemented process improvements and replaced high water use fixtures and landscapes. Businesses and institutions may put water conservation measures in place to be good corporate citizens, but water conservation is also good for the corporate bottom line, reducing operating costs for water and energy without sacrificing quality.

Local water conservation policies and programs vary widely in the region. Larger systems like the ABCWUA and Rio Rancho have more stringent requirements in place than most smaller communities or counties. A consistent standard for water conservation could benefit the long term prospects for the region's water supply.

GROWTH MANAGEMENT

Growth management techniques regulate the timing, location, and type of growth. These techniques do not necessarily limit growth, although timing can be a limiting factor.

Growth management programs are often paired with water management programs. The San Diego region couples growth management with conservation, water recycling, desalination, emergency surface storage, and pursuit of imported water supplies (70 to 95 percent of San Diego's water is imported). Water demand projections are linked to growth forecasts, and water supply is an important component of an overall growth management strategy. The goal of the San Diego region is to ensure water availability for future growth. Growth management techniques include:

Utility service requirements—Local governments factor the capacity and planned extent of public utility systems, including water supply, into development approvals. Water and wastewater extension policies can effectively determine the location and timing of development. Historically, such a policy contributed to Albuquerque's contiguous urban growth. However, the ABCWUA is no longer a city-operated entity, and its service commitments are not tied to city growth policies. Other public systems have enabled growth in Bernalillo County and neighboring municipalities, limiting the effectiveness of growth management in one jurisdiction as a means of reducing regional water demand.

Location of growth—Municipalities and counties can regulate the location of growth to protect surface water and ground water quality and to protect aquifer recharge areas through zoning, subdivision regulations, and open space protection policies.

Conservation-oriented economic development— Water use can be considered in economic development incentives. For example, jurisdictions could increase the incentives available to low water using industries, industries that use water efficiently, and/or industries with a high value added relative to water use.

Growth boundaries—Some communities, including Portland, Oregon, and San Diego County, have established "urban growth boundaries," targeting development to these areas. In general, growth boundaries were established to protect rural land outside of the boundary. In Oregon agricultural interests supported state legislation mandating growth management as a means of protecting their industry. Such an approach might work where landowners perceive a need for agricultural land protection. However, in much of New Mexico urban development is the most lucrative use of land, and there is no political support for growth boundaries.

Experts argue about the success of growth boundaries. Proponents believe that they maintain contiguous development, promote complete communities with jobs and shopping close to where people live, protect precious open space, and provide public services efficiently and cost-effectively. Opponents state that the artificial limitations placed on land supply result in increasing housing costs and leapfrog growth to areas outside the boundary. Portland has experienced a vibrant economy and protected its neighborhoods. However, home prices have risen, and development has been pushed outside of the growth boundary, including into Washington state, where Oregon's laws don't apply.

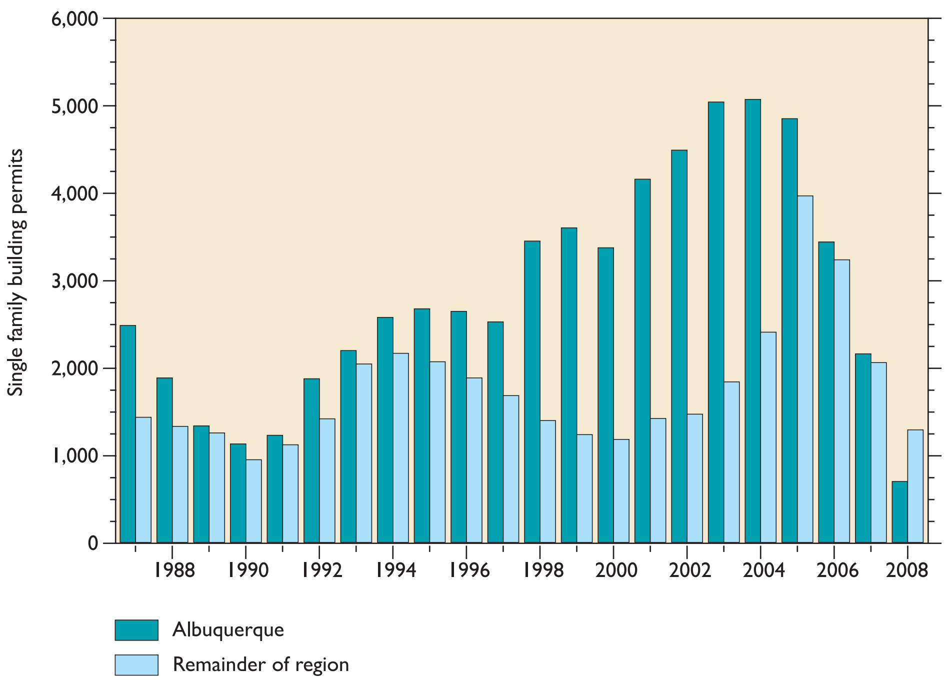
Development fees—Development fees, which assess infrastructure costs to new development, are a management tool that is being used by Albuquerque, Rio Rancho, Bernalillo County, and Los Lunas. Development fees are intended to help communities pay for the cost of growth—primarily infrastructure expansion costs. The New Mexico Development Fees Act specifies how development fees must be established and administered.

Jurisdictions can assess variable fees based on differences in cost of service—lower fees for areas within a utility service area and higher fees for areas that require service extensions. Variable fees are intended to encourage growth that minimizes infrastructure cost. The city of Albuquerque's variable fee structure, adopted in 2005, has had a noticeable impact on the location of new construction in Albuquerque. New infill projects took advantage of lower fees, while development in areas with higher fees slowed dramatically. Impact fees were assessed at their full cost beginning in January 2007. New development within the metro area has also shifted. In 2008, for the first time, Albuquerque's single family building permits fell below the number of permits issued in the rest of the region.

Regional coordination—A growth management strategy is only workable if all jurisdictions in the region approach it in a consistent and coordinated way. Community autonomy, including independent tax structures, inhibits regional cooperation as jurisdictions compete for tax base. In the absence of a regional approach, growth is shifted to the jurisdictions with the least restrictions on development.Regional water plans have begun to coordinate development strategies as a logical next step to making the best use of resources in a way that benefits all of the communities in the region. As Santa Fe realized, conservative use of its resources is key to enabling future growth.

Effect of Growth Management on Water Demand—A study conducted by the San Diego Association of Governments in 2001 simulated the impact of growth-slowing policies. The study noted that if a location has employment opportunities, a high quality of life, and is a desirable place to live, it is likely to grow, as young people elect to stay in the community and new families migrate into the area. The simulation showed that limits on new housing construction, limits on new non-residential construction, and a shift in the job mix to increase the number of high value added jobs can slow growth locally. However, these measures did not provide enough housing or commercial space and resulted in higher costs, longer commuting distances, displacement of lower income residents, and a short-term mismatch between jobs and the skills of the labor force.

The experience of regions with growth management policies in place has shown that local growth measures have no significant impact on overall population growth rates, but they play an important role in the geographic distribution of growth. In the Albuquerque region, policies that discourage growth could impact water demand in neighboring basins that do not have similar policies in place.



Single-family residential construction from 1987 to 2008 in Albuquerque and the remainder of the region surrounding Albuquerque (including southern Sandoval County and Valencia County).

CONCLUSION

Land use policies are an important piece of a comprehensive, integrated approach to water management, and to the prudent use and conservation of other resources, as well. Consistency and coordination among jurisdictions is essential to protect and conserve resources. Otherwise, development will simply be shifted to the jurisdictions with the least restrictions or demands on development.

Xeric median landscape in Albuquerque is designed to harvest water for landscape plants. This approach reduces the requirement for outdoor water use.

Policy makers need to understand who will bear the responsibility and costs of regulations. Costs to the developer will ultimately be borne by the people who buy homes in the subdivision. Costs borne by the local jurisdiction will be spread over the jurisdiction's property owners and utility rate payers. Local governments must act fairly and anticipate the consequences of either development costs or tax rate increases.

The current economic climate may place a temporary brake on economic growth. Housing industry trends have already resulted in a decline in new residential construction in the region, from 4,216 homes in 2007 to 1,954 homes in 2008. Although an economic slowdown may reduce growth in demand for water and other resources in the short run, it is important to continue local efforts to reduce per capita water and energy use. Land use policies are an important means of achieving resource use goals, and consistent policies throughout the region would benefit all of the communities of the Middle Rio Grande.

Suggested Reading

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