ABSTRACT

The time has passed when witching, drilling a test hole and finding good formation is adequate to site a new well for a drinking water supply. Quality, quantity and aquifer management must all be thoroughly evaluated when developing or expanding a groundwater supply. Four case histories that do just that follow.

New appropriations for groundwater rights in the Garden City, Kan., area have been frozen for several years. A public-private partnership between Wheatland Electric Cooperative and the City of Garden City was used to solve local problems with water rights and water quality. Wheatland converted existing industrial water rights and constructed a 6.5 million-gallon-per-day (MGD) reverse osmosis blended treatment plant to sell water to potential customers. Several customers are now being served, and there has been interest by several industries in buying water. Economic development in the Garden City community is back on track because of the availability of good quality groundwater, properly managed.

The water levels in the Equus Beds, a prolific groundwater supply providing the majority of water for Wichita, Kan., have been dropping for several years. This drop in groundwater levels was causing saline water to be drawn into the aquifer from the north and southwest, causing deteriorating water quality. Several alternatives were evaluated, including aquifer storage and recovery (ASR). Several ASR alternatives were evaluated in this multiyear demonstration project to determine the best method to store excess flows from the Little Arkansas River. It is planned to store and recover both surface water from induced infiltration and treated surface water, thus blocking chlorides from local supplies. Wichita can continue to develop because of an adequate quantity of good quality groundwater, properly managed for the city and its neighbors.

A city has provided groundwater to its citizens since it was incorporated using individual water wells, adding wells as the city grew. The groundwater supply exceeded secondary drinking water standards for manganese, and the taps of water users often flowed black. Citizens voted to develop a new water treatment plant to remove manganese and arsenic, a constituent also found that exceeded drinking water standards. The nation’s first manganese removal plant to use biological filtration was built and can provide up to 26 MGD of good quality water. This city can now continue its steady growth in part because it now has good quality water and adequate quantity for many years.

Union County, Ark., had realized for many years that its groundwater supply, the Sparta Aquifer, was rapidly dewatering. A County Groundwater Conservation District was established and a means of financing formulated. The final master plan recommended using surface water from the nearby Ouachita River to supply local industrial users with process and cooling water, leaving the Sparta Aquifer for municipal and domestic supply. A countywide sales tax, voted to sunset in seven years, helped pay for construction. Union County now owns and operates a river intake, pretreatment facility, pumping station and many miles of large water lines. Management of water resources has saved both Union County and the Sparta Aquifer from extinction.
MANUSCRIPT

Do you need new or additional groundwater supply for your water system or industry? It is no longer acceptable to simply cut a forked willow, witch a location, drill a well, bail it until clear and install a permanent pump. Water quality, water quantity and aquifer management must all be thoroughly evaluated when developing or expanding a groundwater supply. Four case histories of projects across the country are described where a variety of solutions for groundwater problems were used with good success. The four water suppliers are:

- Wheatland Electric Cooperative; Garden City, Kan.
- City of Wichita, Kan.
- Confidential Client
- Union County Water Conservation Board; El Dorado, Ark.

Each water suppliers’ groundwater problem is stated and the solution selected to solve the problem is described. In each instance, the water supply for the community is critical for economic development and continued growth. Continuing along the same course of action was not an option.

**Wheatland Electric Cooperative, Garden City, Kan.**

**THE PROBLEM**

Garden City, with a population of approximately 50,000, is the fastest growing City in Western Kansas over the past three decades. With growth comes increasing water demand, a problem for this high plains community. The Kansas Department of Water Resources (KDWR) has placed a moratorium on additional water rights in the area for several years. In addition, the water quality of several city wells has deteriorated to the point that they are usable only in emergency situations.

**THE SOLUTION**

The Wheatland Electric Cooperative, based in Scott City, Kan., once generated power from several power plant units in Garden City. The units used groundwater from a number of wells for once-through cooling, discharging to the Arkansas River. These wells had deteriorated in quality just like several of Garden City’s wells; they are in close proximity. With newer technology, the amount of water needed was reduced over the years, and the water right had not been fully utilized. Wheatland decided to utilize its existing surplus groundwater rights in Garden City to treat and develop a water supply that they could sell to suppliers or industries in the area needing water.

Garden City does not have a treatment plant, but simply disinfects at each municipal well or well field with chlorine. As a part of the project, the City of Garden City agreed to let Wheatland Electric Co-op have water from city wells near the Sunflower Power Plant that were used only in emergencies because of extremely poor water quality. By combining the city wells with the Wheatland wells at the power plant, Wheatland Electric was able to develop a water treatment plant to produce water that meets drinking water standards. One of the principal users is the City of Garden City, who contracted to purchase treated water from the new plant.

The blended raw water quality of the Wheatland and Garden City wells that supply the water treatment plant is brackish with the following approximate concentrations:

- Total hardness: 1000 mg/L
- Total dissolved solids: 1500 mg/L
- Sodium: 200 mg/L
- Chlorides: 100 mg/L
- Sulfates: 600 mg/L
A preliminary design study and report concluded that a reverse osmosis treatment plant would be the most cost-effective and acceptable solution. Negotiations were conducted with the KDWR to arrive at the quantity of municipal water rights that would be allowed in conversion from the old power plants industrial and irrigation rights. The reverse osmosis plant was constructed with two 2.5-MGD RO trains (5 MGD total) and is expandable to 10 MGD. To provide potable water, approximately 25% of the raw water from the plant’s well supply is not treated, but blended back with the RO plant effluent to provide 6.5 MGD of potable water. There are two storage tanks at the plant, one for pure RO water and one for the blended potable water. The RO water tank can provide water to an industry that might require water of this purity. The potable water is pumped to the Garden City distribution system.

Following is a comparison of water quality for a recent typical day at the new RO water treatment plant:

<table>
<thead>
<tr>
<th></th>
<th>Raw Water</th>
<th>RO Permeate</th>
<th>RO Concentrate</th>
<th>Potable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow, gpm</td>
<td>2603</td>
<td>1729</td>
<td>431</td>
<td>2172</td>
</tr>
<tr>
<td>Total hardness, mg/L</td>
<td>575</td>
<td>28</td>
<td>1701</td>
<td>141</td>
</tr>
<tr>
<td>Total sulfates, mg/L</td>
<td>648</td>
<td>39</td>
<td>1914</td>
<td>196</td>
</tr>
<tr>
<td>Conductivity</td>
<td>---</td>
<td>157</td>
<td>7679</td>
<td>520</td>
</tr>
<tr>
<td>pH</td>
<td>7.1</td>
<td>---</td>
<td>---</td>
<td>8.4</td>
</tr>
</tbody>
</table>

As with many RO treatment plants, disposal of the concentrate is a significant problem that must be solved. The solution at the Wheatland plant was to use deep well disposal. Disposal wells are fairly common in this area because oil and gas production is prevalent. The disposal zone is the Arbuckle geologic formation that is approximately 6,470 feet deep and 780 foot thick at the RO plant location. Angle drilling was used so that the total length of hole in the Arbuckle is 1,425 feet.

Water is presently supplied by Wheatland to Garden City, Finney County Rural Water District No. 1, and Tyson Foods and is being planned to supply Sunflower’s power plants at Garden City and Holcomb. Because Wheatland has the only “new” water supply in the Garden City area, many potential users have expressed an interest in purchasing water in addition to those already being supplied. Potable water is being sold by Wheatland at a competitive rate.

Confidential Client

THE PROBLEM

A relatively young city (confidential client) has used individual wells as its water supply since it was incorporated. The groundwater supply developed as the city grew. Well fields were developed and simple chlorination at each well or bank of wells provided disinfection and was the only treatment for many years. A glassy phosphate was fed at several wells later on. The well water contained high levels of manganese (0.3 to 1.5 mg/L) and complaints of “black water” were prevalent throughout the community. During the course of the project, it was found that the well water also exceeded the drinking water standards for arsenic.

THE SOLUTION

As a part of a comprehensive water supply development project, extensive pilot plant studies were conducted to determine the most cost-effective technology to remove manganese and arsenic from the groundwater source. Five different pilot plants, each using water from a test well, were operated side-by-side over a two-month period. Technologies evaluated included continuous regeneration greens and filtration, electromedia filtration, membrane filtration, biological filtration and ozonation followed by conventional filtration.

Operational parameters were varied over wide ranging conditions to establish optimum operation conditions. Extensive water quality testing was conducted to monitor treatment unit performance under state and federal water
quality requirements. Data was collected and evaluated to identify those technologies most likely to meet the requirements for regulatory compliance, water quality, reliability and cost-effectiveness.

A 25-MGD horizontal collector well was constructed to replace two of the city’s three well fields. The horizontal screens extend as far out as 250 feet under the adjacent surface water source from the well caisson on the shore. All wells provide water that exceeds the secondary water quality standard for manganese. A new 26-MGD water treatment plant was designed to reduce the manganese to below 0.05 mg/L and arsenic to below 1 microgram/L.

As a result of the pilot testing and subsequent evaluations, biological filtration for manganese removal was selected for implementation in the city’s new 26-MGD water treatment plant. The innovative use of this treatment process was estimated to save the city 35% on plant operating and maintenance expenses compared to conventional manganese removal technologies.

The treatment train includes influent flow monitoring; cascade aeration; prefiltration chemical feed; biological manganese filtration; ultraviolet disinfection; final chlorination with contact basin; corrosion inhibitor; high service pumping with flow monitoring; and solids handling.

The prefiltration chemical feed system is designed to reduce arsenic and provide nutrients for biological growth. The system includes ferric chloride and phosphoric acid mixed by jet injection. The biological filters provide a suitable environment for supporting the growth of manganese removing bacteria. Each of the four biological filters consists of two cells operating in parallel.

Ultraviolet (UV) radiation provides primary disinfection of filtered water as it passes through closed reactors. UV dose is flow-paced from a meter placed ahead of each reactor. Final disinfection is by a gas chlorination system and chlorine contact basin, with flow paced by summation of the UV meters. A blend of polyphosphate is available as a corrosion inhibitor and caustic soda is available for pH adjustment. Neither chemical has been needed to date.

Filter backwash is held in two holding tanks with decant pumps that return backwash and sludge transfer pumps. Sludge from backwashing is thickened in a parallel plate clarifier, held in a storage tank and transferred to a belt filter press for dewatering. Ultimate disposal is by truck to the city landfill.

Twelve high service pumps, six of them variable speed, pump from the plant clearwell to the north and south distribution systems in the city. Several water transmission improvements were needed to distribute the new water around the system. Operator training was provided for city staff, who did not have experience in operating a water plant.

Manganese levels in the treated water are well below 0.01 mg/L and arsenic levels are non-detectable after a year of plant operation.

City of Wichita, Kansas

THE PROBLEM

One of the most productive sand and gravel aquifers in the Midwest is the Equus Bed Aquifer, several miles north of Wichita, Kan. Fifty-four wells in the Equus Beds provide a majority of Wichita’s water supply. Groundwater levels have been dropping in the well field for several years with increasing irrigation stresses. This has caused saline groundwater to move toward the Equus Beds from an oil brine contaminated area on the north and natural salt from the Arkansas River to the southwest, threatening the quality of the water supply in the Equus Bed well field.
THE SOLUTION

A comprehensive water supply study was completed for the City of Wichita in 1993, which recommended an Integrated Local Water Supply Plan with Equus Beds Aquifer Groundwater Recharge as the most economical way of meeting water demands through the year 2050. Twenty-seven water supply alternatives were evaluated with cost estimates and economic comparisons. The plan provides for use of multiple groundwater and surface water sources, including storing excess water in the aquifer for future use. The original water supply study and a later engineering re-evaluation study in 1997 identified a potential water shortfall for the city by 2010, and projected needs of 112 MGD for average day and 225 MGD for maximum day by year 2050.

Because the concept of aquifer recharge is new to the area, a demonstration recharge project was planned to provide information for design of future facilities, demonstrate water quality compatibility, and prove the suitability of the project to state and local regulatory authorities. In late 1996 and 1997, design was completed for construction of water capture and recharge facilities for the Equus Beds Groundwater Recharge Demonstration Project.

From 1993 through 1999, extensive hydrogeologic data was collected in the city’s well field through administration of subcontracts with several well drillers, completing approximately 100 test bores used for geologic profiles, water level monitoring, pump tests and water quality data collection. In cooperation with the U.S. Geological Survey, the city developed a water quality sampling and analyses plan that was used in obtaining more than 4,000 water quality analyses for the project. Operation of the demonstration project by the owner has been monitored continuously since startup. During this time, significant information and data have been obtained on geologic conditions, aquifer hydrogeology, water levels, recharge rates, recharge techniques, water recovery, well design, pumping rates, aquifer monitoring, water quality, water treatment, chemical feed, chemical and biological fouling, facility layouts, construction materials, system operation, cleaning, telemetry controls, environmental impacts, cultural impacts, regulations, permits, land owner interest, agency concerns, and cost.

The original submittal of the Equus Beds Groundwater Recharge Demonstration Proposal was sent to the U.S. Bureau of Reclamation requesting project funds. As a result of this initial proposal and continued annual funding requests by the project team, the city has received more than $3 million to date from the bureau to offset costs associated with operation of the Equus Beds Groundwater Recharge Demonstration Project.

To date, approximately 24 engineering reports, environmental studies and technical documents have been prepared on the water supply project. A report titled “A Concept Design Study of the Equus Beds Aquifer Recharge, Storage and Recovery Project” was delivered to the city in 2000. This report basically outlined facilities and schedules for the ASR project and other components of the plan from 2000 through 2050. The estimated cost of these improvements is $283 million (February 2000 dollars).

Between 2001 and approximately 2010, a number of improvements (totaling about $83 million) are scheduled for installation to recharge the depleted Equus Beds Aquifer with either direct recharge by ASR facilities or by indirect recharge (or conservation of the aquifer) through management of the local well facilities. Approximately 10 to 15 years will be required to fully recharge the aquifer, at which time recharged water in the aquifer will be available to meet the city’s increasing water demands during an extended dry weather (or drought) period.

Since inception of the plan in 1993, the city has maintained an active program to inform the public and governmental agencies about the aquifer recharge, storage and recovery project. Presentations and informational materials have been provided to the City Council, Chamber of Commerce, and Groundwater Management District No. 2. Public meetings have been held in Wichita, Halstead and Sedgwick, and separate annual agency meetings have been held with attendees from federal, state and local governmental entities. Environmental studies have been an integral part of the project since inception, and an environmental impact statement (EIS) was completed in 2003. The EIS is expected to facilitate various project approvals and acquisition of permits from agencies concerned with environmental and cultural impacts.
Bids were recently received for diversion wells, a river intake on the Little Arkansas River, recharge basins, recharge wells, and connecting piping for Phase 1 of the ASR project. Phase 1 will provide for over 12-MGD recharge potential when the Little Arkansas River is over a base flow of 60 cubic feet per second (cfs).

*Union County Water Conservation Board, El Dorado, Ark.*

**THE PROBLEM**

By the end of the 20th century, it was obvious that bold action was needed to reverse the decades-old decline of the Sparta Aquifer in South Central Arkansas and North Central Louisiana. As the primary water resource for all residents and industries in the region, the Sparta Aquifer was being depleted at an alarming rate. By early 1999, the Sparta Aquifer water level in central Union County Arkansas had dropped from 60 feet above sea level to 180 feet below sea level in less than 60 years. Water quality was also declining due to increased intrusion of saltwater and other contaminants.

**THE SOLUTION**

The Sparta Aquifer is a prolific aquifer under thousands of square miles extending in a southwesterly direction from western Tennessee into eastern Texas. By the 1990s, the aquifer’s greatest depletion rate was in Union County, a relatively large population center in the south-central region of Arkansas, just north of the Louisiana line. The problem was first brought to light in 1996, when the Arkansas Soil & Water Conservation Commission (now the Arkansas Natural Resources Commission) gave Union County and four other adjoining counties a “critical groundwater designation” after monitoring the regional rates of depletion. That finding was mirrored by the U.S. Geological Survey in a recommendation that consumption be reduced by a staggering 72%, or 14 million gallons per day, in order to stabilize and conserve the Sparta Aquifer in the Arkansas-Louisiana area.

Recognizing the urgency of the problem, a coalition of Union County businesses, interest groups, legislators and residents set to work. They focused on drafting a proposal that was passed into law in 1999 by the Arkansas Legislature enabling the creation of groundwater conservation boards with authority to take action to address aquifer depletion in “critical groundwater areas.”

With seven municipalities, 22 rural water associations and 11 major industries, Union County was one of the heaviest users of Sparta water and consequently became the first to form a conservation board. In one of its first actions, the 11-member county board implemented a conservation surcharge of 24 cents per 1,000 gallons of water pumped from the Sparta. Proceeds from the conservation surcharge were utilized to fund a master plan to “Save the Sparta.”

The Master Plan analyzed the feasibility of five options:

1. Building facilities for aquifer storage and recovery
2. Building a dam and surface water reservoir within one of five area watersheds
3. Treating and reusing wastewater
4. Conservation of groundwater
5. Building infrastructure to draw water from the Ouachita River.

Adding to the sense of urgency to develop a long-range water supply master plan was regulatory approval for construction of a 2,205-megawatt (MW) gas-fired power generating facility in Union County. The new power plant would add significantly to the water usage in the county and was included in the master planning.

The options of building facilities for aquifer storage and recovery and building a dam and reservoir system were dismissed as impractical for various reasons. Reservoir construction, for example, would have required high costs
for land acquisition and construction, special permitting, and project duration spanning many years. The option of treating and reusing wastewater for human consumption was dismissed because of perception issues. Water conservation would not result in sufficient reduction in groundwater use.

Likewise, the option of treating Ouachita River water to potable standards was hampered by the high cost of treatment and perception issues. The Ouachita River watershed has large quantities of naturally occurring vegetation whose decay causes water quality concerns and makes water treatment difficult. Surface water from the river carries concentrated levels of solids, especially during the region’s rainy season. In addition, the Ouachita River supports barge traffic and is a controlled release waterway by means of a Corps of Engineers Lock and Dam located upstream from El Dorado, Ark., the county seat and largest city in Union County.

Even though advanced membrane technology could have produced potable water for human consumption from surface or wastewater sources, it was not a cost-effective solution. So a variation of the surface water option was proposed to the Union County Water Board. It was recommended to serve the power plant and other large industrial users with surface water drawn from the Ouachita River. This would remove a significant demand from the Sparta groundwater system. The river water would not be filtered, but treated only for industrial use. By using the river as a source of raw water limited to nonpotable industrial use, the municipalities and water districts could continue to use the Sparta groundwater as their supply. The cost of treatment of the Ouachita River water for future potable use could be delayed or eliminated if conversion of the industrial users to nonpotable river water proved successful in recovery of the Sparta. The power plant and most industries are using the water for cooling. If better quality water is needed, the industries will provide treatment at their facilities.

Although some state and federal grant funds were obtained, local funding would be required for 90% of the $65 million project. Realizing this, a coalition of business and civic leaders united behind a proposed 1 cent sales tax to fund aquifer restoration. The bond election was successful in February 2002, when Union County residents approved the sales tax by a 62%-38% percent margin.

Phase 1 of the plan included construction of a 65-MGD intake from the Ouachita River, industrial water treatment plant, pump station and five miles of 48-inch transmission main to serve the new power generating plant. Water treatment is limited to clarification and disinfection at the settling facility. The treated water is pumped to the power plant and onto a storage tank/booster pump station located near El Dorado, where it is pumped further to serve three other large industrial users. Computer modeling of the aquifer indicated that taking the large users off groundwater would cause the water levels to recover much faster than they have been depleting.

Design and permit considerations included state roadway crossings, railroad crossings, lake crossings and wetland construction issues. Most of the pipeline alignments followed existing rights-of-way and easements for overhead power lines to minimize environmental impacts. Construction in wetland areas was closely monitored with insitu material segregated and replaced within the same strata as the pipe was buried. Temporary fill material was allowed during construction but was removed within 90 days in order to prevent permanent damage to the wetland and ensure minimal disturbance.

Phase 1 was completed in 2002, with the power plant’s owners, Union Power Partners, paying the $52 million cost of building the water infrastructure to the plant site. The Union County Water Conservation Board reimbursed $14 million of those costs to Union Power Partners, however, to cover the incremental cost of increasing capacity of the water supply infrastructure for the other industries. After that reimbursement, Union Power Partners deeded the entire $52 million facility to Union County, making it the largest gift in county history.

Under Phase 2 of the master plan, the three largest industrial water users were connected to the surface water supply. Phase 2 included construction of a 14-mile transmission pipeline from the power plant with sizes ranging from 16 to 36 inches. Also included in Phase 2 construction was a 3-million-gallon reservoir and 17-MGD pumping station. Lion Oil, the first industrial customer, converted to river water in December 2004. El Dorado Chemical and
Chemtura Central Plant (formerly Great Lakes Chemical) then converted in February and December 2005, respectively.

As part of the project, the U.S. Environmental Protection Agency (EPA) in 2002 granted $1 million to the Union County Conservation Board to assist in funding the Sparta Aquifer Recovery Study, to conclude in 2007. Project work to date has included installation of three new monitoring wells, automated and manual water level monitoring at various locations throughout Union County and northern Louisiana, water quality monitoring, development of a public website, and submitting bi-annual reports to the EPA.

Project results have been better than expected. Removal of the three industrial customers reduced aquifer water consumption by 6-MGD and has triggered immediate recovery of aquifer water levels. In less than a year, aquifer water levels have raised 8.2 feet overall, and in central Union County, where the highest rates of depletion were recorded, levels have risen nearly 11 feet.

Proper management of the new nonpotable river supply has paid other dividends to Union County residents. The Union County Water Conservation Board has been able to pay off $23 million in construction bonds three years early and on Dec. 31, 2005, rescinded the 1-cent county sales tax three years earlier than promised.

Future phases of the master plan include further monitoring of groundwater levels and water quality. The new water treatment, pumping and transmission infrastructure were constructed with additional capacity available if the need arises to take additional industrial users off the groundwater system or if a new industry locates in Union County that needs significant water supply. However, that step and some portions of the master plan, including construction of a membrane treatment plant near the existing storage tank, may not be required if aquifer recovery rates continue at current levels.

This project is an example of how a community can solve a problem that involves its precious water supply. Local cities, water districts and industries teamed unselfishly for the good of the community with state and federal water regulatory agencies to “Save the Sparta.” Industries are now paying for nonpotable river water compared to when they were could pump from the Sparta at no charge. Municipal systems and rural water districts can still use the Sparta by paying a conservation fee. The power company worked in harmony with the county to assist in developing the Ouachita River supply for its new power plant and the community.