Sustainable water, unlimited growth, and quality of life: Can we have it all?
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Sustainable water, unlimited growth, and quality of life: can we have it all? This issue not only tackles that thorny topic, it also presents a preview of Southwest Hydrology’s first symposium, sponsored jointly with the Arizona Hydrological Society, in Tucson Aug. 29-Sept. 1, 2007. Interestingly, the response to our call for abstracts produced several that faced the question head on, but with some saying, “yes, of course we can,” and others, “absolutely not!” What do you think? The articles here explore aspects of trying to “have it all” related to accommodating growth, preserving ecosystems, management options, and the strong link between energy and water supplies—they may change your mind or reinforce your initial response. And if you like what you read here, you won’t want to miss the symposium, where we’re bringing together preeminent scientists, planners, and policy makers to confront the difficult issues that lie before us.

The symposium will also offer optional workshops and field trips. Four concurrent technical sessions and a robust poster session will present wide diversity of work. We’re covering science, policy, and technology, and it’s all happening in a beautiful resort setting where the room rates are low! Check out our website for more details (www.watersymposium.org).

Registration is now open and the room block is filling up, along with exhibit spaces and sponsorships. What are you waiting for?

As always, we thank our advertisers, whose support of the magazine is critical. In addition, thanks to our authors, and we look forward to seeing you all at the symposium!

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Can We Have It All?

In this preview of our first regional symposium, we consider some of the tough questions facing scientists, planners, and policy makers: Do our water policies reflect the actual physical limits of our water resources? How tightly are growth and energy consumption tied to water demand? How can we sustain our ecosystems, knowing today’s activities may not impact the hydrologic system for decades? How can we grow differently? Only by answering questions such as these can we try to accommodate the interests of the economy and the environment, and still have a place we want to live in.

Sustainable Water Resources in the Southwest: Can We Have It All?

Jeffrey Loux

Can we create a sustainable water supply, maintain thriving economic development, and sustain or even enhance aquatic ecosystems? Now? For the next 50 years? The next century? If so, what must happen?

Limits to Groundwater Development: Toward a Better Understanding

William M. Alley and Stanley A. Leake

Depletion of a small part of the water in storage can significantly impact surface water, water quality, and land subsidence. Furthermore, impacts may not become evident until decades after pumping ceases.

Rivers and Water Management in the Southwest

Jeanmarie Haney

At the negotiating table, when water needs are discussed, riparian health is often overlooked. Ecologically sustainable water management can be achieved only if we recognize riparian needs and identify the connections between aquifers, streams, and consumptive groundwater use.

At the Crossroads: Energy Demands for Water Versus Water Availability

Mike Hightower

More people in the Southwest create a higher energy demand, which in turn requires greater water use. How much more depends on the type of power plants built, cooling technologies used, emission requirements, and the use of alternative fuels.

Shifting the Burden: Developers Take on Water Services Roles

Michelle Henrie

Developers have begun to locate and purchase their own water rights, install water infrastructure, and initiate water-savings measures. In short, they are acting like municipalities. How well does this work, and who benefits?

Wringing Water-Thrifty Urban Design from Southwestern Water Plans

Jan C. Bush

The strategies a city uses to accommodate growth affect its water consumption. Urban density can be a water demand management tool, but not all municipalities take advantage of it. Read how four Southwest municipalities are planning for the future.

Adapting Water Policy to Meet Future Challenges

Lester A. Snow, John K. Woodling, and John T. Andrew

California’s new water plan identifies and prioritizes numerous programs that can be collectively implemented to augment water supplies while reducing demands. However, new policies in support of the plan must be instituted at state, regional, and local levels for the plan to be successful.

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Mine Water Quality: Predictions versus Reality
Jim Kuipers – Kuipers and Associates
Do predictions of water quality impacts from mines and the effectiveness of environmental mitigation measures bear out once the mines are actually operating?

Mines on land administered by the U.S. Bureau of Land Management, the U.S. Forest Service, and Native American Trust Lands, and those that require certain discharge or wetlands permits are subject to the 1969 National Environmental Policy Act (NEPA). NEPA requires the agencies to evaluate the environmental impacts of the proposed projects. If significant environmental impact may occur, a detailed Environmental Impact Statement (EIS) is required. For hard-rock mines on federal lands, the analysis must include estimating direct impacts to water quality and indirect impacts that occur later but are reasonably foreseeable. How good are the estimates?

Since 1975, 183 major hard-rock metal mines have operated in the United States. Of them, 178 are in the West, with 40 percent in Nevada, and nearly three-fourths are open-pit mines. About two-thirds produce gold and/or silver, and one-fifth produce copper or copper and molybdenum. About half have closed.

Three-fourths of the mines (137) had actions that triggered NEPA analysis, and of these, 71 had EIS documents that could be located. Review of the documents provided information on both potential (tending towards worst-case) and predicted (considering the benefits of mitigation) water quantity and quality impacts. Estimated impacts were based on factors such as geology, climate, hydrology, field and laboratory analyses, modeling results, mitigation efforts, and discharge information.

A subset was selected for characteristics with similar distribution as the 183 mines in terms of location, commodity, mining methods, climate, proximity to water resources, and acid drainage and contaminant leaching potentials.

Impacts Underpredicted
Most case-study mines predicted no impacts to surface water or groundwater quality after mitigations were in place, but in the majority of these mines, impacts have occurred. Nineteen had mining-related exceedances of water quality standards in surface water or groundwater, but eight of those had predicted low contaminant leaching potential in their EISs. The most common impacts were from metals (63 percent), arsenic and sulfate (58 percent), and cyanide (53 percent).

Actual water-quality impacts more closely matched the potential impacts (without mitigation) forecasted in the EISs. Eleven of 15 mines with surface water exceedances had projected a moderate to high impact without mitigation, and 11 of 13 mines with groundwater exceedances had predicted moderate or high impact.

Causes of Failure
Based on analysis of the 25 mines, the lack of adequate geochemical characterization is the single most identifiable root cause of water quality prediction failures. Poor hydrologic characterization and mitigation failure are additional causes. The results also showed that the combination of proximity to water resources and moderate to high acid drainage or contaminant leaching potential increases the risk of water quality impacts and is a good indicator of future adverse impacts.

Improving Future Results
The results of this study could provide the basis for more environmentally conscious mining in the future. For example:

<table>
<thead>
<tr>
<th>mine</th>
<th>location</th>
<th>primary metals</th>
<th>status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greens Creek</td>
<td>near Juneau, AK</td>
<td>Ag, Au, Zn, Pb</td>
<td>open</td>
</tr>
<tr>
<td>Bagdad</td>
<td>Yavapai County, AZ</td>
<td>Cu</td>
<td>open</td>
</tr>
<tr>
<td>Ray</td>
<td>Pinal County, AZ</td>
<td>Cu</td>
<td>open</td>
</tr>
<tr>
<td>American Girl</td>
<td>southeast Imperial Valley, CA</td>
<td>Au</td>
<td>closed</td>
</tr>
<tr>
<td>Castle Mountain</td>
<td>San Bernardino County, CA</td>
<td>Au</td>
<td>open</td>
</tr>
<tr>
<td>Jamestown</td>
<td>western Tuolumne County, CA</td>
<td>Au</td>
<td>closed</td>
</tr>
<tr>
<td>McLaughlin</td>
<td>Napa County, CA</td>
<td>Au</td>
<td>closed</td>
</tr>
<tr>
<td>Mesquite</td>
<td>Imperial County, CA</td>
<td>Au</td>
<td>open</td>
</tr>
<tr>
<td>Royal Mountain King</td>
<td>Calaveras County, CA</td>
<td>Au</td>
<td>closed</td>
</tr>
<tr>
<td>Grouse Creek</td>
<td>near Stanley, ID</td>
<td>Au</td>
<td>closed</td>
</tr>
<tr>
<td>Thompson Creek</td>
<td>east-central ID</td>
<td>Mo</td>
<td>open</td>
</tr>
<tr>
<td>Beal Mountain</td>
<td>near Anaconda, MT</td>
<td>Au</td>
<td>closed</td>
</tr>
<tr>
<td>Black Pine</td>
<td>Granite County, MT</td>
<td>Ag, Au</td>
<td>closed</td>
</tr>
<tr>
<td>Golden Sunlight</td>
<td>Jefferson County, MT</td>
<td>Au</td>
<td>open</td>
</tr>
<tr>
<td>Mineral Hill</td>
<td>Jardine, MT</td>
<td>Au</td>
<td>closed</td>
</tr>
<tr>
<td>Stillwater</td>
<td>near Nye, MT</td>
<td>Pt, Pd</td>
<td>open</td>
</tr>
<tr>
<td>Zortman and Landusky</td>
<td>north-central MT</td>
<td>Au</td>
<td>closed</td>
</tr>
<tr>
<td>Florida Canyon</td>
<td>Pershing County, NV</td>
<td>Au, Ag</td>
<td>open</td>
</tr>
<tr>
<td>Jerrett Canyon</td>
<td>Elko County, NV</td>
<td>Au</td>
<td>open</td>
</tr>
<tr>
<td>Lone Tree</td>
<td>Humboldt County, NV</td>
<td>Au</td>
<td>open</td>
</tr>
<tr>
<td>Rochester</td>
<td>Pershing County, NV</td>
<td>Ag, Au</td>
<td>open</td>
</tr>
<tr>
<td>Round Mountain</td>
<td>Nye County, NV</td>
<td>Au</td>
<td>open</td>
</tr>
<tr>
<td>Ruby Hill</td>
<td>Eureka County, NV</td>
<td>Au, Ag</td>
<td>open</td>
</tr>
<tr>
<td>Twin Creeks</td>
<td>Humboldt County, NV</td>
<td>Au, Ag</td>
<td>open</td>
</tr>
<tr>
<td>Flambeau</td>
<td>northern WI</td>
<td>Cu, Ag, Au</td>
<td>closed</td>
</tr>
</tbody>
</table>

These “case-study” mines, listed by state, were selected for detailed pre- and post-operational water quality comparison. Ag=silver, Au=gold, Cu=copper, Mo=molybdenum, Pb=lead, Pd=palladium, Pt=platinum, Zn=zinc.
• Base the threshold for requiring an EIS analysis on potential (pre-mitigation) rather than predicted water quality impacts.
• Standardize federal and state geochemical testing frequency and parameters.
• Require permitting agencies to more closely scrutinize mines near water resources or with moderate to high acid drainage or contaminant leaching potential.
• Require multiple mitigation measures in recognition of their relatively high failure frequency.
• Given the difficulty of simply obtaining the data needed to evaluate EIS effectiveness, improve public access to water quality data.


The Golden Sunlight open-pit gold mine near Whitehall, Montana, shown here on Sept. 22, 2004, was one of the mines for which predicted and actual water quality impacts were evaluated.
Is Your Model Right for the Job?

John Winchester – Hydrosphere Resource Consultants

Extreme drought. Climate change. New standards. Any of these could reduce available water supplies far below levels historically experienced. To quantify the sensitivity of a system to uncertainty and determine the most beneficial action, water resource managers are increasingly turning to models to simulate scenarios. To help them select an appropriate model, Hydrosphere Resource Consultants compared raw water supply models commonly used in Colorado for the 2007 Colorado Water Congress annual convention.

Water planning models typically are used to quantify how complex systems will respond to change, with the goal of cost-effectively maximizing yield. Models are increasingly being used to study the uncertainty associated with long-term droughts identified in tree-ring reconstructions, with potential changes in hydrology due to climate change, and with new environmental or legal mandates. A variety of water resources planning models is available, each designed for a particular purpose and user group, and often with capabilities that overlap.

Models can be classified by the type of solver used. Linear models add and subtract inflows and depletions in a predetermined order. Network flow models, an efficient form of linear programming, allocate water to provide the greatest value for the system as a whole based on user-specified priorities within a single timestep. Optimization models allocate water to maximize the delivery of water to defined needs over multiple timesteps. All types typically have a daily, weekly, or monthly timestep and impose potential operations or facilities on historical or virgin hydrology.

BESTSM, a proprietary model from Boyle Engineering Company, is designed to allocate water to demands based on the prior appropriation system. BESTSM is capable of modeling water quality for conservative constituents. Based on linear programming, the model uses simplified physical processes (e.g., return flow calculations), does not optimize, and does not calculate channel hydraulics. (See Boyle Engineering website at www.boyleengineering.com/Services/WR.asp.)

MODSIM, available from Colorado State University, is a network flow model in which the priority-based solver mimics water rights allocations. MODSIM is linked to MODFLOW and QUAL2E to calculate groundwater/surface water interactions and water quality. MODSIM has a friendly user interface, but it has a few shortcomings: it is unable to split a water right between multiple owners, implementing rule-based operations is sometimes difficult, and the data storage format can make it difficult to ensure quality assurance and quality control of input data for large networks. (See ftp://ftp.engr.colostate.edu/people/labadie/modsim/Documentation/NewManual.pdf.)

RiverWare, a product of CADSWES at the University of Colorado, is based on linear programming and has three simulation modes: pure simulation, rule-based simulation, and optimization. In pure simulation, all but one operations parameter is specified by the user, and the model calculates the unknown. In rule-based simulation, the user prioritizes rules for operations and the model allocates inflows to meet the rules. In optimization mode, the model allocates water to meet demands in a priority order. RiverWare is expensive, the extensive user interface can be difficult to master, and the optimization solver is not well-suited for complex water rights. (See cadswes.colorado.edu/riverware/.)

<table>
<thead>
<tr>
<th>General Features</th>
<th>Planning and Management</th>
<th>Daily Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ease of Use</strong></td>
<td><strong>Robustness</strong></td>
<td><strong>Functionality</strong></td>
</tr>
<tr>
<td>User interface</td>
<td></td>
<td>Water Rights</td>
</tr>
<tr>
<td>Ability to add water resources components</td>
<td>Ability to specify particular output parameters</td>
<td>Reservoir operations and accounting</td>
</tr>
<tr>
<td>Custom coding option</td>
<td>Selectable timestep debugging</td>
<td>Reservoir loss, return flows</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td>Water quality</td>
</tr>
<tr>
<td>Ability to analyze output at tables and graphs</td>
<td></td>
<td>River quality</td>
</tr>
<tr>
<td><strong>Reservoir</strong></td>
<td></td>
<td>Contract exchanges, exchange by right, type, or color</td>
</tr>
<tr>
<td><strong>Model</strong></td>
<td></td>
<td>Calling right, optimized solution</td>
</tr>
<tr>
<td><strong>BestSM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MODSIM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RiverWare</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>StateMod</strong></td>
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</tr>
<tr>
<td><strong>ExcelCRAM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stella</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WRAP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Comparison of various features of the models described.</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
StateMod is a publicly available version of BESTSM, available from the Colorado Department of Natural Resources. StateMod differs from BESTSM in that it is equipped with enhanced surface water/groundwater routines for agricultural operations. Also, StateMod cannot model water quality and does not perform routing calculations. (See ftp://dwrftp.state.co.us/cdss/swm/sw/StatemodUser_20041029.pdf.)

ExcelCRAM, a proprietary model available from Hydrosphere Resource Consultants, is a network flow model based in Microsoft Excel. ExcelCRAM can repeatedly simulate the same timestep, which allows the model to accurately simulate extremely complex systems and to track water quantity and quality from different sources. Designed for the advanced modeler, ExcelCRAM has a robust interface that can be daunting to novices. (See Hydrosphere website at www.hydrosphere.com/services/cram.htm.)

WRAP, publicly available from Texas A&M University, is a linear accounting model with an exceptionally good reliability and frequency functionality. WRAP calculates the natural hydrology of a basin and then allocates water based on the water rights priorities specified by the user. The user interface is primarily a file manager; all file creation and editing is done through other spreadsheet, text, and word processing programs. It is the only model described here without a graphical user interface. (See twri.tamu.edu/reports/2005/tr256.pdf.)

Stella, a proprietary model developed by ISEE Systems, is a systems dynamics model based on linear programming. It can be applied to any problem by inexperienced users. Stella has a friendly graphical user interface with very good graphical output. But because it was not designed as a water-resources planning tool, it has no predefined water-related facilities, such as reservoirs. All water-resources constructs—reservoirs, accounting, losses, routing, etc.—must be developed from scratch. (See www.iseesystems.com/resources/Articles/STELLA_productsheet.pdf.)

The accompanying chart compares the model attributes. It is most useful for comparing general trends between models. For example, daily operations are generally best performed by RiverWare and WRAP, advanced agricultural operations are modeled well by StateMod, and water rights are addressed well by BESTSM, MODSIM and ExcelCRAM.

Contact John Winchester at jnw@hydrosphere.com. Also visit www.cowatercongress.org.

Reference


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Nevada to Build Lower CO Reservoir

Buried in a tax bill passed late last year, Congress directed the federal government to build “without delay” a reservoir near the Mexican border to capture some of the flow from the Colorado River that otherwise goes into Mexico, reported the Las Vegas Sun. The $84 million reservoir, to be funded by the Southern Nevada Water Authority (SNWA) under an agreement with the other Colorado River Basin states, will intercept unused irrigation water diverted from Lake Mead to Southern California fields. Usually the farmers use the water. But because it takes three days for the water to reach them, if rain falls after the water has been released from Lake Mead, the farmers may not need it and the water may pass on into Mexico. Nevada’s reservoir is designed to capture that unused water, according to the report.

The reservoir will provide a near-term safety net for SNWA to meet its rapidly growing water demand. The terms of the agreement guarantee SNWA as much as 40,000 acre-feet per year for seven years, said the Sun, increasing the current 300,000 acre-feet-per-year allocation to the state by about 13 percent. By the time the arrangement ends, SNWA plans to have the rights and infrastructure in place to transfer water from rural northern Nevada to supply the Las Vegas area.

According to the Sun, “the reservoir deal is important not only for the water it could provide but also for the clout it will give the region in water allocation talks by making permanent improvements to the Colorado River system.”

The “without delay” language may help the project to move forward without lengthy environmental battles, said the Sun; the wording was also used for a congressional mandate in the same bill to move forward with the lining of the All-American Canal, which continues to be delayed by lawsuits.

Environmentalists, who have long sought protection for the Colorado River Delta ecosystem, expressed concern over the reservoir plan. The Sun reported that Jennifer Pitt of Environmental Defense said that while she is not opposed to more efficient use of the Colorado River System, the new reservoir will mean even less water flows to the delta to support wildlife there.

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Feds: CA Has No Compelling Interest to Conserve

In an essay originally printed in the Sacramento Bee, Pacific Institute President Peter Gleick criticized the Bush administration for thwarting California’s efforts to improve energy and water efficiency in the absence of any serious federal actions. “Our state, the federal government would have us know, does not have a compelling interest in conserving water or energy,” Gleick wrote.

At issue is a water efficiency standard for residential washing machines that was passed by the 2002 California legislature and signed by Gov. Gray Davis. A federal waiver is required before states can pass their own such standard, and the Schwarzenegger administration filed for one in 2005. According to Gleick, the U.S. Department of Energy “sat on this waiver request for more than a year, only to deny it on Dec. 28—three days before California’s rules were to take effect and at a time when people were unlikely to notice.”

Gleick wrote that the standard would have saved more than 33 billion gallons of water per year in the state and energy consumption equivalent to that used by 85,000 homes.

DOE’s explanation for denying the new standard? “California failed to prove that it has ‘unusual and compelling water interests,’” according to Gleick.

DOE also cited hardship for washing machine manufacturers as a reason for the denial, but Gleick reasoned that manufacturers already are making more efficient machines, and they still could sell the less-efficient ones in other states.


continued on page 14
2007 Regional Water Symposium

Sustainable Water
Unlimited Growth
Quality of Life

Can We Have It All?

Aug. 29 - Sept. 1, 2007
Westin La Paloma Resort & Spa
Tucson, Arizona

www.watersymposium.org

Keynote speakers:
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Hon. Greg Hobbs, Colorado Supreme Court Justice

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- Rainwater harvesting

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New Dams for CA: Yeas and Nays

In January, California Gov. Arnold Schwarzenegger proposed a $4.5 billion bond to build new water storage and conveyance systems in the state. The bond would be used to construct two new dams that would provide up to three million additional acre-feet of water storage and up to 500,000 acre-feet of annual supply. In addition, new groundwater storage would produce another 500,000 acre-feet annually. The bond issue would be on the ballot in 2008.

Schwarzenegger said the dams are needed to combat climate change effects, which will result in less snowpack and runoff into existing reservoirs. Republican lawmakers, who last year refused to back the governor’s legislation to curb greenhouse-gas emissions, are now embracing the climate-change argument in support of the new facilities, according to the San Francisco Chronicle. They see it as a means to accommodate growth in the state.

Others think there are better ways to prepare for the impacts of climate change and increase water supplies. Jay Lund, of the University of California at Davis’s department of civil and environmental engineering, told the Chronicle that improving the capacity of the existing conveyance system would make more sense. Democrats and environmentalists came out strongly against the dams arguing high costs, poor locations, long construction times, and environmental impacts. Furthermore, they see it as a means to accommodate growth in the state.

However, Lester Snow, director of the California Department of Water Resources, said that the department already has costs and sufficient environmental information that will be made available “by the time the Legislature starts holding hearings on it,” according to the newspaper.

Democrats and environmentalists came out strongly against the dams arguing high costs, poor locations, long construction times, and environmental impacts. Furthermore, reported the Chronicle, Democratic lawmakers claim that feasibility studies for the two dams will not be completed until after the 2008 election.

And yet Arizona tribal communities have a much lower rate of use, according the North Central Arizona Water Supply Study: Report of Findings, published in 2006 by the U.S. Bureau of Reclamation. For the western Navajo region in Arizona, the report cites an average use of 53 gpcd, with the amount in water-hauling areas reduced to a mere 10 to 15 gpcd. The Hopi Tribe as a whole ranges from 10 to 35 gpcd, according to a study by the Hopi Tribe cited by the Reclamation report.


AZ Water Consumption: 10 to 226 GPCD

In a presentation to the Benson, Arizona-area Community Watershed Alliance, Arizona Department of Water Resources manager Tom Whitmer compared water consumption rates in cities and towns across the state, reported the Benson News-Sun. Payson wins the water conservation award with a use of 87 gallons per capita per day (gpcd) and Phoenix wins the biggest user award at 226 gpcd. Tucson’s consumption is 158 gpcd.

However, Lester Snow, director of the California Department of Water Resources, said that the department already has costs and sufficient environmental information that will be made available “by the time the Legislature starts holding hearings on it,” according to the newspaper.

Payson, north of Phoenix and at higher elevation, has an extensive water conservation program, Whitmer told the audience. The town requires businesses to transition to waterless urinals, requires home hot water recirculation pumps, and prohibits a long list of activities: planting grass, installing new swimming pools, daytime watering, having spas at hotels, construction of new motels with more than 44 rooms, and carwashes from being open on certain days, according to the News-Sun. The town even rejected a Starbucks until the company developed a plan that met its water-savings requirements.

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CA Communities Keeping Drugs Out of the Water

With increasing instances of pharmaceuticals being detected in wastewater as well as in groundwater and surface water, two California communities are giving residents an alternative to flushing unused medication or adding it to landfills. The Vacaville Reporter announced a recycling program in that city which allows residents to drop medication into a secure collection container—actually a refurbished

continued on page 16
We deliver intelligent solutions engineered to sustain tomorrow’s water demands

Schlumberger Water Services offers a complete range of technologies and services designed to assess and manage groundwater resources. Our continual investment in leading-edge technologies is a key company strategy that provides us with a toolbox of cost-effective water exploration, utilization and optimization solutions for public and private sector clients.

Schlumberger Water Services’ Technical Services include:

- GIS and Data Management
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- Analysis and Simulation
- Systems Integration

From planning sustainable drinking water supplies to securing water for agricultural or industrial uses, our technologies deliver solutions unobtainable by traditional methods. We maximize the value of data acquired in the field, minimize uncertainty, and reduce risks.
Border Aquifer Studies Receive Federal Approval

Aquifers along the U.S.-Mexico border will be better characterized under legislation passed late last year. The United States-Mexico Transboundary Aquifer Assessment Act authorizes the Secretary of the Interior to cooperate with border states and other entities to conduct a hydrologic characterization, mapping, and modeling program for priority transboundary aquifers. These were specified as the Hueco Bolson and Mesilla aquifers along the New Mexico border and the Santa Cruz River Valley and San Pedro aquifers along the Arizona border, but additional aquifers underlying Texas or New Mexico may be added.

The bill, S214 sponsored by Sen. Jeff Bingaman of New Mexico, authorizes the U.S. Geological Survey (through the Secretary of the Interior) to provide grants or enter into agreements with water resources research institutes, participating state entities, and relevant organizations in Mexico to carry out the program.

For fiscal years 2006 through 2016, an appropriation of $50 million was authorized. Cooperative agreements were encouraged among such entities as Sandia National Laboratory, state agencies, universities, the Tri-Regional Planning Group, and other relevant organizations, as well as Mexico. Funding to entities in Mexico would be contingent upon a 50 percent match (including in-kind services).

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NIDIS Approved

In December, President Bush signed legislation to establish the National Integrated Drought Information System (NIDIS) within the National Oceanic and Atmospheric Administration to improve drought monitoring and forecasting capabilities. NIDIS is to provide an effective drought early warning system, coordinate and integrate federal research in support of such a system, and build on existing forecasting and assessment programs and partnerships. For fiscal year 2007, $11 million was authorized for the program; the amount increases annually by $1 million through 2012.

The bill that contained NIDIS was developed from a 2004 report by the Western Governors’ Association (WGA), “Creating a Drought Early Warning System for the 21st Century: The National Integrated Drought Information System.” The system described in the report would provide all water users, including farmers, ranchers, utilities, tribes, land managers, business owners, recreationists, wildlife managers, and decision makers at all levels, the ability to assess their drought risk in real time, before the actual onset of drought, and make decisions accordingly, according to a WGA news release.

Visit www.doi.gov

EPA Requires Monitoring for Unregulated Contaminants

Approximately 4,000 public water systems will monitor drinking water for up to 25 unregulated chemicals to inform the U.S. Environmental Protection Agency about the frequency and levels at which these contaminants are found in drinking water systems across the United States. The information will help determine whether regulations are needed to protect public health. This is the second scheduled review under the Unregulated Contaminant Monitoring Rule (UCMR 2).

EPA currently has regulations for more than 90 contaminants. The Safe Drinking Water Act requires EPA to identify up to 30 contaminants for monitoring every five years. The first cycle, UCMR 1, was published in 1999 and covered 25 chemicals and one
microorganism. The new rule requires systems to monitor for contaminants that are not regulated under existing law.

EPA selected the contaminants that will be monitored through a process that included a review of EPA's Contaminant Candidate List, which contains priority contaminants that are researched to make decisions about whether regulations are needed. The contaminants on the list are known or anticipated to occur in public water systems. However, they are unregulated by existing national drinking water regulations. Additional contaminants of concern are selected based on current research about occurrence and various health-risk factors.

Costs for the five-year UCMR 2 will total about $44.3 million. EPA will conduct and pay for monitoring of water systems serving 10,000 or fewer people at a cost of $9 million.

Visit www.epa.gov/safewater/ucmr/ucmr2.
I have been asked the simple and modest question: in the Southwest, can we “have it all?” Meaning, can we create a sustainable future for water supplies and water quality, maintain thriving economic development and population growth, and sustain and enhance our aquatic ecosystems and natural resource values and functions?

Acknowledging the caveats and apologies for being hopelessly inadequate to answer this question, my answer is: maybe, no and yes. The answers depend on the time frame analyzed, the global assumptions made, and how one defines, measures and evaluates the notions of sustainable water resources, thriving economy, and healthy aquatic ecosystems.

“Maybe”

When you consider the issue globally and over the long term (100 years plus), the only responsible answer is “maybe.” There is too much we do not know, and too many significant variables and trends that are uncertain.

How will global climate change affect water supplies, water quality, and aquatic ecosystems? How fast will changes occur, how sweeping, and how irreversibly? In California, the Department of Water Resources (DWR) has developed models and scenarios for the California Water Plan (see page 30) suggesting that water supply reliability may be seriously compromised by global climate change in the near term. More precipitation will fall as rain not snow, and the diminished snowpack will be higher in elevation than today. Surface water will be most plentiful for consumptive uses when it is least needed. Our ability to capture and store rainfall in surface water reservoirs is inadequate to make up for snowpack storage. The policy response has been to suggest the need for more surface-water storage opportunities, more conjunctive use projects, and groundwater storage and banking.

Many also argue that we have left a relatively quiescent period of droughts and weather cycles and entered a period where longer and more severe drought cycles (and flooding periods) will be the norm. Under this scenario, water supply reliability becomes increasingly more important. Likewise, major flooding events threaten critical water supplies such as the California Bay/Delta and Sacramento region. I will leave it to the climate change experts to model our way toward the future, but it is difficult to claim that the water supply or quality implications are clearly understood.

Similarly, we do not know how our legal and institutional framework will adapt to changing needs and conditions. For example, in California, we may be approaching the point where a county-of-origin water rights suit will upset the uneasy balance that has existed between where water supply originates and where it is delivered. In many over-drafted basins in the West (particularly California), groundwater extraction regulations may be but one drought away. The federal government may not continue to pour funds into the Central Valley Project (or other western projects). This could have significant effects on the way water is distributed and on water for environmental purposes. As aquatic ecosystems become more stressed, more stringent environmental polices and regulations are likely. How such legal and institutional structures respond to
The volatile global economic marketplace will also play a role. If current trends continue, agriculture in the West will gradually phase out or become so specialized as to produce less of our staple food needs. In theory, this frees water for urban growth, and may reduce some of our agriculturally related water pollutants. However, it is a complex and daunting policy issue when considering the deleterious effects on land use and transportation patterns, rural economies, and food security.

Likewise, the inevitable collapse of the petroleum-based economy will have implications for transportation and land use and how to sustain the sprawling communities of the West. Effects on water supply and quality are less clear, but shifts in the regional economy will be dramatic.

The conclusion? These global variables are complex and interrelated. The most rational policy response is to maintain as many viable options as possible, and create adaptable and flexible systems for infrastructure and accompanying institutions. To date, this has not been the practice.

“No”
When I think long-term, but focus regionally (Southwest), I must answer “no” to the question of sustainability, unless and until we address unbridled population growth and our current consumption patterns for land, water, and other resources. In other words, we need to move in a very different policy direction. To continue to expand indefinitely with a potentially shrinking supply of high-quality water into more difficult lands with a more volatile climate and weather pattern is a losing formula. Poor water quality and lack of reliability for long-term water supply will repel commerce and erode the economic base.

To avoid this gloom-and-doom sequence, the second question is: Can we change course? This is where, I believe, there is some room for optimism, especially for the mid-term (30 to 50 years) and for certain subregions that choose to act progressively.

“Yes”
When I consider the question from a more limited time and geographic perspective, I am both more optimistic and more certain. The seeds of positive change are evident. Consider the “Seven C’s” of water in the West and how we are currently navigating them: creativity, conservation/recycling, conjunctive use, capture, and collaboration in the face of increased conflict and competition.

Water supply sources once deemed too exotic, speculative, expensive, or downright silly are now the favored sources for many purveyors. Many of these water supplies are more environmentally responsible and potentially more sustainable. Water conservation and water recycling form the cornerstone of many water supply strategies and are almost always in the mix. And while water conservation programs are not moving as aggressively as many would like, institutions such as the California Urban Water Conservation Council are advancing the technology and capacity of conservation programs. Water pricing needs much more focus, as does landscape water efficiency. Conjunctive use of surface water and groundwater is not just a good idea, it is being aggressively pursued and implemented throughout the West. While questions remain about the effectiveness and sustainability of conjunctive use, it is a strategy that has become a mainstream approach to water supply reliability.

Creativity and innovation is not limited to these sources. Desalination has become viable in coastal areas as technology has reduced costs and the price of other sources has increased. Contaminated groundwater is being pumped and treated, giving value to a previously “lost” water source. When surface storage is suggested, off-stream reservoir sites (with fewer environmental impacts than traditional reservoirs) are being developed using available winter storm flows to avoid impacts to river systems. Finally, capture and infiltration of urban stormwater for groundwater recharge and to improve water quality is being considered and even required. Low-impact development (LID) techniques common in Oregon and Washington are now showing up in southwestern states. For example, the Inland Empire Water Agency in Southern California considers stormwater an asset significant enough to replace much of their imported supply.

Similarly, we have become ever more creative in our ability to protect water flows and provide them to the aquatic environment. The Environmental Water Account (EWA) of California’s Bay Delta process is one such example. The EWA allows the purchase of water on the open market to solve environmental problems just as they arise. It has been used in the past to provide temporary or

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To continue to expand indefinitely with a potentially shrinking supply of high-quality water into more difficult lands with a more volatile climate and weather pattern is a losing formula.

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How much groundwater do we have left? Are we running out? How sustainable is our use of groundwater, and how responsive is groundwater to different management strategies? These basic and seemingly simple questions are being asked throughout the Southwest and even in more humid parts of the country.

The answers depend, in part, on assumptions about future population growth, agricultural and industrial water demands, water transfers, and technological innovations—each of which can have large uncertainties. For example, what are the future technological contributions from desalination, water reuse, cloud seeding, and so forth? Likewise, changing circumstances (such as climate change) and a growing knowledge base imply the need for periodically updated resource estimates.

Assessments of change induced by groundwater withdrawals commonly have focused on water-level and storage declines. However, depletion of a small part of the total volume of water in storage (sometimes only a small percentage) may have large effects on surface water, water quality, and land subsidence, which become the limiting factors to development of the resource. For example, areas with well-known and significant concerns about the effects of pumping on surface-water resources, yet where depletion of total groundwater storage is limited, include the Edwards aquifer in Texas, the Upper San Pedro Basin in Arizona, and the Upper Republican River Basin in Colorado, Kansas, and Nebraska (Alley, 2007). Likewise, the Central Valley of California and the greater Houston area of Texas have vast groundwater resources, but land subsidence from pumping has forced expensive conversions to a partial reliance on surface water.

Maximum capture in each stream occurs several decades after pumping ceases.

Understanding the limits to groundwater development is thus an evolving and value-laden process. Defining an acceptable level of groundwater use commonly is framed in terms of sustainability, a concept that is not purely scientific, but rather depends on society’s willingness to accept the long-term consequences of different levels of groundwater development (Alley and Leake, 2004). Because many of the changes manifest themselves slowly, modeling is an essential tool for addressing these issues. Water-level data alone will not indicate how future streamflow depletion will evolve from pumping that has already occurred. With these considerations in mind, we highlight three technical areas where improved applications of models can contribute to a better understanding of the limits to groundwater development.

The Dynamics of Streamflow Capture

“Capture” is the total withdrawal-induced change in the rate of groundwater flow to or from surface-water features. The areal distribution and timing of capture is central to many debates about the limits of groundwater development. As an example of the types of questions now being asked, Leake and others (2005) looked at possible capture from proposed groundwater withdrawals from the C aquifer around Leupp, Arizona (see figures below). Of concern was capture of streamflow in lower Clear and Chevelon creeks, about 20-25 miles southeast of the withdrawal site. A relatively simple (superposition) groundwater model was constructed to represent most of the aquifer and the hydraulically connected stream reaches.

Simulated streamflow capture from a scenario of proposed groundwater withdrawals from the C aquifer near Leupp, Arizona. Source: Leake and others, 2005.
of interest. One scenario that was tested involved withdrawals of about 6,500 acre-feet per year (9 ft³/sec) from 2010 to 2060, with no withdrawals occurring thereafter. A number of insights can be gained from the resulting graph of capture (below left). First, the rate of capture is greatest (but not exclusively) from Clear Creek, which is closer to the withdrawal location. Second, with the distances and aquifer properties involved, the process of capture is slow, occurring gradually over decades. Third, the maximum capture in each stream is much smaller than the withdrawal rate and occurs several decades after pumping ceases. These and other insights from capture analyses can be used in the larger decision-making process regarding whether or not a specific proposed withdrawal scenario exceeds an acceptable limit to groundwater development.

**Use of Simulation-Optimization Modeling**

Groundwater simulation models have been linked with optimization techniques to determine optimal water-management strategies. This same approach can be used to evaluate the limits of sustainable groundwater development under specified objectives and constraints (Barlow, 2005). Although the optimal distribution of pumping may not be implemented, insights into system limits and the tradeoffs between those limits and specified constraints can benefit future management.

Consider the Mississippi River Valley alluvial aquifer in southeastern Arkansas (shown at right). A groundwater model indicated that a continuation of 1997 withdrawal rates would violate requirements to maintain saturated thickness at greater than 50 percent of predevelopment levels, and even indicated dry areas within the aquifer. Simulation-optimization modeling was used to estimate maximum possible withdrawals from the aquifer.

Simulated steady-state water levels in the Mississippi River Valley alluvial aquifer using (left) 1997 withdrawal rates, and (right) withdrawal rates calculated with an optimization model that maintained saturated thickness at greater than 50 percent of predevelopment levels. Source: Czarnecki and others, 2003.
In the Southwest, the water needs of a rapidly expanding human population are coming in direct conflict with the water needs of natural systems. Rivers and wetlands support a disproportionately large number of plants and animals relative to the area they occupy and also offer multiple benefits to humans. Each freshwater ecosystem has varying degrees of reliance on surface water and groundwater. Maintaining a natural flow regime and shallow groundwater levels is critically important for sustaining them. Can water management to support continued growth be considered sustainable if it causes loss or impairment of our remaining rivers and wetlands?

The web of water law, policy, and management in the West has developed over decades, varies by state, and is exceedingly complex. That complexity reflects an attempt to achieve equity among the various water use sectors: municipal, agricultural, mining, and commercial/industrial. However, the environment—the plants and animals that inhabit or rely on freshwater ecosystems—is typically absent from the water-negotiating table.

**The Legacy of Past Decisions**

In the Southwest, we all know what degraded rivers look like. Anyone who has stood on the banks of the Salt River in Phoenix, the Santa Cruz River in Tucson, the lower Gila River in Arizona, the Santa Fe River or middle Rio Grande in New Mexico, or just about anywhere on the lower Colorado River, can testify that something seems amiss. Some of these rivers are completely dry, some look more like irrigation canals than functioning alluvial floodplain river systems, and some are incised arroyos.

Human activities—dam construction, surface water diversions, groundwater pumping, flood control, and development in the floodplain—have caused rivers to degrade. The degree of flow alteration corresponds to the decline in ecological condition. Many of these activities were initiated decades ago (Tellman and others, 1997), before society and science began to understand the complex interrelationships inherent in natural systems and the services they provide to humans. Such growing societal awareness is leading communities to seek water management solutions that meet human needs while also maintaining vibrant rivers and their associated plants and animals.

**The Opportunity to Do It Better**

Over the last two decades, advances in the interdisciplinary field of river science that combines hydrology, geomorphology, and ecology (and sometimes economics and sociology) have provided critical insights into the water needs of complex riverine ecosystems. We have learned that organisms inhabiting freshwater ecosystems have evolved life cycles keyed to the natural seasonal and annual fluctuations in flow, demonstrating that the full range of natural variation is needed to maintain fully functional freshwater ecosystems (see figure, above right).

Ecologically sustainable water management addresses the question, “How can we manage water to meet human needs while also maintaining a desired level of ecosystem function?” The boundary beyond which human water use causes undesirable consequences to
natural systems is the “sustainability” boundary (see figure below). Beyond that, we alter landscapes and lose functions critical to humans and wildlife. Science can provide the tools and methods for defining the water needs of specific river ecosystems and delineate the consequences of particular development scenarios. With this information in hand, water managers and citizens can decide what consequences they are willing to accept, and can work toward meeting human needs for water while maintaining adequate hydrologic conditions for the ecosystem.

**Environmental Water Requirements**

Southwest rivers rely on two major water sources: 1) surface-water runoff from precipitation and snowmelt and 2) groundwater discharge. Both of these provide vital flows for maintaining habitat and species and are interconnected. The highly variable surface runoff regime supports the high flows and floods that mobilize sediment, revitalize habitat, and recharge the alluvial aquifer. The relatively stable baseflow regime, reflecting groundwater discharge, supports the aquatic and riparian habitat between runoff events. The life cycle needs of aquatic and riparian plants and animals are tied to these natural patterns. When the natural patterns of flow and groundwater levels are interrupted, the ecosystem suffers.

Opportunities exist to re-operate dams and diversions to meet human water needs while also improving ecological condition and function downstream. Alamo Dam on the Bill Williams River in Arizona is one example (Shafroth and Beauchamp, 2006). Here, state, federal, and academic scientists are working with water managers to develop a flow prescription that optimizes ecologic health while meeting recreation and flood control needs.

Similar ecologically sustainable water management could be conducted on surface water diversions to optimize conditions below a diversion while also meeting the needs of agriculture or municipal water users. Current law and policy may offer little incentive for changing operations of existing diversions; however, if incentives were offered, considerable ecologic improvement could result while maintaining water rights and human uses. To provide the necessary scientific guidance, an interdisciplinary team of system experts works collaboratively to define hydrologic requirements of key components of the ecosystem, such as native fish, aquatic invertebrates, or riparian-dependent birds. Where new diversions are shown to be necessary, there is the opportunity to protect riverine ecology from the
Water is an integral part of energy development, production, and generation. Water is used directly in hydroelectric power generation and is used extensively for thermoelectric power plant cooling and air emissions control. It is also widely used in energy-resource extraction, refining, and processing, as well as for energy resource transportation. As shown below, the U.S. energy sector now withdraws about 140 billion gallons per day (Bgal/day) of fresh water and 60 Bgal/day of saline water, accounting for 39 percent of daily fresh water withdrawals and 50 percent of total water withdrawals (Hutson and others, 2004).

Energy sector water withdrawals are currently dominated by cooling water for thermoelectric power generation, though many current power plants return the cooling water to the source for reuse downstream. Therefore, while total water withdrawals for energy are high, fresh water consumption in 1995—the last year data were collected—was only about 4.3 Bgal/day (Solley and others, 1998). Still, this accounts for more than 25 percent of all daily nonagricultural fresh water consumption in the United States.

**Growing Energy Demands for Water**

In its reference case for 2006, the Energy Information Administration (EIA) projects the U.S. population to grow by 70 million by 2030, increasing electric power demands by 50 percent and transportation fuel demands by 30 percent. Much of this growth is expected in the Southeast, Southwest, and West, significantly increasing water demands for energy growth in regions with already-stressed water supplies. EIA projects major growth in coal-fired power plants, modest growth for natural gas and renewable power, and a slight growth in nuclear power. Also, traditional domestic petroleum supplies are projected to remain constant at about 10 million barrels per day, while alternative domestic petroleum supplies are projected to grow substantially.

By 2030, EIA projects that the United States will produce almost 5 million barrels per day of ethanol and biodiesel fuels, and as much as 3 to 5 million barrels per day of alternative fuels from oil shale. Beyond 2030, hydrogen production from steam reforming of natural gas, the use of concentrating solar and wind resources for the electrolysis of water, and construction of new hydrogen producing nuclear power plants could also provide alternative transportation fuels (DOE, 2007).

The increased water needed to meet this growth in electric power generation and fuel production will depend on the type and number of power plants built, cooling technologies used, air and carbon emission requirements, and the type and quantity of alternative fuels produced. The figures at right show estimates of the increased water consumption for energy development projected from 1995, based on these assumptions: 1) current trends in evaporative power plant cooling will continue; 2) carbon emission requirements will not be imposed; and 3) projected petroleum, oil shale, and biofuels development will occur (Cameron, 2006). The estimates include the significant growth in gas-fired power plants and biofuels production that have occurred since 1995, but have yet to be quantified through water consumption assessments by the U.S. Geological Survey.

Not included in the charts are two potentially significant water requirements that must be considered. If carbon...
emission caps are implemented, water consumption for electric power generation could increase an additional 25 percent, or an additional 1 to 2 Bgal/day, by 2030. Also, irrigation of biofuel feedstocks will depend on crop market conditions, oil prices, and incentive policies. Much of the biomass feedstock is expected to come from areas with high rainfall, but even small amounts of irrigation to stabilize yields will substantially increase water consumption. Irrigation of only two percent of grain and cellulose-based biofuel production would consume an additional 5 Bgal/day by 2030. While some of this water demand could be transferred from agricultural uses, the volumes of water required warrant serious consideration.

Therefore, water consumption for the energy sector, including power generation plus fuels production, could grow from the 4.3 Bgal/day used in 1995 to somewhere between 11 and 17 Bgal/day by 2035. Other alternatives, such as hydrogen production as proposed in the Hydrogen Posture Plan (DOE, 2004), could require as many as 300 new high-efficiency nuclear power plants. While the hydrogen from these power plants could replace alternative fuels and reduce associated water demands, with evaporative cooling they would consume over 3 Bgal/day of fresh water.

**Water Availability Challenges**

The projected growth in water demands for future energy development is occurring at a time when the nation’s water supplies are seeing increasing stress from surface-water storage limitations, depletion of groundwater, instream ecological needs, and uncertainty about climate variability impacts on water resources. From 1920 to 1980, the United States tripled its surface water storage capacity by building many large dams, which supported significant increases in surface water withdrawals as shown in the chart on page 24, right. But since 1980 few new reservoirs have been built, and without expansion of dams or changes in operations, fresh surface-water withdrawal rates will remain fixed. If...
Local governments are increasingly shifting the burden of costs relating to new development from public to private shoulders. It is now common for developers, homeowner associations, and special districts to pay capital costs as well as those for ongoing operations and maintenance. By taking on these roles previously filled by local government, developers are acting as municipalities. How did developers move into this role and what are the current trends?

**History of Exactions**
Local governments traditionally bore the up-front cost of infrastructure development, such as extension of water lines or street paving, and recouped this cost by distributing it among the citizenry in the form of taxes. By the 1930s, municipalities began to shift the task of recovering costs to private developers, requiring them to dedicate land within the subdivision for roadways, schools, parks, etc. By the 1950s, it was common for local governments to require developers to not only provide land, but also to install needed infrastructure on that land. Now, infrastructure installation and improvements often extend beyond a project’s boundaries. For water and wastewater issues, off-site improvements might include upgrading treatment plants, expanding the capacity of plants or pipelines, providing new pump stations, and drilling new wells. We also now see required cash payments for use by a local government for a specific purpose, such as “in lieu fees” or “impact fees.” In addition, other compensating payments are often required, such as “tap fees” or utility expansion charges (UECs) that must be paid before connecting to a public utility. The actions, donations, and costs that are required of developers as a condition of developing are known as “exactions.”

**What Is The Trend?**
Local governments are becoming more creative about identifying costs that can be shifted. Developers, too, are finding new ways to work with government to identify, budget for, and offer appropriate exactions early in the process—and thereby minimize their own risks.

**Shifting Operations and Maintenance Costs:** Homeowner associations typically own, insure, provide security for, manage, and maintain common areas. Common areas might include open space, streets and sidewalks, recreational facilities, and infrastructure such as water lines, shared wells, or community wastewater treatment facilities.

Under the traditional model, local governments provided capital, performed work, and supplied ongoing operations and maintenance in areas that are now typically “common areas.” Under the neotraditional model, developers paid capital costs, performed construction to the local government’s required standards, and dedicated completed infrastructure and facilities to local government. Local governments then provided ongoing operations and maintenance costs for the infrastructure and facilities, and paid capital replacement costs. Now, many community associations are performing ongoing operations and maintenance and budgeting reserves for capital replacement costs, thus relieving local government of this responsibility, too.

**Acknowledging Water Acquisition as a Capital Cost:** Local governments commonly include projected long-term capital costs of acquiring new water rights in impact fees, tap fees, and UECs. Active strategies for acquiring new water rights are less common. In the past, a word-of-mouth standing offer to buy water rights might have been a sufficient way to slowly grow a municipal portfolio, and slow growth had to be accepted because municipal attempts to actively purchase and move agricultural water rights were viewed as aggressive, resulting in public relations problems.

New Mexico municipalities are now pushing the burden of acquiring new water rights to developers. In Santa Fe, developers of certain types of projects must: 1) locate and purchase transferable water rights acceptable to the city in an amount that offsets the project’s use; 2) donate these water rights to the city; and 3) supplement the water rights if the state engineer declines to transfer the entire donated amount.
Santa Fe and the applicant equally share all transaction costs, including the transfer proceedings before the state engineer. It is now developers who are proactively reaching out to water rights holders with offers to buy, not a municipality waiting passively for a seller to come to it with an offer to sell.

Developers have found willing sellers in downstream agricultural communities. So far, the water rights transfers have not impacted Rio Grande flows because downstream surface use is transferred to upstream city wells and the state engineer requires offsets (nonuse of surface water rights) for any wells that are hydrologically connected to the river. However, the transfers are subject to protest and hearing at the state engineer level, which typically takes up to two years. Santa Fe now allows developers to post a bond and pull a building permit after the city accepts the tendered water rights rather than waiting for the state engineer to complete the transfer process.

In other settings, developers have found long-term lease rights. Tribes, local governments, and water districts lease imported San Juan-Chama water flowing through the Rio Grande system. The Jicarilla Apache Nation leased water rights to Santa Fe, and it may decide to make more lease rights available to developers. Similarly, the Interstate Stream Commission has made Ute Lake reservoir water available by lease to local governments, some of whom subleased reservoir water to developers for use in lakeside subdivisions. The developers will build the infrastructure and a treatment plant needed to serve their projects.

Requiring Water Savings: The City of Santa Fe encouraged toilet retrofitting by requiring developers of new projects to retrofit a certain number of existing non-low-flush toilets within the city’s water utility service area in order to free up water. The retrofits were intended to implement a policy of not allowing new demands on the municipal water system while allowing new development to occur. Here, too, the developers became proactive and created a market for retrofits, which, many believe, has resulted in a faster phase-out of low-flush toilets than could be accomplished by incentives such as rebates.

Partnering via Special Districts: In some states, another trend involves a developer and local government partnering to create special districts such as public improvement districts (PIDs). This partnering allows local governments to oversee and comment on the master planning of infrastructure projects without bearing any costs or risks of the project—which will be borne by the special district. The developer provides the footwork and expertise for the project. The local government forms the special district, which is a quasi-governmental entity that raises capital by issuing and selling bonds. This capital can be used to fund major projects such as water and wastewater treatment and distribution facilities or to reimburse the developer who has fronted these costs. Meanwhile, the bonds are paid off over time by homeowners living within the district boundaries.

Everybody Wins
For many developers, exactions are a part of doing business. However, developers should be able to know in advance what is required of them. Exactions should be clearly stated in an ordinance. Additional exactions should not be imposed as a condition of project approval. Added exactions increase the costs of a project, which may require the developer to renegotiate financing, cut costs elsewhere, or increase the costs of home prices or per square foot rental rates.

From the perspective of local government, there is no downside to shifting all costs of development from general taxpayers to developers, including hard costs (such as land acquisition, easements, paving, steel, and water rights), soft costs (such as staff costs involved in project review and attorneys fees for transferring water rights), and ongoing costs. This shift seems to be meeting public approval. Furthermore, local government benefits from an increased tax base from new projects without having to increase its budget for providing services.

Contact Michelle Henrie at mhenrie@BHFS.com.
A 2006 water report from the Western Governors’ Association notes that 22 percent of the U.S. population now lives in the West, where “decisions about where and how to grow are rarely influenced by the water policy or the availability of water.” Of the top six states experiencing rapid growth from 2004 to 2005, five are in arid western regions.

Fortunately, one strategy popular in the West—land development that increases urban population density—addresses both the problem of sprawling land use and the need for water conservation. Higher density development can make urban areas water thrifty.

A review of recent strategic plans from southwestern metropolitan water providers shows differences in how four large water providers analyze and model the effects of increased urban density on water consumption. This article structures a comparison of the plans around three questions: Which regions are serious about managing water demand? How is higher urban density a demand-management tool? What are the social benefits of using higher urban density to manage water demand?

The reviewed plans are from the City of Denver Board of Water (Denver Water), the City of Phoenix, Southern Nevada Water Authority (SNWA), and the City of San Diego. The table at right summarizes service area statistics for each utility.

All four utilities identify single-family housing (SFH) as the major determinant of urban water use. They agree that customer demand patterns are changing, that overall per person consumption is falling, and that SFH demand is controlled by outdoor water use for landscaping and pools. However, there is significant disagreement as to how and why to manage outdoor water demand in the future.

### How is higher urban density a demand management tool?

SNWA has yet to identify urban design as a demand management tool, but water plans by Denver (Integrated Water Resource Plan, 2002) and San Diego (Long-Range Water Resources Plan 2002-2030) recognize a nexus between the pattern of urban development and subsequent water use in residential and nonresidential sectors. Both anticipate more compact future development as markets react to limited land availability within their service areas. They predict that rising densities will lower rates of water use and slow growth of the total volume of water consumed.

To generate its forecast, Denver Water assumed increased densities in specified “areas of change” that will absorb the expected regional growth in jobs and housing. Existing regional plans, intergovernmental agreements, zoning and subdivision codes, and market factors will direct growth to these areas and away from functional existing neighborhoods and rural areas. Two market trends also influence compact growth: more single-family units on small lots and a higher proportion of multi-family housing (MFH) units relative to single family housing. The result is less landscape irrigation: the big fish in urban water consumption. Overall urban density is expected to rise 10 percent by 2050, with SFH units averaging 3.55 per acre.

### Which regions are serious about managing water demand?

Phoenix’s Water Resources Plan 2005 Update reveals an unwillingness of the municipality to discourage outdoor water use except as a means to reduce drought-derived financial losses. The plan expresses concern that efforts to curb outdoor water use could negatively impact quality of life for residents. It views nonessential water use as a buffer that gives the utility flexibility in dealing with a drought crisis.

SNWA’s 2006 Water Resource Plan is at the opposite end of the policy spectrum. SNWA actively promotes reductions in consumptive outdoor uses to bring demand into balance with existing supplies. It offers a $2 per-square-foot rebate for the first 1,500 square feet of turf removed, and $1 per square foot thereafter, and estimates the program saves 3.5 billion gallons of water yearly. Other incentive programs work through private-sector partnerships. SNWA views incentives as one of four interrelated demand management tools that, when used with the others (regulation, education, and water pricing), maximize water conservation at the community level.

### What are the social benefits of using higher urban density to manage water demand?

SNWA views incentives as one of four interrelated demand management tools that, when used with the others (regulation, education, and water pricing), maximize water conservation at the community level.
Denver Water expects per-account demand to decrease. By 2050, SFH use is predicted to fall from 450 to 445 gallons per household per day. MFH units, which are combined with commercial and industrial users, are expected to reduce water use from 110 to 103 gallons per capita per day in 2050. Institutional and governmental customers are expected to continue to use water at the current rate of 17 gallons per person per day.

Phoenix also plans higher-density land use in its central business district as land redevelops in response to construction of a regional light rail transportation system. Unlike Denver, it expects this new, more compact growth to actually increase demand for water over that demanded by growth patterns consistent with the city’s current general plan. High-density growth in central Phoenix is apparently modeled as population in addition to the baseline growth in population. Analysis of water demand projection detail in the plan’s appendices shows that Phoenix modeled increasing densities to 2055 for its urban core without a corresponding decline in growth rate for surrounding areas.

This is a critical point. U.S. EPA, Denver Water, and San Diego all model increased urban density on a different assumption, namely that there is no net gain in predicted future population when analyzing differences between dispersed and compact development scenarios. Total future population remains the same while the urban form becomes more compact in selected areas. Overall water consumption rises because population rises. But water consumption measured on a per-account or per-capita basis falls as compact growth reduces lot sizes, landscape irrigation, and SFH pools. In this way, higher-density urban design wrings water out of growth, especially residential growth.

What are the social benefits of using higher urban density to manage water demand?

To meet projected water demands, Phoenix plans to use a traditional approach of acquiring new water resources through the least costly structural proposals. It will seek out new, imported groundwater supplies from McMullen Valley in western Arizona to augment increased use of its local aquifer and reclaimed water supplies. Importation will have large capital, environmental, and social costs to overcome.

Unlike other utilities, Denver Water has committed to finding additional supply from within its existing water rights. It has determined that it needs another 100,000 acre-feet to support the build-out of its service area by 2050. It will look to conservation, system refinements, and wider use of reclaimed water to meet future needs. Encouraging compact regional growth should be an important companion strategy.

Denver Water’s policies actively support regional growth while transitioning the local economy to low-profile water resource consumption. This strategy allows the utility to avoid two financial pitfalls. First, it is easy to overbuild water infrastructure before the regional economic and environmental issues that necessarily attend rapid urban growth (such as air pollution, congestion, and very high housing prices) exert a moderating influence on continued population expansion. Second, expansive capital improvement projects make it difficult to accept the short-term revenue declines that result from successful conservation programs.

If Denver Water successfully avoids expensive projects for acquiring new water resources, it will put its regional economy in a very competitive position vis-à-vis other southwestern areas. It will have turned the changing nexus between water and economy to its regional advantage.

Contact Jan Bush at jbush@theriver.com.

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California and the rest of the American Southwest face a number of challenges with respect to current and future water supplies. California’s population is expected to reach nearly 50 million by 2030, and Arizona and Nevada are projected to double in population between 2000 and 2030. With population growth will come changes in land and water use. New residential development and agricultural development on formerly unirrigated lands will be accompanied by voluntary or court-ordered allocation of water for the environment. Wise land-use decisions that reflect an understanding of water resources and include an ethic of environmental stewardship will be critical to success.

California and the Southwest have a legacy of groundwater overdraft that has led to water quality degradation, subsidence, conflicts among water users, increased pumping costs, and negative impacts on the environment. Of approximately 15 million acre-feet of groundwater used annually in California (DWR, 2003), up to 2 million acre-feet originates from overdraft of groundwater basins. Groundwater must be better managed so that aquifers provide sustainable supplies for people and agriculture, continue to play an important role in providing water for a healthy environment, and can be optimized for development of new storage. Additional challenges to our ability to provide safe drinking water include groundwater contamination by agricultural and industrial activities that will take decades to fully remediate; emerging contaminants with new or more stringent water quality standards; and aging water and wastewater infrastructure.

Climate change may be the greatest challenge facing water managers in the West. Decreased snowpack and runoff throughout the western United States were observed over the course of the 20th century, and increasing air temperatures are projected to further reduce the snowpack in the Sierra Nevada by as much as 66 percent in this century (DWR, 2006). Reduced runoff will decrease hydropower production, and earlier timing of runoff will increase the risk of flooding. Increased temperatures may negatively impact threatened and endangered species and result in greater rates of evapotranspiration. Along with reduced runoff, sea-level rise threatens the sustainability of the Sacramento-San Joaquin Delta and adds to the risk of seawater intrusion into coastal groundwater basins. We must adapt our water management systems to the effects of climate change, while also reducing greenhouse gas emissions resulting from the operation of these systems.

The California Water Plan identifies two initiatives to ensure reliable water supplies: improving statewide water systems and pursuing regional planning and implementation.

California has developed a widespread network of facilities that make up the backbone of water management, providing for the delivery of water supplies to much of the state, facilitating transfers between users, and allowing sharing of supplies during emergencies. To sustainably provide future water supplies, California must: repair its aging facilities; develop a plan for sustaining both the environment and water delivery capability of the Sacramento-San Joaquin Delta, which serves 23 million people and 7 million acres of irrigated agriculture; improve flood management; and undertake evaluation and construction of new surface storage and conveyance.

At local and regional levels, water agencies, municipalities, and others must collaborate to integrate their water management functions to provide added benefit, reduce costs, leverage existing infrastructure, develop solutions to regional problems, and protect and enhance the environment. Integrated regional water management (IRWM)
will help water users develop portfolios of water management alternatives that are more robust in responding to future uncertainty. Decision-making on a collaborative regional basis will reduce conflict and produce implementable solutions that reflect the unique physical setting and social values of each region of the state.

The California Water Plan identifies two dozen water and land management strategies that can be considered by regional and local entities. These strategies serve to reduce water demand, increase water supply, improve water quality, practice resource stewardship, improve operational efficiency, and facilitate transfers. As examples, urban water-use efficiency and recycled municipal water together could provide over 4 million acre-feet annually, while additional groundwater and surface-water storage have the potential for as much as 3 million acre-feet of annual supply (see figure above).

New Policies Needed
Population growth, groundwater overdraft, impaired water quality, and a host of possible impacts that could result from climate change will test our infrastructure and abilities as water managers in the future. A number of policies must be instituted at state, regional, and local levels to fully implement the California Water Plan and meet the state’s water needs. Land-use decision makers must take on a larger role in water management. Water conservation, water quality protection, maintaining groundwater recharge areas, and stewardship of the environment can be fully realized only if land-use policies and decisions are coordinated with water management. State assistance, in the form of grants and loans funded through general obligation bonds, has provided an incentive for improved planning and helped to construct numerous water supply and water quality projects. However, the state must work with local agencies to develop sustainable funding sources to retire a backlog of deferred maintenance and provide for future infrastructure improvements. We must continue to develop our understanding of the relationships between surface water and groundwater, and manage both in a coordinated fashion to maximize water available for people, farms, and the environment. Finally, to respond to the threat posed by climate change, water managers must attack both the cause and the effect. We must be leaders in evaluating and reducing greenhouse gas emissions from our water systems, and also build the flexibility necessary to respond to an uncertain future.

Contact John Woodling at woodling@water.ca.gov.

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augmented water supplies to users south of California’s Delta when the water system pumps must be turned off to prevent fish entrainment. Think of it as a “water district” for the environment.

The Sacramento Water Forum has developed a unique way to improve salmon runs on the Cosumnes River near Sacramento. The aquifer beneath thousands of acres in this county has been contaminated by a major Aerojet facility. As part of clean-up requirements, Aerojet pumps and treats the contaminated groundwater and may do so for several hundred years. Through multi-party negotiations, a portion of the water (5,000 acre-feet) will be sent via an existing canal to the Cosumnes River to restore winter spawning runs by pre-wetting the channel during the fall in dry years. This complex and collaborative solution recharges groundwater, assists farmers, improves the aquatic environment and uses otherwise “wasted” water. Flow standards, based on sophisticated science and carefully negotiated arrangements, have been agreed upon for the Yuba and American rivers and elsewhere.

Collaborative governance is not a passing fad, but a proven approach to resolve regional differences and address competing needs. Sacramento’s Water Forum, consisting of 40 disparate organizations (water suppliers, cities, counties, environmental groups, businesses, and developers) has hammered out a historic consensus agreement for management of the lower American River. The solution is sustainable, comprehensive, and inclusive and seems to be withstanding changes in policy, administration, and environmental conditions. Such deliberate collaborations are becoming increasingly common in water resources management. DWR is championing the idea of integrated, regional water management plans throughout the state, and has provided substantial financial incentives to those regions that will pursue them. There is little doubt that collaboration is occurring and innovative approaches are being developed.
**What Can We Do?**

What can we do to facilitate these policy changes in organizational and water management behavior? First, we need to shed our feudal water management systems and embrace the collaborative and interconnected nature of problem solving. Incentives such as the promise of infrastructure bond money can make a difference. Second, changes in legal, institutional, and water-use behavior must accelerate to keep pace with growth. We must rethink where water comes from, how it is used, where it goes, and how many times we can use it. Third, we need to shed our inefficient land use practices and get serious about developing compact, mixed-use, dense, walkable, transit-oriented communities that reduce consumption of natural resources, land, water, and energy and increase our ability to sustain population and economic growth and protect ecosystems. The “smart growth” model can also be a smart water model. Fourth, we need to expand our efforts in ecosystem protection, restoration, and management at the regional or greater scale, much as has been initiated under California’s Bay Delta process. And, this effort must include incentives for private land and water owners, as well as public lands. Finally, we must nurture the more flexible, responsive, and regional water management institutions that we are experimenting with, to respond to this challenging future.

**Concluding Remarks**

So can we have it all? In the short- to mid-term, I believe we can, but significant changes of policy and practice are required at all levels, along with the formation of partnerships with stakeholders from government, business, environmental, and social organizations. If we do not alter our path, one or several of the “goods”—water supply, water quality, aquatic health, economic growth—will erode and others will follow. In the long-term, if we do not seriously address population growth and land/water/energy consumptive patterns of settlement, the future is dim.

*Contact Jeff Loux at jdloux@ucdavis.edu.*

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**Integrated Monitoring and Modeling**

Monitoring and modeling are complementary activities, but too often are treated separately, ignoring important linkages and feedbacks. In a more integrated approach (see chart below), monitoring data serve as primary information for calibration of computer models. But the process of model calibration and use also provides important insights into the adequacy of and gaps in monitoring data. Unfortunately, evaluation of monitoring networks at the conclusion of a modeling study rarely occurs. Likewise, periodic model updates are needed to incorporate new data and understanding about aquifer systems. For example, estimates from environmental tracers of the age of groundwater (time since recharge) compared to ages inferred from modeling may lead to updated conceptual models of how the groundwater system works. Overall, an iterative process is needed to periodically update conceptual and simulation models, which in turn provide feedback to long-term monitoring strategies and scientific studies. This is a simple concept rarely achieved in practice.

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**Going Forward**

Defining limits to groundwater development is complex because of the dynamics of groundwater systems, climate, population, and technology. The significant uncertainties associated with the spatial and temporal effects of pumping on surface-water resources present particular challenges. Simulation-optimization modeling tools can help provide bounds on possible sustainable groundwater use under different management objectives and constraints. Using an integrated approach to monitoring and modeling, the status of the groundwater system can be tracked and a better factual foundation obtained to determine the limits to groundwater development.

*Contact William Alley at walley@usgs.gov.*

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**Integrated Monitoring and Modeling**


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Most rivers in the Southwest are groundwater-dependent, flowing primarily in a baseflow regime supported by discharge from the connected aquifer. In an undeveloped aquifer, the rate of recharge to the aquifer is balanced by the rate of discharge from it. Aquifers naturally discharge through two principal pathways: 1) to the land surface via rivers, springs, and wetlands; and 2) through vegetation via transpiration. Pumping through wells is the one artificial pathway of aquifer discharge.

In aquifers that still support surface-water discharge, consumptive groundwater use (by pumping) captures water that would otherwise discharge to the stream or spring system (Filippone and Leake, 2005; Anning and Konieczki, 2005). Thus, every drop of water consumptively used by humans is a drop lost to the riverine ecosystem. To the public, groundwater is out of sight, out of mind, and impacts to streams from groundwater use are often spatially and temporally distant from the place of pumping, and thus are easy to ignore or discount. Understanding the spatial connections of the natural and human-built environments is critical to managing water efficiently to meet both human and ecosystem water needs. In the Upper San Pedro Basin in southeast Arizona, for example, Cochise County utilized results from regional groundwater modeling to define a corridor adjacent to the river where future pumping and increases in development density would have the most immediate and direct impacts on riparian health and sustainability. The county subsequently established an overlay district that, among other things, sets up a process for the transfer of development rights from this sensitive corridor into other areas of the watershed where pumping will not as directly impact the river (Cochise County, 2006).

**Reality Meets Theory**

Protecting our remaining rivers and wetlands is a considerable challenge, given the limited water availability; the time and space separation between groundwater pumping and streamflow depletion; the largely unmanaged growth
that the Southwest is experiencing; and the disconnect between surface water and groundwater in many states’ laws. We have already lost many flowing streams, and many of those remaining are degraded. As a society, we must make choices and tradeoffs. Science provides the information to allow society to understand the consequences of its choices.

What can we do now? Identify the water needs of freshwater ecosystems and the connections between aquifers and streams in different parts of the region. Spatially delineate and understand the full ecological implications of current and future human water demands. Develop legal tools to allow local and county governments to link growth to water availability and determine for themselves how they will grow. Finally, provide information to communities to allow them to understand their physical setting, the consequences of growth, and the economic and biological value of streams in their region.

Contact Jeanmarie Haney at jhaney@tnc.org.

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National Phenology Network Developing

For more than two years, Julio Betancourt of the Desert Laboratory of the USGS in Tucson has been collaborating with Mark Schwartz of the University of Wisconsin-Milwaukee and scientists from various disciplines, federal agencies, academic institutions, and environmental networks to develop a national phenology observation network for the United States (USA-NPN). Now, with funding from the USGS and the University of Arizona, the National Coordinating Office has been established at the University of Arizona, an executive director is about to be hired, and design of the cyber infrastructure to manage all the observations is underway.

Phenology is the study of periodic plant and animal life cycle events that are influenced by environmental changes, especially seasonal variations in temperature and precipitation driven by weather and climate. Such events include the timing of leafing, flowering, and fruiting in plants, agricultural crop stages, insect emergence, and animal migration. Variations in phenophase affect the abundance and diversity of organisms, their interactions, their ecological functions, and their effects on fluxes in water, energy, and chemical elements at various scales. Phenological data and models are used in agricultural production, integrated pest and invasive species management, drought monitoring, wildfire risk assessment, and treatment of pollen allergies.

The USA-NPN aims to establish a national network of integrated phenological observations comprising four components or tiers, representing different levels of spatial coverage and quality/quantity of phenological and related environmental information: 1) locally intensive sites focused on process studies (such as AmeriFlux, which monitors ecosystem-level exchanges of carbon dioxide, water, and energy); 2) spatially extensive scientific networks focused on large-scale phenomena (such as National Weather Service cooperative observer stations and National Park Service monitoring sites); 3) volunteer and educational networks; and 4) remote sensing products that can be ground-truthed and assimilated to extend surface phenological observations to the continental scale.

Visit www.uwm.edu/Dept/Geography/npn/.

Pacific Institute Fights for Science Integrity

From the Pacific Institute

The California-based Pacific Institute recently launched an Integrity of Science Initiative to respond to and counter what it perceives as the assault on science and scientific integrity in the public policy arena, especially on issues related to water, climate change, and security. The new initiative supports sound science, exposes fraudulent use and abuse of scientific discovery, educates policymakers and the public, and refutes the doubters.

During the past decade, a small number of organizations have waged a concerted effort to substitute partisan “science” in order to advance narrow political agendas, silence researchers, and muddy good science. The media paid close attention to the deliberate tampering and editing of EPA climate change documents by non-science senior White House officials. Unfortunately, most efforts to subvert science do not command such media attention. As a result, these efforts to undermine sound policymaking and blur the public perceptions of science go unanswered and are alarmingly successful.

In recent years, the Pacific Institute has worked to educate journalists on the science behind climate change, the economics of effective water policies, and the dark side of bottled water marketing; successfully fought off a lawsuit from a “climate change skeptic”; joined more than 8,000 scientists to voice concern over the current administration’s misuse of science; and written numerous editorials calling for an end to science-bashing.

Going forward, the Pacific Institute is committed to continuing the fight through its new Integrity of Science blog and other efforts.

Send examples of science misuse and abuse to integrityofscience@pacinst.org. Read and comment on the Integrity of Science blog at scienceblogs.com/integrityofscience/.

‘Nanorust’ Removes Arsenic from Drinking Water

The discovery of unexpected magnetic interactions between ultrasmall (smaller than viruses) specks of rust is leading scientists at Rice University’s Center for Biological and Environmental Nanotechnology to develop a new, low-cost technology for cleaning arsenic from drinking water. The new technique was described in the Nov. 10 issue of Science.

“Magnetic particles this small were thought to only interact with a strong magnetic field,” center director and lead author Vicki Colvin said. “Because we had just figured out how to make these particles in different sizes, we decided to study just how big of a magnetic field we needed to pull the particles out of suspension. We were surprised to find that we didn’t need large electromagnets to move our nanoparticles, and that in some cases handheld magnets could do the trick.”

The experiments involved suspending pure samples of uniform-sized iron oxide particles in water. A magnetic field was used to pull the particles out of solution, leaving only the purified water. By measuring the particles after they were removed from the water, researchers determined that the particles were not clumping together after being tractored by the magnetic field.

“It turns out,” co-author Doug Natelson explained, “that the nanoparticles actually exert forces on each other. So, once the hand-held magnets start gently pulling on a few nanoparticles and get things going, the nanoparticles effectively work together to pull themselves out of the water.”
Because iron is well known for its ability to bind arsenic, Colvin’s group repeated the experiments in arsenic-contaminated water and found that the particles reduce the amount of arsenic to levels well below the EPA’s drinking water standard.

Preliminary calculations indicate the method could be practical for settings where traditional water treatment technologies are not possible. The cost of the materials could be quite low if manufacturing methods are scaled up. The primary raw materials used to prepare the iron oxide are rust and fatty acids, which can be obtained from olive oil or coconut oil.

Visit cben.rice.edu.

New Mexico’s First Artificial Recharge Project Planned

Having observed its neighboring states artificially recharging aquifers for decades, the first such project in New Mexico has appeared on the horizon. The Albuquerque-Bernalillo County Water Utility Authority is planning a $1 million study to test the feasibility of diverting river water treated to drinking water standards directly into the aquifer 300-500 feet below the surface.

Crossroads, continued from page 25

Groundwater resources will not be the answer: impacts to aquifers from excessive pumping in the latter half of the 20th century will limit new groundwater development and future use. Furthermore, climate variability is expected to affect snowfall and precipitation, the timing of spring runoff, and streamflow volumes, resulting in many regions experiencing significant reductions in reservoir storage, and surface-water and groundwater availability.

These limitations on fresh water supplies are forcing expansion of the use of nontraditional waters such as brackish water, seawater, and wastewater to supplement supplies in many areas. The growth in nontraditional water use over the past decade has been remarkable as water treatment technologies have matured. Wastewater reclamation and reuse and desalination are growing at rates of 15 and 10 percent per year, respectively. As shown in the chart below left, nontraditional water consumption is predicted to equal fresh water consumption for nonagricultural needs by 2035.

Addressing Energy and Water Resource Challenges

The chart below right shows that projected growth in water consumption for energy is the major driver for future water demands. These new water demands will increasingly be met by the use of nontraditional water resources. Energy demands for water alone could outstrip available nonagricultural fresh water supplies by 2035. These interdependencies between energy and water and their impact on future economic growth are being recognized by energy officials and energy and water managers. For example, in mid-2005, Congress funded the Department of Energy to develop an energy-water report to Congress to help identify and quantify emerging energy and water challenges and issues (DOE, 2007). Congress also funded a series of regional workshops to help identify research and development efforts to address these emerging challenges and issues (see www.sandia.gov/energy-water). These efforts are the first steps in improving and coordinating energy and water resource planning and development to ensure future energy and water reliability and sustainability.

Contact Mike Hightower at mmhight@sandia.gov.

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Scientists Call for Restoration of Integrity

From the Union of Concerned Scientists

As of mid-December, 10,600 scientists had signed a document calling for the restoration of scientific integrity to federal policy-making. The Union of Concerned Scientists (UCS) announced the latest numbers at the annual meeting of the American Geophysical Union. Released in February 2004, signatories of the document include Nobel laureates, National Medal of Science recipients, and members of the National Academies of Science.

At the same meeting, UCS announced the release of an “A to Z” guide that documents dozens of allegations involving censorship and political interference in federal science. The compendium details censorship and political interference in federal science on issues as diverse as air quality, childhood lead poisoning, and prescription drug safety. For example, in late October UCS released documents tying high-level political appointees at the Department of Interior to the manipulation and distortion of numerous scientific documents to prevent the protection of six species under the Endangered Species Act.

Visit www.ucusa.org to view or sign the document, search the signatories, and look up allegations of integrity abuses.

WEF Expansion Efforts

The 36,000-member Water Environment Federation, a not-for-profit technical and educational organization that focuses on water quality, has been busy growing its resources. Last October, the organization signed a memorandum of agreement with the National Association of Clean Water Agencies, an association of wastewater treatment agencies, describing events and activities in which the two organizations will collaborate.

In January, WEF announced the acquisition of the journal World Water & Environmental Engineering from a British publisher, and the subsequent formation of WEF Publishing UK Limited, a for-profit subsidiary. According to a WEF news release, WW&EE is a bimonthly international water quality magazine with a readership of 10,000 worldwide. WEF will continue to produce its flagship publication, Water Environment & Technology.

Later in January, WaterTech Online reported that WEF had approached the American Water Works Association, representing the water supply industry, about a possible merger. AWWA claims 57,000 members, including 4,700 North American water utilities. According to WaterTech Online, the proposal received a lukewarm response, with AWWA expressing interest in exploring joint opportunities, but citing the need for a more fully developed proposal before taking any action.


NWRA Meeting Breaks Record

The Nevada Water Resources Association (NWRA) held its 2007 annual meeting in Reno Feb. 20-22 with record-setting attendance of nearly 300. Featured speakers included Lonnie Thompson, a climatologist from Ohio State University who studies the effects of climate change through ice cores, and Gregory James, a lawyer and former director of Inyo County Water Department, who provided a historical perspective on the Owens Valley water transfer.

The technical program featured speaker panels that addressed climate change in Nevada, how the integrated resource planning approach differs from more standard water resources management, updates of 2007 legislation and policy in the state, issues related to consumptive use, quantifying impacts of out-of-basin transfers, and whether an “Owen’s Valley situation” could happen in Nevada.

Tom Eakin, co-developer of the oft-used Maxey-Eakin approach for estimating recharge, was awarded the Lifetime Achievement Award at the meeting in recognition of his contributions to the understanding of complex systems in Nevada. The Longley Lane Hidden Valley Membrane Water Treatment Plant received the Major Project of the Year award.

The meeting was preceded by an optional field trip to the Longley Lane Treatment Plant and a geothermal plant, and a workshop on groundwater principles. For those more interested in the frozen form of water, the semi-annual NWRA ski day was held at Mt. Rose ski resort. Finally, the second annual Run for the Water, a 5K race to raise money for NWRA scholarships, attracted a strong field of competitors.


New Alliance for Water Efficiency

Last late last year, the Alliance for Water Efficiency announced the formation of a charter board of directors for this new national nonprofit organization dedicated to water efficiency. It is to be a clearinghouse and advocacy group for water efficiency research, evaluation, and education. The 19 individuals named to the charter board represent water utilities, product and appliance manufacturers, irrigation manufacturers, environmental organizations, academic institutions, and others. The board planned to begin formal development of the organization and its membership in February.

The organization was created by the California Urban Water Conservation Council, with financial support from the U.S. EPA, and modeled after existing national organizations devoted to energy efficiency. The goal of the new organization is to represent the needs of the water efficiency community by developing initiatives for improved products, researching new technologies for saving water, and assembling programs for water utility involvement across the United States.

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Aquifer Storage Recovery: A Guide to Groundwater Recharge Through Wells (2nd Ed.)
by R. David G. Pyne, ASR Systems, $158

Reviewed by Adam Hutchinson – Orange County Water District

As we all know, in the Southwest and many places elsewhere in the country and around the world, there is a pressing need to more efficiently utilize our water resources to meet ever-growing demands. Aquifer storage recovery (ASR), the use of dual-purpose wells to recharge and later recover stored water from aquifers, is a valuable addition to our arsenal of tools to achieve greater efficiencies in the use of water resources.

In Aquifer Storage Recovery: A Guide to Groundwater Recharge Through Wells, author R. David Pyne, with contributions from leading experts, has presented a comprehensive look at the current body of knowledge on ASR. The book presents the building blocks of an ASR program, including a feasibility study, pilot testing, well and wellfield design, well equipment, well plugging and redevelopment, water quality changes, and geochemistry. Non-technical issues such as ASR economics, water rate impacts, legal and regulatory issues, and public involvement are also covered. Alternative ASR applications that are addressed include surface water storage, riverbank filtration pretreatment, reclaimed water storage and aquifer thermal energy storage. Nineteen case studies are presented, of which 17 are updates from the first edition, which was published in 1994. These updates provide an interesting retrospective view of what has and has not worked and how some ASR projects have morphed into projects that have different objectives from those originally intended. In the final chapter, the author looks to the future to discuss water philosophy, regulatory and management issues, growth management, and global applications of ASR.

The strength of the book is that it presents the bulk of current ASR knowledge in one volume. When the first edition was published, only 18 ASR systems were operating in the United States. By the writing of this second edition in 2005, the number had increased to 72. As a result, the second edition incorporates many lessons learned during the expansion of ASR over the past 11 years.

Weaknesses of the book include its length (608 pages) and lack of flow. Many topics are touched on multiple times, but the redundancy can be useful if one uses the book as a reference to seek information on a topic of interest. However, the book can be difficult to read due to the lack of flow and discontinuities in style, likely due to the multiple sources and contributors to the book.

Professionals who currently are or plan to be involved with ASR will find this book most useful. In the academic realm, it could serve as a good optional reference for university courses covering one of the many areas touched by ASR.

Overall, Aquifer Storage Recovery does an admirable job covering the myriad facets of this technology. But even with this volume as a reference, this topic is difficult to cover. As the book states, “The probability of successfully implementing an ASR program is enhanced by assembling a multi-disciplinary technical team that includes a balance of engineers and hydrogeologists, with capabilities in the areas of geochemistry, hydrogeology, water treatment processes, utility operations, hydraulics, aquifer simulation modeling, economics, water chemistry, and design of wells, pipelines, pumping stations, and related elements of a water utility system.” As this list shows, there are so many areas of expertise required for this technology, a multidisciplinary team approach to ASR is necessary. What this book does is to provide teams involved in ASR and potential users of ASR with enough information to ask the right questions to navigate a course to a successful ASR program.

Weaknesses of the book include its length (608 pages) and lack of flow. Many topics are touched on multiple times, but the redundancy can be useful if one uses the book as a reference to seek information on a topic of interest. However, the book can be difficult to read due to the lack of flow and discontinuities in style, likely due to the multiple sources and contributors to the book.

Professionals who currently are or plan to be involved with ASR will find this book most useful. In the academic realm, it could serve as a good optional reference for university courses covering one of the many areas touched by ASR.

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Groundwater Modeling System (GMS) 6.0


Groundwater Modeling System (GMS) is a comprehensive software package for building and running groundwater flow and contaminant transport models. The Environmental Modeling Research Laboratory at Brigham Young University in Utah oversees the continued development of GMS (currently at version 6.0), but GMS is distributed commercially through many vendors.

GMS provides tools for site characterization, model development, post-processing, calibration, and visualization. It supports triangular irregular networks (TINs), solids, borehole data, 2-D and 3-D geostatistics, and both finite-element and finite-difference models in 2-D and 3-D, including MODFLOW, MODPATH, MT3D, RT3D, FEMWATER, SEEP2D, ART3D, MODAEM, SEAM3D, and UTCHEM. Parameter estimation is supported through the processes included with MODFLOW-2000, PEST, and UCODE.

GMS allows the user to select modules in custom combinations to perform such operations as pre- and post-processing, model selection, and calibration routines. Discussion of all modules is beyond the scope of this review, but websites of commercial vendors contain detailed descriptions and applications of each one (search the Internet for “GMS 6.0”). New users can select specific modules for a current project and add more as their needs expand or change. Although the initial learning curve is steep, use of GMS ultimately saves time by providing a “package” of modeling modules that is the same for a variety of programs.

GMS uses the same conceptual model approach for all models, which is built into the map/GIS module. Here, a user defines model properties (such as boundary conditions, hydraulic conductivity values, 2-D and 3-D model domains) in a GIS interface that is independent of the simulation codes. With the click of a mouse, model properties are transferred from the GIS interface to the appropriate grid cells or mesh elements, allowing one to quickly change a conceptual model, transfer these conditions to a new simulation, and evaluate the results. More advanced users can easily see and edit the grid-by-grid values without going to the final text file (although a quick check of the text files is always a good idea). GMS 6.0 can be fully integrated with ArcGIS (if the user has an ArcGIS license), providing a seamless transfer from creating conceptual models to producing final figures of results.

Although GMS has excellent modular, visualization, and conceptual model development capabilities, its complexity can be a disadvantage. Early versions of upgrades have contained bugs in some new features, particularly related to the ArcGIS and other graphical interfaces. These eventually were worked out in revised releases.

In summary, GMS 6.0 is a useful multipurpose groundwater modeling package that offers the advantages of modular purchases, multiple model support, linkages to ArcGIS, conceptual model development, and integrated inversion routines. As with many software programs, new releases should be used with the understanding that some of the latest features may require revision before the full range of capabilities are functional.

Basic GMS packages start at about $1,650 and are available through the EMRL at www.emrl.byu.edu and at commercial sites. Mention of trade names does not imply any endorsement by the author or the USGS.

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## THE CALENDAR

### MAY 2007

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
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<tbody>
<tr>
<td>May 15-19</td>
<td>ASCE-Environmental and Water Resources Institute. World Environmental and Water Resources Congress</td>
<td>Tampa, FL.</td>
<td>content.asce.org/conferences/ewri2007/</td>
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### JUNE 2007

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<tbody>
<tr>
<td>June 3-6</td>
<td>Association of State Wetlands Managers. Strengthening the Roles of Land Trusts and Local Governments in Protecting and Restoring Wetlands and Riparian Areas.</td>
<td>Park City, UT.</td>
<td><a href="http://www.aswm.org/calendar/lt&amp;lg/lt&amp;lg2.htm">www.aswm.org/calendar/lt&amp;lg/lt&amp;lg2.htm</a></td>
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<tr>
<td>June 5</td>
<td>Arizona Water Resources Research Center. 20th Anniversary of the Environmental Quality Act and ADEQ: Assessing, Protecting, and Remediating the State’s Water Quality.</td>
<td>Phoenix, AZ.</td>
<td>ag.arizona.edu/AZWATER/</td>
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### JULY 2007

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### AUGUST 2007

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<tr>
<td>August 20-22</td>
<td>International Association of Science and Technology for Development. 2nd IASTED International Conference on Water Resources Management.</td>
<td>Honolulu, HI.</td>
<td><a href="http://www.iasted.org/conferences/cfp-578.html">www.iasted.org/conferences/cfp-578.html</a></td>
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<tr>
<td>August 29-September 1</td>
<td>Southwest Hydrology and Arizona Hydrological Society. Sustainable Water, Unlimited Growth, and Quality of Life: Can We Have It All?</td>
<td>Tucson, AZ.</td>
<td><a href="http://www.watersymposium.org">www.watersymposium.org</a></td>
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### SEPTEMBER 2007

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### OCTOBER 2007

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### NOVEMBER 2007

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<tr>
<td>November 8-10</td>
<td>California Groundwater Association. 59th Annual CGA Convention and Trade Show.</td>
<td>Reno, NV.</td>
<td><a href="http://www.groundh2o.org/events/events.html">www.groundh2o.org/events/events.html</a></td>
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