ARIZONA
WATER RESOURCE

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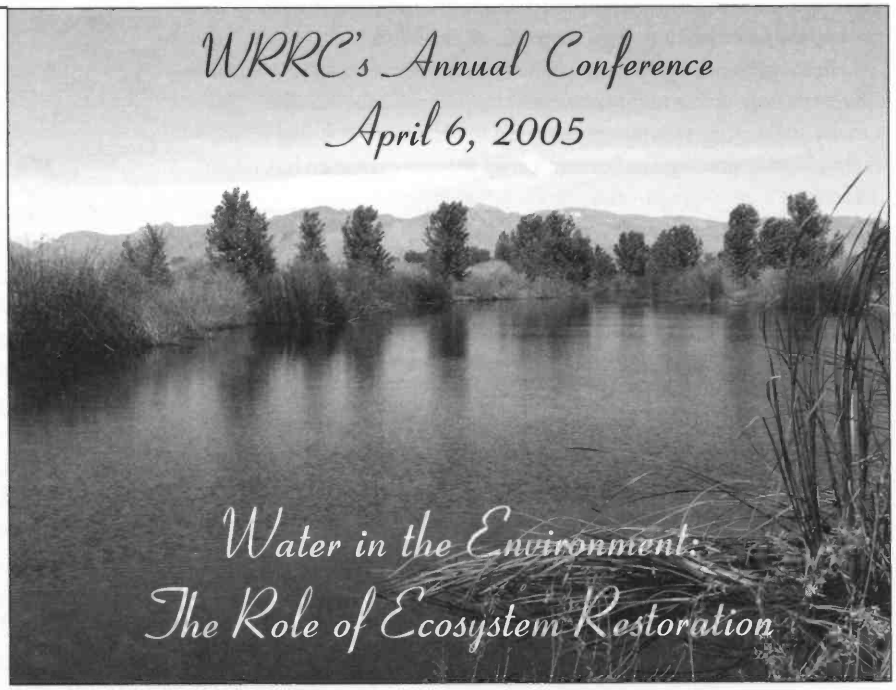
Scheduled April 6 in Tucson, the annual Water Resources Research Center's conference will bring together various experts to address the timely topic of ecosystem restoration. Their expertise backed by field experience, the speakers will discuss the purposes and benefits of ecosystem restoration and discuss ongoing project implementation. The one-day conference will feature a mix of keynote speakers, panel discussions and commentary; this will ensure that the issue will receive full and diverse coverage.

Panel session topics include: examples of successful ecosystem restoration projects; ongoing efforts in the Verde Watershed; the legal system as a tool for effecting environmental policy; the Colorado River Multispecies Conservation Plan; and funding opportunities for ecosystem restoration. Representatives from federal and state agencies, environmental organizations and others will provide insight and a range of views on these topics of broad appeal to water/environmental professionals, lawyers, academics, public officials and the general public.

The spring event is the latest in a series of conferences sponsored by the Water Resources Research Center.

Check the WRRC web site for additional information about the upcoming conference: http://cals.arizona.edu/azwater/



A project of the U.S. Army Corps of Engineers and Pima County, the Ed Pastor Kino Environmental Restoration Project was once a flood control basin. In 1997, the Corps considered the feasibility of modifying basin features for restoration of riparian habitat. Modifications were completed in 2002, with the original facility expanded to 141 acres. This includes 50 acres of wetlands; 12 acres of wildlife and open water areas; and 38 acres of mesquite bosque and ephemeral grassland.

Biomonitoring Checks Bodily Tissues, Fluids for Exposure to Chemicals

Technique used to detect water contaminants in humans

by Joe Gelt

Biological monitoring, or biomonitoring as it is more commonly known, and water quality testing set out to accomplish similar objectives, although they have different focuses. The objective of both activities is to identify and measure substances or contaminants, with water quality testing focusing on water and biomonitoring looking within the human body.

Biomonitoring assesses human exposure to natural and synthetic chemicals by sampling and analyzing a person's tissues and fluids. Blood, urine, breast milk and expelled air are the most commonly analyzed, but also sampled and measured are hair, nails, fat, bone and other tissues. Biomonitoring is a rapidly developing field of research

Monitoring the human body can produce diverse results. This is because the body absorbs natural and synthetic chemicals by performing basic human activities – breathing, drinking and eating. The air we breathe, the water we drink and the food we eat can contain natural chemicals, such as lead or arsenic, as well as a large variety

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Biomonitoring...continued from page 1

of more complex compounds; synthetic or man-made chemicals may also be present.

Whatever shows up in water quality testing – heavy metals, perchlorate, pesticides, mercury etc. – also can be measured by biomonitoring to determine their presence within the human body, if the appropriate methodology or tools are available.

Prior to the development of biomonitoring technology, scientists were only able roughly estimate the potential for human exposure by measuring substances detected in air, water, soil and food. Today, biomonitoring studies can verify that an exposure has taken place.

Rocky Mountain Consortium

Arizona is a member of a Rocky Mountain consortium working to gear up participating states' biomonitoring capability. Other member states are Colorado, Montana, New Mexico, Utah, and Wyoming. A five-year grant from the Centers for Disease Control and Preventive Medicine provided funds for consortium states to purchase essential biomonitoring equipment and to support training. CDC funding also supports various pilot projects, including a six-state study of people exposed to arsenic in drinking water.

Officials from the Arizona Department of Health Services are now working on plans for the state's study of arsenic: this will be part of the larger consortium study. The studies will help determine what use this specialized tool is to those who manage and regulate our water supplies. That it can measure substances or contaminants in end users – i.e., those who drink the water – would suggest that biomonitoring might help interpret what effects the potentially toxic exposures have on humans. What are the potential and limitations of biomonitoring when used for this purpose?

The extensive use of biomonitoring to assess general population exposures to various chemicals in the environment is a relatively recent development. Many government health agencies have just begun to commit resources to biomonitoring. (See side bar for action taken in California to boost biomonitoring.) CDC's grant to the Arizona Health Services is essentially seed money to build the agency's biomonitoring capacity; thus supporting applications for more significant funding from other sources. At the University of Arizona, biomonitoring projects have been done within the College of Pharmacy and the College of Public Health.

Workings of Biomonitoring

Chemicals that have entered the human body through air, water or food leave markers reflecting this exposure. These biomarkers may be the chemical itself or may be a breakdown product of the chemical. A biomarker also might be a change in the body resulting from the action of the chemical on the individual. Biomonitoring picks up on these biomarkers.

The measure of the natural and synthetic chemicals detected through biomonitoring is referred to as body burdens, although some are wary of this term. They say it is misleading because it implies that whatever substance biomonitoring detects causes adverse effects when in fact the technique only measures exposure. Biomonitoring data tell us how much of a substance is present in a sample but not the toxicity or risk.

Biomonitoring is becoming increasingly precise, with newly developed sampling and analytical techniques enabling researchers to detect and quantify various kinds of human biomarkers at levels previously undetectable. In this regard, biomonitoring is like water quality testing which also has been able to identify more minute quantities of various ingredients or contaminants in water.

By biomonitoring human subjects for arsenic ingested through drinking water the study may help researchers to better track the pollutant from its source to an eventual water user. Dr. David Mills, director of laboratories, New Mexico Department of Health, and principal investigator of the consortium grant, explains, "It's just a different way of approaching the problem. Just measuring the stuff in the air or ground or water doesn't really give you a direct assessment of what its impact on the population is. This gives you a more direct measure. ... We will look at how the drinking water level correlates with what you see in direct exposure in their urine.

"The idea is that instead of trying to assume or guesstimate exposure based on environmental hazards in the field, we look directly and see what the actual exposure is ... and how it correlates with the drinking water level. You get much better exposure data and do better linking of exposure to health outcomes."

USGS Sponsors Supplement

This edition of the "AWR" contains a 4-page supplement sponsored by the U.S. Geological Survey to provide information about its work. At the same time, USGS, by sponsoring the supplement, is supporting the publication of this newsletter. We appreciate the opportunity to work with USGS and for the agency's generous support.

California Bill Sets Up Biomonitoring Program

Legislation was introduced in California to create the country's first state biomonitoring program. It would begin by looking for 57 chemicals in the breast milk of volunteer women in three California communities. Its scope would later expand to other body fluids, chemicals, and communities. Sen. Deborah Ortiz, the bill's sponsor, says her legislation is an opportunity to collect necessary data to determine if exposure to toxic contaminants encountered in daily life is adversely affecting health. The bill's most controversial feature is the strategy to finance its activities: fees would be levied on the manufacturers and distributors of the 57 chemicals. The bill is titled the Healthy Californians Biomonitoring Program.

Arizona's Biomonitoring Project

Consortium study plans call for collecting a total of 5,000 urine specimens from the six states, with each state contributing about a sixth of the total. In Arizona, work is underway to identify geographical areas that likely have arsenic in the water source to include in the study. The Arizona Department of Water Quality database is a source researchers are consulting for information about such communities.

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Water Vapors

Lawmakers Learn About Water Sustainability

Event occurs during boil-water alert

Water Expo — 2005 was an opportunity for Arizona lawmakers to obtain information about projects in the state concerned with water sustainability. Conducted Jan. 25 on the Senate lawn of the Arizona State Capitol, the event was sponsored by the University of Arizona's Water Sustainability Program, with support from the Central Arizona Project and the Salt River Project. (The Water Resources Research Center along with three other UA water centers make up the Water Sustainability Program.)

Forty-six legislators as well as a number of legislative staff members attended the event. The 40 exhibitors participating in the event included the Agri-Business Council of Arizona, U.S. Bureau of Reclamation, County Graham Cooperative Extension, Northern Arizona University Fossil Creek Initiative and various cities throughout the state, from Flagstaff to Tucson.

Water Expo — 2005 provided the occasion for WRRC Director Sharon Megdal to present Governor Janet Napolitano with a fitting Southwest artifact: an agave potted in a watering can. Photo: Joe Gelt

The timing of Water Expo proved oddly fortuitous occurring on the same day that Phoenix water users were alerted about boiling their water before directly using it. The coincidence — if indeed it were a coincidence — prompted project exhibitor Val Little to quip to Dana Flowers, the organizer of the event, "I think it was especially cool that you were able to foul the entire Phoenix water supply to draw attention to water issues. It's tough to get visibility like that at any price!"

Alert Takes on Added Significance

This was not the only instance of the Phoenix boil water alert taking on a significance beyond whatever health threat and inconvenience it posed to the city's water users. A writer of a letter to the editor in the Phoenix Republic used the occasion to get attention to an issue of particular concern to him. He suggested that Phoenix change its city motto to, "Welcome to Phoenix: where our library computers are filtered better than our drinking water."

The headline of an article by Arizona Republic columnist Laurie Robert read: "Boil your water? How about let's boil the planners?" She views the recent boil water advisory as the most recent of a series of failures including gas and power shortages.

Columnist Montini found much extracurricular significance to the boil water advisory. He suggests Phoenix citizens have in fact been drinking contaminated water since November. He says, "This would help us to explain to outsiders how the sheriff (Arpaio) and most of Arizona's other politicians got elected and re-elected."

He concludes: "The truth is, I can't understand why we're so eager for the contamination scare to be over. We should be celebrating. For the past few days those of us who have lived in Phoenix for years could honestly answer a question that we've heard dozens, maybe hundreds, of times: 'Is there something in the water out there?' Yes."

Another letter writer seemed to agree that the water scare might serve a purpose. He wrote, "... maybe we should consider establishing an annual holiday when we shut down our entire infrastructure. Then we would perhaps realize that even with all of our infrastructure hiccups, we're still more comfortable than nearly everyone on the planet."

Phil Boas, deputy editorial page editor, referred to the water alert to put a much more significant issue in perspective. He wrote: "Last week was a scary one in the Valley. No, not the water. The Cardinals announced they were changing their logo."

Finally columnist Clay Thompson, a true wordsmith, did not speculate about the overall significance of the alert; instead he very much liked the word itself: turbidity. He wrote, "Turbidity. Isn't that a great word? Say it five times real fast. See? It's fun to say, plus it sounds vaguely dirty. Who cares what it means; I'm going to say it all the time from now on." He then went on to say, "Let's get to today's question, which I find pleasingly turbidgous."

Well, there you have it: Phoenicians creatively and turbidly cope with their water emergency. It almost makes one look forward to the next boil water alert.

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News Briefs

BuRec to Buy Land to Mitigate Dam's Impact

To meet an obligation incurred when Roosevelt Dam was modified, the Bureau of Reclamation is proposing to buy about 700 acres of floodplain along the Gila River between Fort Thomas and the Eden Bridge. The land, which the Salt River Project would managed, would be reserved as habitat for the Southwestern willow flycatcher.

In 1996, the U.S. Fish and Wildlife Service determined that BOR's modifications to Roosevelt Dam would jeopardize the existence of the Southwestern willow flycatcher. In accordance with the Endangered Species Act, the agency directed the BOR "to mitigate, or reduce, those impacts through the purchase and management of land to benefit the willow flycatcher."

In 2002, FWS approved the Salt River Project's Roosevelt Habitat Conservation Plan. This long-term management plan for the dam called for SRP to purchase and manage additional riparian habitats to mitigate impacts on the flycatcher. The recently proposed land purchase is a joint BOR-SRP effort to meet the plan's land acquisition and management requirements.

The BOR is currently working on an environmental assessment to identify anticipated environmental consequences resulting from the proposed purchase. The potential impacts on biological, cultural and water resources and land use will be considered

The Graham County Board of Supervisors has expressed concerned about the purchase and its possible effect on land use and water resources in the area. More specifically, concern has been raised about whether the purchase will impact agricultural activities in the area. Questions also have been raised about the purchase's possible effects on ongoing efforts to eliminate phreatophytes along the river.

A 15-day public review of the draft environmental assessment is scheduled for March. Copies of the draft assessment are available by calling Ruth Konst at 602-216-3864.

Arizona Project WET Director Kerry Schwartz received the 2004 Regional Water Conservation Award, presented by the Phoenix Area Office, U.S. Bureau of Reclamation. In presenting the award, the agency commended Schwartz "for her initiative and enthusiasm in implementing a statewide water resource training program." Seen above, left to right, are Michael Pryor, Reclamation Acting Area Manager, Kerry Schwartz, Eugene Sander, Vice Provost, College of Agriculture and Life Sciences, University of Arizona, and Sharon Megdal, Director, UA Water Resources Research Center. Arizona Project WET (Water Education for Teachers) is a WRRC program. Photo: Lynne Fisher

ASU Research Seeks to Split H2O for Hydrogen Source

Researchers at Arizona State University are studying more efficient ways of producing hydrogen from water as part of a strategy of developing a nonpolluting energy source to replace gasoline for fueling automobiles.

The U.S. Department of Energy awarded ASU's Center for BioOptical Nanotechnology, located within the Biodesign Institute, a $1.5 million grant to conduct the research. The funding is part of the Hydrogen Fuel Initiative, dedicated to reducing the U.S dependence on foreign oil. Neal Woodbury, director of the center, is the lead researcher of the project.

ASU researchers are attempting to find catalysts that will act to promote the efficient generation of hydrogen from water. Natural processes are being examined, specifically naturally occurring manganese-based catalysts that facilitate the splitting of water into hydrogen and oxygen. The researchers are studying the interaction of clusters of manganese atoms with water in nature, with the intent of translating that into a workable laboratory process.

Current processes to split water into hydrogen and oxygen consume more energy than is chemically required, with about 2.2 volts of electricity needed to create hydrogen. ASU researchers hope to reduce it to 1.3 or 1.2 volts. Whatever electricity is needed to power the conversion process could come from renewable sources such as solar or wind energy. The project would then be environmentally friendly, both entirely clean and independent of fossil fuels.

SRP Reservoir to Deliver Water to Payson Area

An agreement recently signed by the Salt River Project and Phelps Dodge Corp. sets the stage for the transfer of the Blue Ridge Reservoir and its water production facilities from the mining company to the utility. The reservoir has a 15,000 acre-feet capacity.

Plans call for SRP selling 3,000 acre-feet of Blue Ridge water to Payson and 500 to Gila County for use in the Rim country, with the balance of the reservoir's annual average yield of 11,000 acre-feet used in the Valley.

Payson officials are understandably pleased about SRP's acquisition of the reservoir since the town, now totally reliant on groundwater, will be getting a renewable source of water. Some claim its significance to Payson can be compared to what the delivery of Colorado River water via the Central Arizona Project meant to Phoenix.

The plan is that SRP will transfer ownership of Blue Ridge to the U.S. Bureau of Reclamation. It will then be operated much like the other reservoirs of Salt River Federal Reclamation Project, with Reclamation

On-The-Ground, In-The-Air Efforts to Control Salt Cedar

Bill Seeks to Eradicate Salt Cedar

The Salt Cedar and Russian Olive Control Demonstration Act (S.177) recently gained committee approval when passed by the Senate Energy and Natural Resources Committee. The bill is now ready for Senate consideration.

Initially introduced by Senator Pete Domenici in 2003, the bill authorizes a research and demonstration program to accelerate the eradication of the water-depleting salt cedar and other non-native species thriving along rivers in the western United States. Domenici serves as chairman of the committee.

Salt Cedar, the scourge of western waterways. Photo: George Andrejko, AZ Game and Fish Dept.

The Domenici legislation, cosponsored by Senator Jeff Bingaman, was amended last Congress to incorporate aspects of a similar bill introduced by former Senator Ben Nighthorse Campbell. It passed the Senate last year but did not clear the House of Representatives before the end of the 108th Congress.

The bill directs the Secretary of the Interior, working with other federal agencies, to complete an assessment of the extent of salt cedar and Russian olive infestation in the western United States, undertake a minimum of five eradication demonstration projects, and analyze possible beneficial uses of the resulting bio-mass.

The bill authorizes $20 million in FY2006, and $15 million each fiscal year thereafter. Each demonstration project can utilize up to $7 million in federal funding, and would be subject to a non-federal cost share match on non-federal lands. The bill does not specify demonstration project locations, but does encourage them to be paired with existing programs where possible.

NASA Joins Invasive Species Effort

The National Aeronautics and Space Administration has become the 13th cabinet agency to join the National Invasive Species Council. NASA's current work on maintaining the biological integrity of Earth and other solar system bodies along with work with remote sensing of Earth's biotic and abiotic environment from space will make it an invaluable addition to the council.

Lori Williams, NISC executive director, says, "NASA will add a unique voice to the Council and help further the development of a broad, comprehensive approach to invasive species issues which often present a complex array of agricultural, environmental, health and economic issues that cross geographical and jurisdictional boundaries."

Executive Order 13112 defines an "invasive species" as both non-native (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm, or harm to human health. Invasive species can be aquatic or terrestrial; plants, animals (including insects) and microorganisms. Salt cedar is an invasive species of special concern in the West.

NASA has agreed to make its satellite observations of the Earth, computer modeling and engineering experience available to NISC, to improve the ability to help control and eradicate invasive species that are harming the environment in the United States.

owning the reservoirs and SRP operating them under contract.

Timing is a concern: SRP officials say water-strapped Payson may have to wait ten years before reservoir water is delivered. Various issues need to be resolved, including environmental concerns. U.S. Forest Service land will be traversed requiring that the National Environmental Policy Act process be worked out.

Cost is a drawback. SRP figures upgrading the existing Blue Ridge pump, plant and pipeline will cost millions of dollars, with costs passed on proportionately to Payson and other water users. Add to that whatever Payson ends up paying to build a treatment plant and a 14-mile pipeline. The bottom line is that an acre-foot of reservoir water may end up costing Payson water users double or triple the approximate $120 that Central Arizona Project charges for an acre foot of water delivered to central and southern Arizona.

Blue Ridge Reservoir is in Coconino County, about 25 miles north of Payson, atop the Mogollon Rim in the Coconino National Forest.

At ADWR – One Moves Up, Another Moves On

Recent personnel changes at the Arizona Department of Water Resources include Tom Carr becoming the new assistant director of the office of statewide conservation and strategic planning. His new responsibilities will eventually include Colorado River management, drought coordination, statewide conservation, statewide water planning, the Water Protection Fund and an expanded water resources planning section.

In another change, Jim Holway will be leaving the agency for a position at Arizona State University. His primary position at ASU will be serving as one of the deputy directors for the newly formed International Institute for Sustainability. He also will be a professor of practice in civil and environmental engineering and a senior research fellow with the Morrison Institute for Public Policy. Holway has worked at ADWR for 12 years and in the assistant director position for nine years.

Guest View

Water Utilities and Arizona Universities Benefit as Research Partners

Bruce Johnson, Tucson Water assistant director, and Daniel R. Quintanar, Tucson Water project manager, contributed this Guest View.

In the United States acceptable drinking water quality is taken for granted. Drinking water utilities, however, need to become more innovative in dealing with drinking water quality issues concerning public health, water system security, evolving regulations, and the general public's assessment of safety based on water taste. Conducting active research with universities is an innovative and creative way for utilities to learn more about their source water and distribution system quality. Information gained through research allows utilities to implement improved water quality management practices.

Since the early 1970s great strides have been made in improving surface water quality (Clean Water Act) and setting national health-based standards for drinking water (Safe Drinking Water Act). Although the United States Environmental Protection Agency and the Arizona Department of Environmental Quality provide guidance through the regulatory process, drinking water utilities may need to take the initiative to solve some immediate water quality concerns, especially local water quality issues. Drinking water utilities need to develop a working research philosophy, become actively involved in problem solving through research, and become accustomed to incorporating research results into day-to-day operations.

In Arizona, all the state universities conduct water related research at some level. Drinking water utilities should work with and utilize these institutions as information resources to address water quality problems. Water quality challenges are gathering on the horizon on several fronts. These challenges can be grouped into three categories: water safety; water and health; and water aesthetics. Addressing these can be formidable especially for smaller utilities. Leveraging your local university can be beneficial to both parties.

Tucson Water has been active in conducting and participating in research for several years with groups such as the Awwa Research Foundation (Awwarf), private companies, and consultants, in addition to conducting internal research projects. Our research philosophy has been developing in recent years based on our challenges and operational experiences associated with several research efforts. Specifically we have learned that research needs to be: 1) actively managed by the utility; 2) focused on solving a specific problem or set of problems; 3) able to be applied to real world situations; 4) able build on the outcome to conduct further research as required; and 5) able to support the utilities business goals

In Tucson Water's experience, collaborating and working with the University of Arizona and the UA - National Science Foundation Water Quality Center on different research projects have proven very beneficial. We utilize both formal and informal methods of collaboration with the UA, from being a board member of the NSF W-Q-C to assisting individual students, graduate and undergraduate, with water sampling, data and access. This type of approach has created a friendly atmosphere of cooperation and collaboration on different research projects ranging from technical and analytical projects to risk communication projects, with resources leveraged to effectively and successfully manage and complete a specific project.

Through these avenues we have been able to learn more about recharged Colorado River water and our main drinking water distribution system. Two analytical research projects come to mind. In one we were able to determine if trihalomethanes and halo acetic acids would increase as a result of increasing amounts of natural organic matter combining with free chlorine in our recharged Colorado River water. The other research effort was characterizing the changing microbial populations from varying source waters to the customer tap. In addition, the UA NSF W-Q-C is an active partner of our EPA-funded EMPACT (Environmental Management for Public Access and Community Tracking) project. This program focuses on collecting and distributing timely water quality information to the community. The results have increased public awareness and improved our risk communication efforts.

The University of Arizona and Arizona State University National Science Foundation Water Quality Centers have been very successful in gaining national recognition for greatly improved possibilities for focused current and future research. Through collaboration with these entities water utilities have direct access to a large pool of research scientists, biologists, chemists, physicists, hydrologists and engineers working together to resolve water quality problems. Although these resources are available, the state's utilities and the NSF Water Quality Centers need to maintain a dialogue to successfully identify specific state and utility research needs. In addition, this type of collaborative research can also begin to address statewide and regional water quality and water resource issues, with the research results utilized on a larger scale with a greater benefit.

Governor Napolitano's idea of creating a "virtual water university" by tapping the collective water expertise of the state's universities plays into the idea of leveraging collaborative research. This virtual institution also can provide an effective avenue for all the state's utilities to begin identifying both local and state research needs. The UA and ASU NSF W-Q-Cs can greatly assist in facilitating a dialogue, both locally and at the state level, that will be needed to begin planning the creation of this virtual institution. Without statewide collaboration between research scientists and state utilities many water issues in the near and distant future may be more difficult to resolve successfully.

Tucson Water's research program will continue to grow as we continue to identify drinking water quality and water resource issues needing to be resolved through collaborative research. Our research philosophy is a work-in-progress and must remain flexible as we investigate better ways to resolve water issues by being innovative and forward thinking as we learn to utilize collaborative research more and more as a tool in our arsenal.

USGS
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National Water-Quality Assessment Program

Where do the salts go?

The potential effects and management of salt accumulation in south-central Arizona

Introduction

Land in arid and semiarid regions of the world is irrigated to sustain agriculture, urban yards and lawns, and other vegetation. To prevent the accumulation of salts in the root zone, the quantity of water applied must be sufficient to flush the salts beyond the root zone as well as meet the plant requirements. Many factors determine the extent and severity of salt accumulation including chemical composition of the water supply; nature and composition of the soil and subsoil; topography of the land; quantity of water used and the methods of applying it; kinds of crops grown; climate of the region, especially the quantity and distribution of rainfall; and nature of groundwater and surface-water drainage systems (Hem, 1985). Irrigated agriculture can result in rising water tables, waterlogged soils, progressive mineralization of water and soils, briny wastewater-disposal problems and concerns, and contamination of ground water by fertilizers and pesticides applied to the land and by chemicals in treated sewage effluent when it is used for irrigation (Bouwer, 1990; Bouwer and others, 1998).

In south-central Arizona, the conversion of desert and rangeland to irrigated agricultural and urban land has been possible because of the impoundment of rivers, the pumping of ground water, and the importation of water. The salts that remain in the soil when these waters are used for irrigation are of concern because they can adversely affect crop production; quality of the underlying ground water; and domestic, municipal, and industrial water uses. In order to understand the causes and effects of salt accumulation in water and soils and how to manage or mitigate those effects, we need to understand where the salts come from and where they go.

What are salts?

The terms "salt content" or "salinity" of water actually refer to the quantity of mineral constituents that are dissolved in the water. The dissolved minerals or salts in water typically are reported as the

A lesson from an ancient civilization

The accumulation of salts in soils and ground water in arid and semiarid regions as a result of agricultural and irrigation practices is as much a concern to modern civilizations as it was to ancient civilizations. For example, the flood plain of the Tigris and Euphrates Rivers, known as the "Fertile Crescent" in ancient Mesopotamia (present-day Iraq), was first irrigated more than 6,000 years ago. The resulting agricultural surplus provided the foundation upon which the civilization was built; however, canals built in 4000 B.C. did not sufficiently drain excess water from the agricultural areas, and salts accumulated in water and soils. Progressive waterlogging and salinization were evident from the historical succession of crops—a 50/50 split of wheat and barley was grown in about 3500 B.C.; by 2500 B.C., the more salt-tolerant barley represented 80 percent of the crop, and finally by 1700 B.C., wheat could not be grown because of the salts that had accumulated in the ground water and soil. Centuries of irrigating poorly drained soil with highly mineralized water in an arid climate left a thick crust of salt on the land surface and soil hardened by salt deposits. By 1950, 60 percent of the tillable land in the area was affected by salt accumulation (Earthscan, 1984). A more recent example is the western desert of Egypt on the fringe of the Nile River delta. Irrigation began in 1956, and in 5 years, salinization of ground water and waterlogging of crop lands were causing deterioration in crop production (Hassan and others, 1979). As Scofield (1938) noted, "The application of irrigation water in abundance to soils in arid regions may have consequences unsuspected by those engaged in developing projects and farmers settling on the land."

U.S. Department of the Interior
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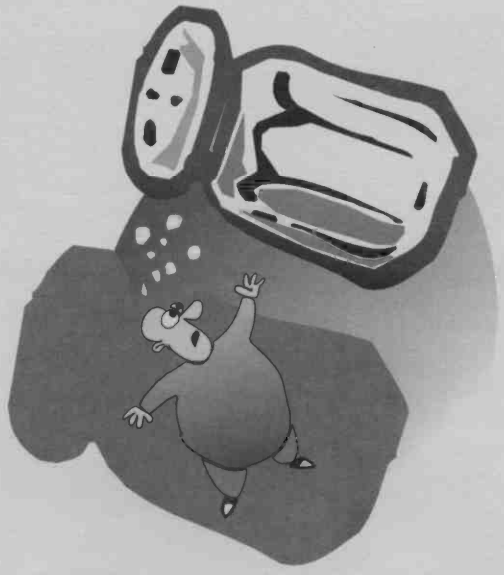
"dissolved-solids concentration" in milligrams of dissolved salts in one liter of water (mg/L). Water with a dissolved-solids concentration of less than 500 mg/L—about a quarter of a teaspoon of salts per gallon of water—generally is suitable for most uses (Swenson and Baldwin, 1965). Water may have a mineralized or salty taste when the dissolved-solids concentration exceeds 500 mg/L, which is the Federal secondary maximum contaminant level for drinking water (U.S. Environmental Protection Agency, 1994). At concentrations greater than 2,000 mg/L, water generally is unsuitable for many uses including long-term irrigation (Swenson and Baldwin, 1965). The salts that constitute a major part of the dissolved-solids concentration in waters of south-central Arizona are calcium, magnesium, sodium, sulfate, chloride, and bicarbonate. Concentrations of nitrate, fluoride, and trace metals such as arsenic or selenium are particularly significant because they affect the suitability of water for certain purposes (Hem, 1985).



The total imported salt load in south-central Arizona equals about 900 pounds of salts per person per year!

Salt River, east of Phoenix, Arizona. (Photograph by Gail Cordy.)

Where do the salts come from?

Natural processes add salts to surface water and ground water. The concentration of salts in water is determined by many factors including reactions with minerals in the soil and rock formations across which and through which the water moves. For example, the average dissolved-solids concentration of the Salt River as it enters the Salt River Valley east of Phoenix (Salt River below Stewart Mountain Dam) is about 480 mg/L (Baldys and others, 1995). The average concentration of imported lower Colorado River water used in the area (Central Arizona Project Canal at 7th Street in Phoenix) is about 580 mg/L (David Anning, hydrologist, U.S. Geological Survey, oral commun., 1998). Ground water in south-central Arizona generally has a dissolved-solids concentration of less than 500 mg/L; however, higher concentrations are present in many areas.

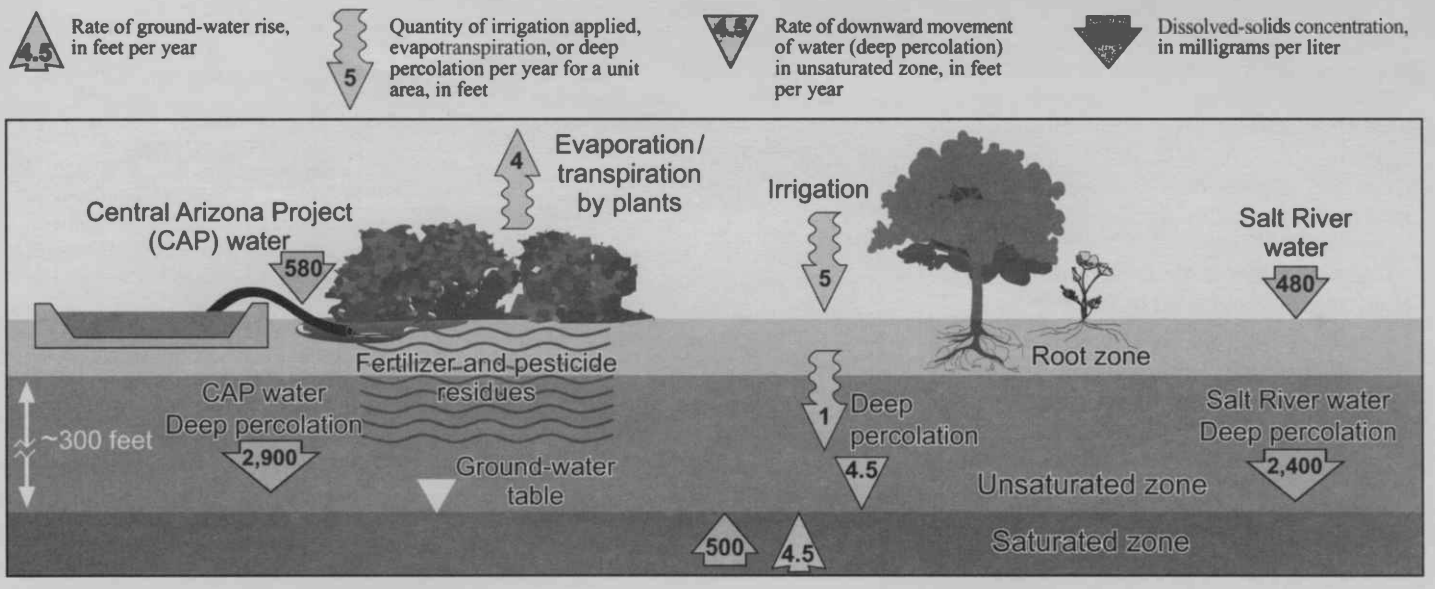
Human activities also can add salts to natural waters. For example, irrigation water may leach mineral constituents from the soil and deeper geologic formations and carry them to the ground water, which in turn, can discharge to surface water where the water table intersects the land surface. Mining activities can release dissolved mineral constituents to local streams and ground water. Storm runoff from urban areas and municipal wastewater also can contribute salts and chemicals.

The Salt and Colorado Rivers bring not only water into central Arizona, but also salts—about 1.1 million tons for the estimated 1.4 million acre-feet (Central Arizona Project, 1998) of Colorado River water imported in 1997 through the Central Arizona Project (CAP) canal, and about 520,000 tons in the roughly 0.8 million acre-feet (Tadayon and others, 1998) of Salt River water that flowed into the greater Phoenix area in 1997. This is a total imported salt load of about 1.6 million tons per year, the equivalent to a half-ton pickup-truck load of salts entering the area about every 10 seconds or about 900 pounds of salts per person per year for each of the 3.6 million people in south-central Arizona in 1997 (estimate for Maricopa, Pinal, and Pima Counties from Valerie Rice, University of Arizona, Economic and Business Research Program, oral commun., 1998). An equal quantity of salts would have to leave the area to maintain a salt balance. Yet there is no substantial removal of salts from the area because almost all of the water from the Salt River and the CAP canal is used in south-central Arizona (David Anning, oral commun., 1998). So where do the salts go?

Where do the salts go?

The answer is simple—The salts go where the water goes, and they accumulate in soils where evapotranspiration (combined evaporation from soils and transpiration by plants) exceeds combined precipitation and irrigation. For south-central Arizona, salts accumulate in irrigated agricultural and urban areas (parks, golf courses, and residential yards). The water that is returned to the atmosphere by evapotranspiration essentially is distilled water, leaving the

Central Arizona Project Canal, west of Phoenix, Arizona. (Photograph by Darryl Webb, Mesa Tribune, published with permission.)



Diagrammatic illustration showing quantity of irrigation, evapotranspiration, or deep percolation; rate of ground-water movement; and dissolved-solids concentration for waters in the Salt River Valley, Phoenix, Arizona.

salts in surficial soils and in the root zones of plants. To avoid salinity damage and possibly killing plants or crops, the salts brought in by irrigation water must be leached from the root zone by applying more irrigation water than can be evaporated. The leaching results in sustainable crop production and plant growth. Generally, the leach water or deep-percolation water continues to move downward through the soil and basin-fill sediments of the unsaturated zone until it reaches the ground water (saturated zone).

As an example (see illustration above), consider cotton grown in south-central Arizona with an efficient irrigation system that applies 5 feet of water per year, of which 4 feet are evaporated or transpired (Erie and others, 1982), and about 1 foot leaches salts from the root zone. The leaching process produces 1 foot per year of deep-percolation water that moves down to the ground-water table; however, this 1 foot of water per year contains almost all of the dissolved salts from 5 feet of irrigation water. As a result, salt concentrations in the deep-percolation water will be as much as 5 times higher (Bouwer, 1990) than those of the original irrigation water—about 2,400 mg/L if water from the Salt River is used and 2,900 mg/L if water from the CAP canal is used.

What are the potential effects of salt accumulation in ground water?

During much of this century, more ground water has been withdrawn in south-central Arizona than has been replenished by natural and artificial means (Arizona Department of Water Resources, 1994). As a result, ground-water levels generally have moved downward more quickly than the deep-percolation water from agricultural fields and urban areas, and the quality of deep ground water has not been degraded by the slower moving salty water (Bouwer, 1997). Since the mid-1980's, the trend has been to rely less on ground water and use more CAP water, especially for agriculture (Cordy and others, 1998). This trend could result in ground-water levels declining more slowly or even beginning to rise. Water levels also would rise if salty deep-percolation water reaches the ground-water table.

In the southeastern part of the Salt River Valley where irrigation has continued but ground-water pumping has stopped, ground-water levels have risen an average of about 4.5 feet per year in the last 15 years, and the concentration of salts in shallow ground water has increased (Karol Wolf, hydrogeologist, Salt River Project, oral commun., 1998). By applying this rate of water-level rise to other areas in south-central Arizona, ground water at a depth of 300 feet today could rise to the land surface in about 70 years if pumping was discontinued and all of the deep-percolation water continued to reach the water table. Rates of rise in ground-water levels depend on the water storage capacity (interconnected pore space between soil grains) and water content of the soils above the water table, the quantity of irrigation water applied, the quantity of evapotranspiration, and the natural recharge from precipitation and surface runoff. As previously noted, the deep-percolation water could contain about 2,400 mg/L of salts if water from the Salt River is used for irrigation and 2,900 mg/L if water from the CAP canal is used. In addition to the salts, ground water may contain elevated concentrations of contaminants from fertilizer and pesticide applications, especially where ground-water levels are near the land surface.

As salty ground water approaches land surface, plants begin to show signs of salinity damage and die from salty water in the root zone and waterlogging, basements may flood, water levels may rise into landfills, and underground pipes can be damaged.

If water levels are allowed to remain at or near land surface, salt marshes and salt flats could form. How can the salty ground water be managed to prevent these problems?

How can the salty ground water be managed?

Because salinization of ground water and soils is a common problem in arid and semiarid parts of the world where land is irrigated, many solutions have been proposed and tested. The salt load can be reduced through improved irrigation practices or modifications in cropping practices that reduce deep-percolation losses (Ayars and other, 1997). Improved irrigation practices might include reducing preplanting irrigation, using different irrigation technologies such as drip systems that deliver water directly to each plant, and

using shallow ground-water management techniques such as tile drains to collect the salty water where ground-water levels are high. Cropping modifications could include allowing some land to lie fallow, growing crops using dryland techniques, and retiring land from agricultural use.

If ground water in the upper parts of the aquifers is contaminated by deep-percolation water, it could be too salty for drinking or irrigation of salt-sensitive crops; however, there are several options for managing the salty water. One option is to pump ground water from the upper parts of the aquifers to stabilize ground-water levels at acceptable depths (Bouwer, 1997). This salty water could then be disposed of in evaporation lakes after minimizing the volume of water and maximizing the salt content by sequential irrigation of increasingly salt-tolerant plants (Shannon and others, 1997). In this process, the deep-percolation water from salt-sensitive crops like vegetables is captured and used to irrigate a more salt-tolerant crop, such as cotton, from which the deep-percolation water could be used on very salt-tolerant plants ending with halophytes (extremely salt-tolerant plants). The salty water at the end of the process could be managed in evaporation lakes; however, these lakes can become environmental hazards by creating areas of high salt concentrations that can be detrimental to animals and plants.

Another option is to desalt the pumped ground water using reverse osmosis or other membrane-filtration processes. Desalting produces a reject brine that can be stored indefinitely in lined evaporation ponds. Salty deep-percolation water and (or) reject brines could be injected into deep wells far below the potable ground water; however, Federal regulations must be met in the selection of disposal wells, and the migration of these waters into potable water supplies cannot always be predicted or controlled. A third option is to convey the leach water and (or) brines by a "brine line" to the lower end of the Colorado River for commercial desalinization (reverse osmosis) and (or) for expanding wetlands at the end of the Colorado River (Bouwer, 1997). Other options are possible, but the accumulation of salts in ground water and waterlogging of soils in south-central Arizona could cause significant problems if practices that allow salt accumulation continue.

—Gail Cordy (USGS) and Herman Bouwer (USDA)

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Legislation and Law

Feds Pay Farmers for Water Diverted to Protect Species

Judge rules diverted water constituted a taking

In what many believe is a precedent-setting move, the federal government has agreed to pay four California water districts $16.7 million for water a government agency diverted a decade ago to protect two rare fish. It is an action likely to resonate throughout the West, whenever government's efforts to save threatened species raise conflicts with property owners, an oft repeated theme in the region.

The action was in response to a controversy sparked in the early 1990s when the federal government determined that Endangered Species Act requirements for endangered winter-run chinook salmon and threatened delta smelt had precedent over several water districts' contractual water claims.

The water lost to the Tulare water district was about 58,000 acre-feet over three years, with the Kern County Water Agency losing about 319,000 acre-feet of water during the same period. In sum, the action deprived several thousand California farmers of billions of gallons of water between 1992 and 1994.

The Tulare, Kern, Lost Hills and Wheeler Ridge-Maricopa water districts along with several ranching partnerships sued. They adopted the unusual strategy of suing the federal government, although it was a California state agency that refused to deliver State Water Project supplies. California, however, was abiding by federal directives.

In December 2003, Court of Federal Claims Senior Judge John Wiese found in the farmers' favor, ruling that the government's action constituted a "taking." In other words, the diversion of the water for ESA purposes intruded on the farmers' private property rights in violation of the Fifth Amendment to the US Constitution prohibiting government from taking private property without fair payment.

In his opinion Wiese stated, "At issue is not whether the federal government has the authority to protect the winter-run Chinook salmon and Delta smelt but whether it may impose costs of their protection solely on (the water districts)."

The judge computed that the federal government owed five water districts about $26 million including $14.6 million for lost water, plus $9.8 million in interest. He also directed the government to pay attorneys' fees totaling about $2 million. Subsequent negotiations reduced the total amount.

In response to the ruling, the Bush administration agreed to pay San Joaquin Valley farmers $16.7 million as compensation for undelivered irrigation water diverted to help the endangered species. Although the amount is less than what Wiese originally ordered, the amount far exceeds what some California officials wanted paid.

Sen. Dianne Feinstein, D-Calif., says settling the lawsuit is a mistake since a precedent is now set, and the public will end up paying tens of millions of dollars to water users even if a small portion of anticipated deliveries is diverted to protect endangered species.

The settlement marks the first time the federal government has paid out money to interests claiming that ESA protections represented an unconstitutional taking of private property. What attracted national attention was the principle not the amount of the settlement. Environmental groups fear government will now have to pay millions of dollars each time it reserves water to protect threatened wildlife.

What effect this settlement will actually have on similar lawsuits, however, remains to be seen. One such lawsuit is a $1 billion claim by farmers in the Klamath Basin along the California-Oregon border.

Biomonitoring...continued from page 2

A goal of the study is to focus especially on small communities whose small scale drinking water systems may not be regulated by ADEQ. Not having ADEQ information to help identify such communities, researchers are examining state hydrologic and geologic information. Although the study is focusing on arsenic, which is the consortium's top concern, it will also measure other heavy metals in the urine to establish a baseline. This will determine if state measurements are in line with national averages as indicated by CDC's Second National Report on Human Exposure to Environmental Chemicals. This comprehensive report assesses the U.S. populations exposure to environmental chemicals.

Researchers will collect urine specimens to analyze using biomonitoring techniques to determine whether people in the test areas have a body burden of arsenic. If they do, the next step will be to determine to what extent the arsenic comes from drinking water, the food they eat, or other sources. Arsenic can either be organic or inorganic; exposure to inorganic arsenic is associated with the occurrence of cancer, whereas organic arsenic does not appear to be carcinogenic. The Arizona study will speciate arsenic between inorganic and organic arsenic.

Patricia Adler, ADHS State Laboratory, chemistry office chief, describes the technique for interpreting biomonitoring data to provide this kind of information. She says, "What we are testing are the metabolites of arsenic. Those coming from a food source are organic arsenic compounds; those from water go through the body without adding any sort of organic compounds. Doing a speciation of the arsenic helps scientists identify the possible sources. This involves complex instrumentation."

Adler says that among its findings the study will determine if body burdens increase when people drink water with increased amounts of arsenic. If no differences are noticed among those drinking water with ten parts per billion and those consuming 50

Continued on page 12

Publications & On-Line Resources

EnviroMapper for Water (Version 3.0)

The Environmental Protection Agency's Office of Water has just released a new version of EnviroMapper, a web-based Geographic Information System that creates customized maps portraying the nation's surface waters. EnviroMapper also houses a wealth of text reports containing environmental data. Data can be viewed and mapped on such topics as impaired waters that do not support their assigned uses; water quality monitoring information; and the location of discharges. Maps can be viewed at the national, regional, state or local levels. EnviroMapper for Water is available at www.epa.gov/waters/enviromapper/

The World's Water 2004-2005: The Biennial Report on Freshwater Resources

Peter H. Gleick et al., Pacific Institute, 362 pp., $35 Island Press at www.islandpress.org

Water is a critical issue on the international agenda. The United States is struggling, along the rest of the developing world (including other wealthy nations), to meet the water needs of its populace. This edition of the biennial report focuses on state and national issues, as well as international concerns about water resources.

According to the report, over 1 billion people are left without access to clean water every year. If the world were to spend $10 to $20 billion a year on foreign aid for water supply and sanitation projects, instead of the current $3 billion, this problem would be eradicated. The report calls for a modest increase in U.S. spending to help global water problems.

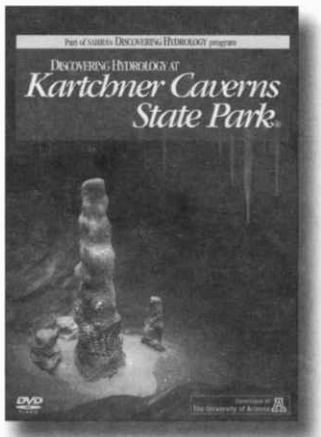
Other topics addressed include urban water use efficiency, groundwater, United Nations millennium goals for water, bottled water, water and privatization, and water and conflict.

On the domestic front, the report calls for the establishment of a National Water Commission to develop a comprehensive national water policy. This would address such issues as investments in new technology for efficient use and water treatment; a research program to study drought and flood risks; the setting of new national water efficiency standards; and revising the approach to river basin management.

Water-Use Trends in the Desert Southwest: 1950-2000

A.D. Konieczki, J.A. Heilman, U.S. Geological Survey, Scientific Investigations Report 2004-5148.

With more Arizona farms being replaced by homes, groundwater consumption in the state is falling, despite rapid population growth. This U.S. Geological Survey report shows that from 1975 to 2000, groundwater pumping in Arizona fell 28 percent, a 476-million gallon decline. The report also compares and examines trends in water use and withdrawal for Arizona, California, Nevada, New Mexico and Utah. In 1950, California accounted for 82 percent of the total domestic water withdrawals among the five states. Its decrease to 70 percent in 2000 indicates that domestic water withdrawals in the other four states are increasing at a faster rate. The major source of information for the report was water-use data compiled and published every five years since 1950 by the U.S. Geological Survey. The entire report is available online at http://water.usgs.gov



Discovering Hydrology at Kartchner Caverns State Park DVD

Developed and distributed by the NSF Science and Technology Center for the Sustainability of semi-Arid Hydrology and Riparian Areas, with funding from Cochise County Cooperative Extension and the UA Water Sustainability Program and support from Arizona State Parks and The University of Arizona. $10 each; $6 for five or more. Check web site below for ordering information.

Water was and is a vital force in the formation of Kartchner Caverns. This DVD explains that the water cycle created and continues to shape the caverns. Discussions focus on how water enters the cave today and continues to shape the caverns and how the cave drains; Kartchner Caverns' place in the water cycle of the San Pedro Basin; the age of the caverns as indicated by formations; and the local climate over the past 200,000 years. Kartchner Caverns State Park is located outside of Benson and is the destination for a third of a million tourists each year. The DVD can be viewed online at www.sahra.arizona.edu/kartchner

Drought and Water Crises: Science, Technology, and Management Issues

Donald A. Wilhite, ed. CRC Press, 432 pages, $139.95. (For ordering information, check: www.crcpress.com)

With the world facing a water crisis of considerable magnitude, many questions about drought remain unanswered. "Drought and Water Crises" explains the complexities of drought and the role of science, technology and management in resolving many of the issues associated with the world's expanding water crisis. It includes contributions from more than three dozen top scientists and engineers across numerous disciplines. Contributors discuss topics such as the role of science and technology in water management; new technologies for water conservation; and drought policies around the world. The book also features case studies showing how other nations and localities implemented principles discussed in the book. The editor of the volume has been serving as a consultant as Arizona develops its drought plan.

Special Projects

WRRC Announces 104B Funding Awards

The Water Resources Research Center, in its role as administrator of the Section 104B program of the Water Resources Research Act, has selected five programs for funding. Funded by the U.S. Geological Survey, the 104B program supports small research projects investigating water issues of state and regional importance. The WRRC-administered 104B funding is limited for use by faculty members at Arizona's state universities.

Proposals submitted to WRRC are evaluated by its Technical Review Committee based on merit, educational experience for students, usefulness in resolving Arizona water issues, feasibility and researcher qualifications. Making up the TRC are personnel from universities, consulting firms, state and federal agencies and water providers. The WRRC director uses TRC's evaluations and comments when deciding which projects to fund.

The five projects, which are described below, will receive a total of $51,558.

–Salt River Riparian Ecosystem Restoration; Principal Investigator: Julie Stromberg, associate professor, Arizona State University; Award: $8,869.

The vegetation and surface water in several reaches of the Salt River in the Phoenix metropolitan area will be monitored prior to implementation of several large-scale restoration actions. The monitoring will provide valuable pre-restoration information to restoration designers, as well as early-stage input on success or failure of the restoration measures.

–Big Chino Basin 3-D Digital Hydrogeologic Framework Model; Principal Investigator: Abe Springer, associate professor, Northern Arizona University; Award: $9,000.

A Digital Hydrogeologic Framework Model (DHFM) will be constructed to characterize the subsurface geology of Big Chino Basin, located at the headwaters of the Verde River. The DHFM will serve as a tool for understanding and conveying the complex subsurface hydrology of the region to water managers and others. The model will also be utilized by the USGS Water Division in Tucson to construct a Groundwater Flow Model for the region.

–Preliminary Evaluation of Perchlorate Contamination of Ground Water in The Lower Colorado River Region; Principal Investigator: Charles Sanchez, professor, University of Arizona; Award: $11,949.

Groundwater in the Yuma area of the lower Colorado River region will be evaluated for perchlorate contamination. Little information presently exists on the extent that seepage from surface water conveyance systems and irrigation drainage has contaminated groundwater sources in the Yuma area.

–An Outdoor Multi-Stage, Continuous-Flow Photobioreactor for Bioremediation of Nitrate-Contaminated Groundwater; Principal Investigators: Qiang Hu, assistant professor, and Milton Sommerfield, professor; Arizona State University; Award: $11,740.

A Multiple-stage, Continuous-Flow Photobioreactor (MCP) will be designed, fabricated and operated to remove nitrate from groundwater in a cost-effective and environmentally-friendly way. The photobioreactor will utilize a microalgal species that can thrive in groundwater and take up nitrate at high rates. The algal biomass produced as a by-product from the photobioreactor can be used as an organic fertilizer or animal feed.

–Treatment of Nitrate in Groundwater with Autotrophic Bioreactors; Principal Investigator: Reyes Sierra, associate professor, and James Field, professor; University of Arizona, Award: $10,000.

The project goal is to evaluate the feasibility of a low-cost, low-maintenance packed-bed bioreactor utilizing insoluble sulfur as the electron donor for denitrification. Additionally, the project investigates the role of naturally occurring groundwater alkalinity in fulfilling neutralization and inorganic carbon requirements of the process. The outcome of the project will be a simple design concept that can be utilized by small water utilities for the affordable and reliable treatment of nitrate in groundwater.

ADEQ Awards Funds for Nonpoint Source Projects

The Arizona Department of Environmental Quality recently announced FY 04-05 projects to be funded under the Water Quality Improvement Grant Program. The WQGP enables ADEQ to allocate US Environmental Protection Agency funding to program applicants for implementing nonpoint source management and watershed protection within Arizona. The distribution of EPA grant funding is pursuant to Section 319(h) of the Clean Water Act and is administered by ADEQ's Water Quality Division.

–Apache; EC Bar Ranch; EC Bar Ranch Turbidity Reduction Project, Phase VII; $60,000.

Best management practices will be implemented to control nonpoint source pollution and restore natural resources.

–Cochise; Coronado RC&D Area Inc.; Campomocho-Sacaton Watershed Stormwater Runoff Control, Phase II; $179,800.

This project will reduce the amount of sediment produced off 12,800 acres of rangeland in the Campomocho sub watershed of Willcox Playa.

–Coconino; Boy Scouts of America Grand Canyon Council; Boy Scout Camp Raymond On-site Sewer System Improvements; $150,600.

The primary goal of this project is to reduce potential pollution to a pristine area of the Verde Watershed. The goal is to effectively eliminate any potential contamination to the groundwater, adjacent springs, streams and an existing well by upgrading the sewer systems at the camp that have been in place for over 30 years.

Continued on page 10

Announcements

Conference on Resolving Environmental Conflict Set

"Pathways to Successful Environmental Conflict Resolution" is the title of a conference to be held May 24-26 in Tucson. Sponsored by the U.S. Institute for Environmental Conflict Resolution of the Morris K. Udall Foundation, the University of Arizona's Udall Center for Studies in Public Policy and various federal agencies, the national conference will feature training workshops, panel sessions, interactive roundtable discussions and opportunities for agency-specific side meetings. The conference will focus on enhancing the effectiveness of ECR processes through better understanding of ECR principles and practices; engaging multiple governments, parties and affected communities; and encouraging innovation and new applications. For more information, check http://www.ecr.gov/

Call for Papers Issued

The Virginia Water Resources Research Center is issuing a call for abstracts and workshop proposals for the National Water Research Symposium, "Balancing Water Law and Science." Researchers from colleges and universities (faculty, graduate and undergraduate students), federal and state agencies, private organizations, law firms, consulting firms and others are encouraged to send 200-250 word abstracts or 1-2 page workshop outlines by March 31. Discussions will include (but are not limited to) the privatization of water supplies, scientific bases for state water rights, wetland construction and water conservation goals. For more information, including where to send the papers, go to www.vwrrc.vt.edu

Water Security Conference Scheduled

The American Water Works Association hosts its 2005 Water Security Congress April 10-12 in Oklahoma City. The event will enable water industry leaders to learn, network and share ideas and will serve as an opportunity for utility managers, security staff, manufacturers/distributers, consultants and public officials to work with leading water and water security experts. Sessions will be in the form of in-depth conferences, exhibits and evening receptions; topics will include risk communication, water quality monitoring, security enhancements and financial issues. For more information, check www.awwa.org

Fellowships for Students From Developing Nations

The Ivanhoe Foundation is offering $5,000 fellowships "to needy and deserving students from developing countries" studying for a master's degree in engineering or science, with an emphasis on water resources. Candidates are also recommended to have a bachelor's degree or equal level certificates, a proficiency in English and a research assistantship or eligibility for one. Extra consideration is given to applicants with work experience between degrees or field-related intern experience. For more information, go to www.theivanhoefoundation.org

Groundwater Conference Upcoming

The National Groundwater Association will host its 2005 Ground Water Summit April 17-20 in San Antonio, Texas. The summit is an opportunity for recent issues and advances in groundwater technology, science and policy to be discussed. Session topics include water resource strategies in arid environments, groundwater education, and recycling remediation technologies. Meetings will enable local, national and international science partners to better facilitate the exchange of technical information and new science developments; discuss policy and regulatory issues pertaining to groundwater; and promote goodwill among groundwater professionals. Check www.ngwa.org for more information.

Adeq Awards...continued from page 9

–Gila; Franciscan Friars of California, Inc.; The Gibson Mine Total Maximum Daily Load Reduction to Pinto Creek; $570,106.
The Franciscan Friars of California, Inc. and Brown and Caldwell will remediate the abandon Gibson Mine to improve water quality in Pinto Creek.

–Gila; Gila County Division of Health and Community Services; Gila County Ground and Surface Water Improvement Project; $252,467.
This project will protect and preserve the groundwater and surface water in Gila County by replacing, repairing, and upgrading current waste water systems in the Tonto Creek (headwaters) and Christopher Creek Total Maximum Daily Load focus areas.

Graham; Gila Watershed Partnership; Central Detention Dam Rehabilitation; $15,600.
The Gila Watershed Partnership will rehabilitate the Central Detention Dam, a 27-foot high earthen structure built in 1948 as a flood control dam serving to reduce erosion and allowing maximum recharge to the hydrologic system.

–Greenlee; Gila Watershed Partnership; Kaler Ranch Erosion Control Project; $167,000.
The project's goal is to preserve, protect and improve water quality by reducing sediment discharge and excess organic input to the San Francisco River.

–Santa Cruz; Coronado RC&D Area Inc., Partnership to Improve Water Quality in Redrock Canyon/Upper Santa Cruz Watershed; $249,302.
This project addresses sediment production on the entire Red Rock Canyon Watershed that drains the Canelo Hills east of the town of Patagonia in Santa Cruz County.

Public Policy Review

by Sharon Megdal

Water Pricing Has Potential to Promote Water Conservation

The pricing of water is an interesting and important topic. The rates water utilities charge are designed to recover the cost of delivering water to customers. That means water prices generally cover the costs of the construction, maintenance and operation of the water delivery infrastructure, from pipelines to dams and canals. Also included are costs of all administrative functions, from meter readers to outside consultants and lawyers. Yet, no cost is associated with the water molecules themselves. This is true for groundwater, surface water and effluent.

For most goods and services, the price system usually is viewed as a mechanism for allocating scarce resources. Water stands out as an exception, its pricing not generally incorporating a scarcity value of water, despite a general awareness that water is in fact scarce. Water is not sold at a market-clearing price for several reasons. This is partly due to our legal system governing water rights and ownership. It is also due to the general belief that water should not be treated like other commodities, with private interests owning and then selling it at whatever the market-clearing price may be. This may seem paradoxical, and, in fact, introductory textbooks in economics identified the diamond-water paradox years ago. Diamonds are not a necessity but are very expensive whereas water is essential for life but is often free for the taking. The paradox can be explained by the relative scarcity of the two goods. Water has been relatively plentiful relative to demand while diamonds are very scarce and costly to produce.

Due to growing local, national and global populations, fresh water is not plentiful in many locations. In the West, many communities must seek new, often expensive water supplies to serve rapidly growing populations. We see officials imposing water resource fees related to providing water and entering into water transactions to secure necessary water supplies.

Drought has heightened Arizonans' awareness of the imbalances of water supplies relative to demand. Having sustainable state water supplies means acknowledging and addressing actual and potential imbalances between long-term demands and supplies. Work on long-term water balances region-wide has been underway in the Active Management Areas for some time; in other areas work is just beginning.

Using price signals to assist with demand management is not a new concept. A pump tax to discourage groundwater use has been often proposed, and the adoption of conservation rate structures has been advocated and in many cases adopted.

Active Management Areas have a modest groundwater withdrawal fee, established initially to provide funding for the Arizona Department of Water Resources and for conservation and augmentation programs. Statutory change diverted the first component to the general fund. A large portion of the second component funds banking of Colorado River water. Utilizing a groundwater withdrawal fee to discourage groundwater use, however, has not been generally embraced. Governor Hull's Water Management Commission raised the issue but recognized that a significant tax on water would adversely affect certain industries, especially agriculture. Yet, even if it did not apply to all industries, a pump tax could further the goal of reducing water consumption. Designed carefully — for example, it would have to address concerns regarding low-income water ratepayers — a groundwater use surcharge could effectively reduce water consumption, as well as help fund much-needed infrastructure investments or other programs, such as the Arizona Water Protection Fund.

More is at issue, however, than discouraging only groundwater use. Even communities with ample renewable water resources are concerned about a future demand-and-supply imbalance. In emphasizing the need for a statewide "culture of conservation," Governor Napolitano notes this may mean different things to different communities. Work on the effectiveness of different conservation methods is ongoing, and the installment and use of graywater systems and the increased use of effluent has been highlighted. Another viable means of achieving reductions in water usage is through water pricing.

Adopting rate structures to encourage water conservation is increasing, by water companies governed by cities and towns as well as companies regulated by the Arizona Corporation Commission. Predicting the effectiveness of this tool is a complex task due to the price elasticity and income elasticity of demand as well as the nature of the use itself (e.g., indoor versus outdoor use).

If demand for water is price-inelastic, i.e., if the percentage reduction in water use is less than the percentage increase in price, economic models indicate that utility revenues will increase. What then is to be done with the "windfall" or increased revenues? Recovering only the cost of service would require an offsetting rate reductions somewhere in the system. As previously suggested, however, the "windfall" revenues could fund infrastructure or riparian restoration projects, which are attracting increased interest. If demand for water were price-elastic, which according to most studies is not yet the case, reduced revenues would be the issue. In a system requiring revenues to cover at least the cost of service, this would have to be addressed. The task of predicting response to price changes is complex. Price elasticity estimates based on econometric models, where they exist, are considered predictive only for small changes in price. They cannot generally be used to predict behavioral response to large price changes.

Despite these complexities and the difficult equity, legal and other considerations, pricing tools should be in our water policy toolbox.

Biomonitoring...continued from page 7

or 100 ppb, then questions are raised about the adverse health effects of water with increased amounts of arsenic.

One of the complexities arising from biomonitoring's focus on human subjects is that body metabolism differs among people. What in one person may contribute to a body burden may be readily processed by another with little or no measurable results. A pack-a-day smoker may live to a ripe old age while others who smoke a good deal less fall victim to lung cancer at mid-life.

Limitations of Biomonitoring

What the biomonitoring study is able to detect and measure is a person's body burden resulting from an environmental contamination. Biomonitoring, however, does not link a person's measurable exposure to a contaminant or an adverse health effect. Biomonitoring, however, is a step along the way of establishing such a link.

There are other limitations to biomonitoring. By focusing on arsenic and selectively choosing areas to study with the contaminant in the drinking water, the Arizona project can with some assurance identify a body burden with a source, either drinking water or a person's diet. In studies with a source not so well defined, identifying a body burden with a particular source may be more problematic. The method falls short in providing other kinds of information as well.

Richard Becker, American Chemistry Council toxicologist and senior director says, "Generally one could compare the type of biomonitoring that's done to a grab sample in a water column where you go out and sample at a random point at a random instant in time. That doesn't tell you when the exposure occurred relative to what the concentration is that you're measuring. You don't have an idea about the magnitude of the exposure, the frequency of the exposure nor the duration of the exposure. It really kind of gives you a snapshot in time of the concentration in that specimen."

Also Becker acknowledges the difficulties of conducting biomonitoring. He says, "It is generally easier, cheaper and faster to go in and measure the substance in the medium of concern, whether it's water, soil or air, than it is to actually to do human biomonitoring." But he adds, "Though a question would be: what's the value of the information relative to the decisions you have to make?"

Challenges of Biomonitoring

Becker describes the work ahead: "The analytical detection methods are getting so exquisite these days ... you could find things you had not necessarily suspected; that goes for humans, water or whatever medium. I think one of the challenges for biomonitoring is understanding the implications of those concentrations to human health. ... I think a challenge for the water quality community is to understand what levels of detection mean as potential risks to humans."

Some see biomonitoring breakthroughs as identifying areas for further research. Biomonitoring is increasing an understanding of sources of human exposure; this could raise questions about the need for more monitoring of air, water, and food. A better understanding of the major sources of human exposure could trigger additional research into further sources of exposure.

Becker views biomonitoring as a tool that provides a scientific way for agencies to better identify emerging contaminants in water for which maximum contaminant levels may need to be set. Biomonitoring could demonstrate human exposure to such contaminants. This will enable agencies to assess the levels of exposure more quickly than is presently the case: the current EPA procedure has been criticized by some for taking too long and not taking into considering new information.

A state official, however, fears biomonitoring also could play an anti-regulatory role. He says, "With the current administration, I have this sneaking suspicion they might find this as a way to avoid cleaning up environmental sites. If they measure the people next door to it and can say, 'Well there's nothing in their blood,' they then might refuse to clean it up. We're focusing on the positive side though; but I'm aware there could be a downside."

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