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Mapping a Mythical River

by Joe Gelt and Melissa L. Lamberton

Maps do more than record geography; maps also reflect myths and human longings. Consider the mapping of the Buenaveventura River.

The Buenaventura River was once thought to flow from the Rocky Mountains to the Pacific Ocean over what is now the western United States. Such a river was much sought with several candidates identified before the Buenaventura River. Explorers were seeking the Great River of the West that would be the western segment of a coast-to-coast waterway, an easy route for travel and trade. Coloring these explorations was the dream of a Northwest Passage. A map by Robert Sayer (1750?) has the Great River of the West flowing from Lake Winnipeg.

Historian Bernard DeVoto wrote of the Great River of the West: "It must exist because it had to. The logic of deduction from known things required it to, and so did the syllogism of dream — both on no grounds whatever."

Settlers facing the vast expanse between the Rockies and the Sierra Nevada believed fervently in this riverine mirage. John Melish in 1816 and Albert Finley in 1826 (See Finley map at right) both drew maps displaying the Buenaventura connecting the Great Salt

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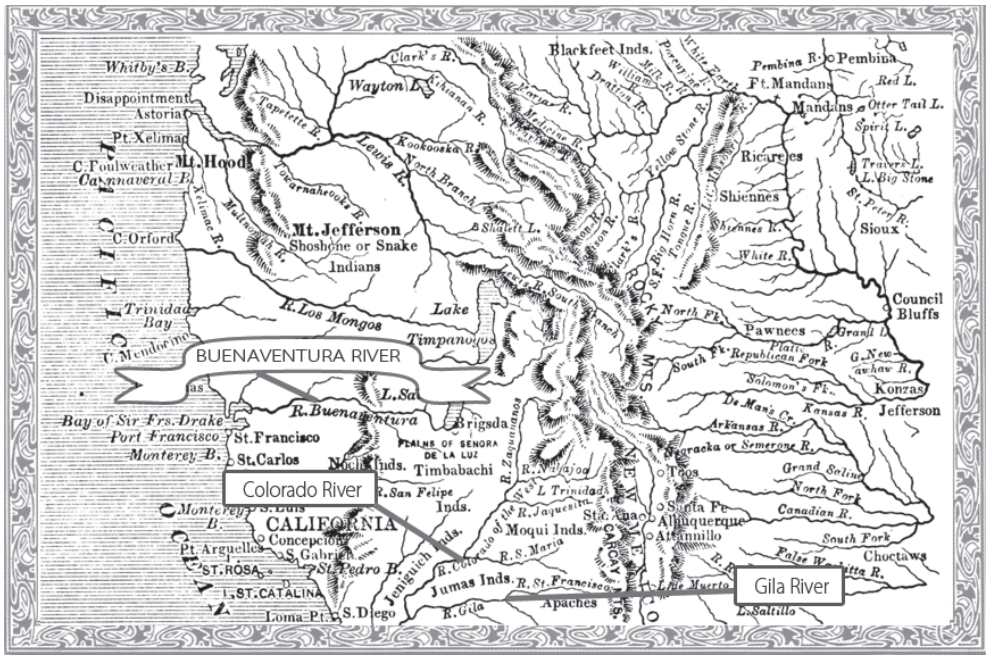

Albert Finley's influential 1826 map continued the myth of the Buenaventura River as the Great River of the West, a segment of a coast-to-coast waterway.

Nanotechnology Promises Water Resource Gains But Raises Concerns

Small world of nanotechnology is big research area

by Joe Gelt

Some say a nanorevolution is at hand, perhaps not an overly zealous assessment considering the emerging pervasiveness of nanotechnology and its rapid pace of development. The water resource field is among those areas expected to benefit from nanotechnology, its application holding special promise for treatment and remediation; sensing and detection; and pollution prevention. That cuts a rather wide swath in the water resources field.

The nanorevolution or movement is being met with both optimism and caution as scientists ponder how best to take advantage of its benefits and at the same time understand and reckon with its possible risks.

What is Nanotechnology?

A promising prospect with something of a sci-fi appeal, nanotechnology or nanotech is about size rather than a particular scientific discipline. Nanomaterial, a billionth of a meter, is to matter what a nanosecond is to time, a billionth of a second. A nanometer is roughly 10,000 times smaller than the diameter of a human hair and 1 million times smaller than a single grain of sand. Without hyperbole, *Nano Magazine*, devoted to covering nanotech issues, bills itself as the "Magazine for Small Science."

Understanding the small science of nanotechnology requires thinking at an ultrasmall scale, downscaling one's perceptions to the atomic and molecular level. Researchers at the nanoscale work to control matter about 100 nanometers or smaller, the smallest particles of matter that can be manipulated.

Nanotech involves assembling atoms and molecules to meet exact specifications to create

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new materials or modify existing ones. Nano-scaled materials and devices can be developed with a vast range of applications. Stuart Lindsay, Arizona State University Regents' professor and director of the Biodesign Institute's Center for Single Molecule Biophysics, says, "What is so striking is that events occurring at the nanoscale have implications for chemistry, biology, physics, materials science, engineering, you name it." Lindsay is the author of the just released *"*Introduction to Nanoscience*,"* a comprehensive guide to the nanotech world.

Even prior to the recent burgeoning interest, nanotechnology had been used in water treatment. Troy Benn, an ASU researcher in environmental engineering, explains: "Water treatment has always worked at the nanoscale but it was not recognized as nanotechnology. Nanotech is about size, and for years filtration has worked at the nanoscale. Dissolved ions or particles are removed at the nanoscale.... What is new today is a greater control of the process."

Key to understanding the workings of nanotechnology and its possible real world applications is knowing the changes that occur to materials at the nanoscale. Nanomaterials are not merely a greatly downsized version of the same material at the micro or macroscale; the physical and chemical properties of nano-scaled materials often change from what characterizes them at the bulk scale.

For example, nanotitanium dioxide is a more effective catalyst than microscale titanium dioxide and can be used to treat water by chemically degrading organic pollutants that are harmful to the environment. Nanosilver also is used to disinfect drinking water. Both are successful adaptions to the nanoscale to serve a beneficial use. Other materials at the nanoscale might act differently, possibly posing environmental or health hazards. Researchers seek to optimize nano-benefits and avoid nano-risks.

Regulatory problems have arisen because of possible changes occurring at the nanoscale. Of an earlier vintage, current regulations do not adequately address the development and use of nanomaterials. Complicating the regulatory task is the need to determine if a nanomaterial is actually a new substance or not. This can be a controversial issue. EPA would have the authority to regulate a nanoform if its different properties warrant it being considered a new substance.

Nanotechnology and Water

Some nano-scaled particles have properties that make them very suitable for treating water. They often have enhanced catalytic properties, with the potential to improve such processes as adsorption, catalysis and disinfection. Nanoparticles are especially valued as a type of building block to custom make other particles for specific applications.

A prime water resource application of nanotechnology is to further improve membrane technology. Nanofiltration membranes are already in use removing dissolved salts and micro pollutants as well softening water and treating wastewater. Meanwhile new classes of nanoporous materials are in the works with pores sufficiently small to filter out the tiniest micro-organism.

Further, the pores can be developed that are straighter than conventional filters allowing water to flow through faster. Acting as a physical barrier, the membrane filters out particles and microorganisms larger than its pores and selectively rejects substances. Nanotechnology may significantly reduce the cost of desalination.

Work is underway to apply nanocatalysts and magnetic nanoparticles to treat heavily polluted water for use in drinking, sanitation and irrigation. Nanocatalysts have stronger catalytic properties due to their nanosize or their modification at the nanoscale. They can chemically degrade pollutants including those that current technologies treat inefficiently and at great cost.

Also, research is looking at the use of magnetic nanoparticles to bind with contaminants that are then removed by a magnet. Having large surface areas relative to their volume, magnetic nanoparticles readily bind with water-borne contaminants such as arsenic or oil. Along with treating water-borne contaminants nanotechnology also can be applied to detect them. New sensor technologies combining micro and nanofabrication are being developed to create small, portable and highly accurate sensors capable of detecting single cells of chemical and biochemical substances in water.

Another promising application of nanotechnolgy is its use to address water problems in developing countries by helping to resolve technical challenges to removing water contaminants. Nanotechnology holds promises for more varied, affordable, effective water treatment methods that are more adaptable to the needs of developing countries.

Nanotechnolgy research is underway at Arizona universities. See page 6 for a description of a University of Arizona research project using nano scale zero valent iron to bioremediate water containing uranium. James A. Field and Reyes Sierra of the UA department of chemical and environmental engineering are conducting the research. The two researchers along with Farhang Shadman, also from ChEE, Scott Boitano, UA college of medicine, and Buddy Ratner, University of Washington, also are involved in a project studying the toxicity of nano-sized materials for the semi-conductor industry. In another project Sierra, Shadman and Field are looking at the fate of nanoparticles in municipal wastewater treatment plants.

At ASU, Paul Westerhoff, civil, environmental and sustainable engineering, has researched the fate of commercial nanomaterials in drinking water and wastewater treatment plants, and their potential human toxicity.

Caution is Urged

Amidst the promising news, the potential risks of nanotechnology are not to be overlooked, with some advocating more research to determine the potential health and environmental risks of using nanotechnology for water treatment. A prime concern is that the enhanced reactivity of nanoparticles increases their toxicity. Further, nanoparticles are extremely small and very difficult to contain raising the concern that they could escape into the environment and pose a threat to aquatic life. Whether handled at the treatment plant or consumed in treated water nanomaterials pose an unknown risk. Benn says, "Nanotechnology provides a strategy to improve water quality through treatment and remediation. Also, however, the use

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Arizona NEMO Sponsors AWR Supplement

NEMO sponsored the newsletter's four-page supplement. The supplement describes the revised WRRC water map that NEMO underwrote and assisted in developing. NEMO's sponsorship of the supplement helps pay the expenses of publishing this newsletter. WRRC appreciates the program's generous support.

WRRC News and Information

Leadership, Focus of WRRC's 2010 Conference

In June, young emerging leaders and professionals in water and the environment will have a chance to learn from each other and together build a foundation of leadership for the future. The WRRC is gearing up for its 2010 Annual Conference, titled *Creating New Leadership for Arizona's Water and Environment in a Time of Change*. The conference will be held at the University of Arizona Student Union Memorial Center on June 9-10. Its goal is to provide a forum for emerging leaders, young professionals and established professionals to interact and develop strategies for fostering leadership to face Arizona's future challenges in water and the environment.

The conference will open with inspirational stories from people who are making a difference in the environmental field. Lattie Coor, president and founder of the Center for the Future of Arizona, will set the stage with a keynote address that will define Arizona's environmental legacy and offer a vision for leadership in this state. Kristin Mayes and Jihan Gearon will speak in the first session about the importance and impact of leadership, offering insights from their own experience. Kristin Mayes is Chairman of the Arizona Corporation Commission and Co Chair of the Governor's Blue Ribbon Panel for Water Sustainability. Jihan Gearon is the Native Energy Organizer for the Indigenous Environment Network, where she works to help communities affected by energy development and climate change.

Speakers in two more panel sessions will provide perspectives on leadership from multiple sectors of society, including politics, education, business, water resources, journalism and the arts. A mid-day showcase will provide time for individuals and organizations to display information about their work, programs or special projects and interact informally with conference speakers and other participants. In the afternoon roundtable sessions, participants will engage in small group discussions about specific environmental issues.

Day one will wind up with a dinner and evening program that will interconnect water, environment and art. Optional workshops on the second day will provide opportunities for participants to lay out strategic action plans. Four concurrent workshops will cover the topics of statewide water planning, communication, education, and the creation of an environmental leadership institute.

The conference agenda and online registration is available on the WRRC website at http://ag.arizona.edu/azwater/programs/conf2010.

You can support the WRRC's efforts to involve young people in the conference by making a tax deductible donation at http://www.uafoundation.org/give/fund/wrrc2010, which will help provide free registration to students.

Palo Verde Trees, Saguaros, Water Leadership and Up-and-Comers

The palo verde tree shelters the small saguaros until it can grow on its own in the full sun. This is the concept underlining the WRRC conference which will team students and young professionals with established leaders in the environmental and water fields to foster future leadership.

Mexican, U.S. IBWC Commissioners Visit WRRC

Roberto Fernando Salmón Castelo, Mexican Commissioner of the International Boundary and Water Commission, and Commissioner Edward Drusina, the U.S. Commissioner, were guest lecturers in Dr. Sharon Megdal's Arizona Water Policy class on Feb. 26. Following the class the two commissioners conducted a brown bag seminar for the UA community and members of the public.

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Legislation and Law

Court Action Sought to Prevent State Taking Water Banking Funds

by Melissa L. Lamberton

Arizona is in the midst of a tug of war over funds for a commission designed to protect the state against future shortages on the Colorado River. On Feb. 3, the Central Arizona Water Conservation District filed a lawsuit against Governor Jan Brewer and Treasurer Dean Martin, claiming that a series of funding sweeps that occurred in 2009 are unconstitutional.

The lawsuit seeks to protect funds held by the Arizona Water Banking Authority, a commission that stores unused Central Arizona Project water underground. In January 2009, Governor Brewer signed a bill that authorized sweeping nearly $12.6 million from various accounts held by the commission. Another sweep in July took $5.4 million, and a third in December transferred $684,700 into the state's general funds.

Susan Bitter Smith, president, Central Arizona Water Conservation District Board of Directors, said there's no question that these funding sweeps will affect the water banking operations. "We have water sent to us to use for a specific purpose," she said. "We shouldn't be treated as a slush fund."

The crux of the case is a series of agreements between Arizona and Nevada for Colorado River water. The Law of the River, which divided Colorado River water among seven states, tribal groups and Mexico, entitles Arizona to 2.8 million acre feet annually. While originally the state didn't need its full allotment, the possibility of future droughts was worrisome. The Central Arizona Project has a junior priority on the river, so if shortages arise, CAP water is the first to go.

The Arizona Water Banking Authority, created in 1996, mitigates this risk by purchasing excess CAP water and storing it underground. This creates "credits" that can be redeemed if future shortages disrupt the state's supply of CAP water.

Enter Nevada, which was looking for more water supplies to serve its rapidly growing population. In 2005, Arizona agreed to bank a total of 1.25 million acre feet for Nevada's benefit. In exchange, Nevada gave $100 million to AWBA and promised to pay an additional $230 million over a 10 year period to cover the costs of delivering and recharging CAP water. Those payments began in 2009.

This is the money the Legislature has dipped into to patch the state's budget deficit. Attorney Robert Lynch, who represents the water district, argues that the Legislature has no authority to take funds acquired per the interstate agreement. "We've got to figure out what to do with this $230 million that's on its way from Nevada," Lynch said. "This is very serious business that affects the entire future of Central Arizona."

When Nevada needs water, Arizona is obliged to reduce diversions from the Colorado River and supply Arizona users with banked water instead. Nevada can then pump additional water upriver on the Colorado River. This obligation to Nevada must be met even if AWBA can't afford to bank water, leaving Arizona users high and dry. That's why Nevada paid the initial $100 million, to ensure the commission can purchase alternative supplies for Arizona if necessary. The agreement specifies that this money is supposed to stay intact for the life of the contract.

Bitter Smith says the funding sweeps are problematic because Nevada has paid Arizona to bank water, and AWBA must perform that service even though the money isn't in their account. "Should Nevada call and say we need our water now, we have to produce it. The state has really put us in a bind," she said.

Lynch argues that because the Legislature's authority is limited to state revenues, i.e. taxes and fees, it has no right to claim the money from Nevada. Moreover, the appropriation bills siphoning off AWBA's accounts in effect override the laws that direct how those funds should be used, a situation the Arizona Constitution does not condone.

Meanwhile, the Legislature has continued to fill its budget deficit with funds from the commission, sweeping another five million in March 2010. Bitter Smith hopes a decision from the Maricopa County Superior Court will prevent the sweeps from continuing. "The best outcome would be for the court to do two things: Return the monies swept and preclude any future sweeps," she said.

Lynch said that it's unlikely the water district will recover all of the funds, some of which has already been spent. He has asked the court, however, to stop the executive branch from spending the funds swept in July and December. More importantly, Lynch hopes that the court will settle the issue of what the Legislature can and can't do in its search for funding once and for all. "As far as I'm concerned, the law is crystal clear: This isn't legal," Lynch said. "But the court hasn't said so."

Mapping...continued from page 1

Lake with the Bay of San Francisco. John Robinson's 1819 map shows no less than three rivers flowing to the Pacific.

The myth was laid to rest by Explorer John Fremont who regretfully concluded at the end of his journey that the Buenaventura never existed. He had difficulty convincing President Polk that so many official maps were wrong.

Consider also case of California, shown on many old maps as an island. Its actual attachment to the mainland, the next-door neighbor to Arizona, has been the cause of many interstate conflicts, the most acrimonious having to do with water. Many Arizona officials, no doubt, have longingly reflected on those old maps that display a California Island.

In a much different cartographic category is the Water Resources Research Center's water map. Despite Arizona's longing for additional water resources the map provides no mythical water body that would offer the state a new water source. Instead, accuracy is stressed, both cartographically and hydrologically. (See insert after page 6 to learn about the new WRRC water map.)

Guest View

Weather Modification, a.k.a Cloud Seeding, a Technology Whose Time Has Come

Don Griffith, North American Weather Consultants, submitted this Guest View. NAWC website is www.nawcinc.com

Little did Dr. Vincent Schafer realize, while working in a General Electric laboratory in 1946, that he would stumble upon the first scientific indication that man might beneficially modify clouds. Dr. Schaefer was doing research on a hot summer day and cold temperatures were required. He was using a chest-type deep freezer, and he decided to lower the temperature further by placing a chunk of dry ice into the deep freeze. He noticed an unexpected reaction. While working over the open freezer, his breath had created a small cloud of "supercooled" (colder than freezing) water droplets. These droplets appeared as a sort of haze in the freezer when light was shone through them. Introducing dry ice caused the water droplets to freeze due to the very cold temperature of the dry ice. They froze forming tiny ice crystals that scintillated in the light. Dr. Schaefer's serendipitous discovery demonstrated that "supercooled" cloud water droplets (common in clouds) could be artificially induced to freeze. This classic experiment is easily replicated.

There are some famous photos taken in the 1940s and 50s when Dr. Schaefer flew in an airplane equipped to drop dry ice particles into "supercooled clouds". Ice crystals formed via the "seeding" grew into snowflakes which fell to the ground, leaving a hole in the seeded cloud deck. Further research conducted on different types of particles that might also cause "supercooled" water droplets to freeze on them identified silver iodide as an excellent particle to cause such freezing. It remains the most widely used cloud seeding agent for seeding cold (below freezing) clouds.

These developments were greeted with enthusiasm in the 1950s. Research programs in the United States and other countries were conducted to determine if precipitation could be increased through "cloud seeding." These programs and others following in the 1960s though the 1990s showed mixed results. Difficulties were due to a number of factors including the complex cloud interactions involved, seeding coverage variability, short experimental period length, and large precipitation variability that can mask the seeding effects. Some disillusionment developed within the scientific community. Research in the field declined to near zero in the latter 1990s.

The acid test adopted to determine if a seeding experiment increased precipitation was whether the indicated results were "statistically significant." This was the model of randomized trials used in pharmaceutical testing exported to the atmosphere to "prove" that cloud seeding worked in research experiments. A 5 percent statistical significance level was written into the design of weather modification research programs. Attaining a 5 percent significance level would indicate that there was only a 5 percent chance that the experimental results would randomly occur without the cloud treatment or stated differently, 95 percent confidence that observed differences were due to seeding. Some research programs that demonstrated positive seeding results were rejected by purists because the 5 percent significance level was not obtained. These pioneering and positive experiments were unfortunately and unjustly labeled as failures.

Coincident with the beginning of research programs in the 1950s,"operational" cloud seeding programs began in the United States and a number of other countries. These programs were designed to create positive benefits, for example, increased spring and summer streamflow from the melt of augmented snowpacks or augmented rainfall on croplands. Continued to the present time, these operational programs are truly an international phenomenon involving Argentina, Canada, Chile, China, Cuba, France, Greece, India, Indonesia, Italy, Israel, Jordan, Morocco, Philippines, Spain, Thailand, United States, United Arab Emirates, Venezuela, and Zimbabwe. Some programs in the Sierra Nevada of California date back to the 1950s and early 1960s. Estimates of the results achieved from precipitation augmentation programs typically range from 5 15 percent seasonal increases.

The obvious $64,000 question (not adjusted for inflation) might be: Why are large numbers of operational programs conducted around the world despite some skepticism within the scientific community? Several factors may be at play but I believe the primary reasons are: 1) the potential for "new" water from precipitation augmentation programs; 2) a perceived substantial return on investment, and 3) a lower expectation of "proof" that cloud seeding "works."

Various studies of U.S. programs indicate additional streamflow derived from winter snow augmentation costs a few dollars per acre foot to produce, often resulting in estimated benefit to cost ratios of 10/1 or higher. Managers of water districts, municipalities, hydroelectric companies, irrigated agricultural districts, etc. do not often have the luxury of demanding a 95 percent confidence level when making workday decisions. Why then should they demand this level of confidence to fund a cloud seeding program?

Cloud seeding offers the potential to tap an "atmospheric ocean" to provide additional precipitation. Contrary to popular belief, studies have indicated that precipitation is actually increased, not decreased, downwind of cloud seeding programs. Few other technologies offer the potential for producing "new" water. One example is desalinization. It is quite expensive, costing over about $1000 per acre foot compared to an estimated cost of a few dollars per acre-foot for water produced with cloud seeding.

An ever increasing worldwide population and growing per capita demand for water will increase demands on existing fresh water supplies. Varied approaches are needed to satisfy these increased demands, with weather modification one such approach. A technology whose time has come, it will become increasingly important in the future.

Special Projects

WRRC Announces Five Projects for Section 104(b) Funding

by Melissa L. Lamberton

The University of Arizona's Water Resources Research Center provides research grants through Section 104(b) of the Water Resources Research Act. Funded by the U.S. Geological Survey, the Section 104(b) program supports small water related projects of importance to the state and the region. These projects seek to increase our understanding of scientific phenomena, educate students, and foster the entry of new scientists in water research. Faculty at all three Arizona state universities are eligible for 104(b) funding. The WRRC awarded grants for five projects in 2010.

Perfluouronated Compounds in Arizona Groundwater: Sources of Contamination. In 2009 the Tucson Water Department detected a trace organic contaminant called perfluorooctane sulfonate at minute levels in four wells, and in the finished Central Arizona Project water produced by the Clearwater Recharge and Recovery Facility. The origin of PFOS contamination in the Tucson region is unknown. Effluent infiltrating into the local aquifer from the Santa Cruz River is one potential source. Recharged CAP water and stormwater runoff may also contribute.

University of Arizona researchers David M. Quanrud, Leif M. Abrell, Robert G. Arnold and A. Eduardo Sáez intend to identify major sources of PFOS in Tucson's groundwater and determine if a related compound, perfluorooctanoic acid, is also present. The investigators will collect data at critical locations in Tucson and Marana, and study the contaminants' fates at a CAP recharge facility and the Sweetwater Recharge Facilities. This project is an initial step toward developing a management strategy for PFOS contamination in Tucson's groundwater.

Bioremediation of Uranium Plumes with Nano Scale Zero Valent Iron. Levels of uranium exceeding EPA standards have been found in Arizona wells, including the Sierrita mine site near Green Valley. A potential carcinogen and endocrine disrupter, uranium leaches into water from mine tailings, former processing plants, and natural background levels in granite bedrock.

UA researchers James A. Field and Reyes Sierra are developing a low cost, onsite bioremediation method with microorganisms that use zero valent iron as a substrate. Previous research has shown that ZVI can chemically reduce uranium to an insoluble form. The investigators hypothesize that ZVI provides a buffer against reoxidation, and that microorganisms will enhance the reaction. They will prepare a controlled experiment to evaluate the potential of this form of treatment. This research will help develop cost effective treatment systems for uranium and other oxidized pollutants in drinking water, addressing a critical global need.

Use of Fish as Integrative Samplers of Uranium and Lead Isotopes in the Colorado River. Uranium contamination is also a concern in the Colorado River. UA investigators Charles A. Sanchez, John T. Chesley, and Peter N. Reinthal intend to identify the sources and sinks of uranium, lead and other metal contaminants in the Colorado River by using fish tissue as integrative sampler for the contaminants of interest. They will compare the new data with historical fish samples at the UA and Arizona State University from the past 100 years. The project will help determine potential sources and pathways of contamination in the food web of the Colorado River Basin, a necessary step for designing management strategies. The data will also provide a baseline in case future mining activity alters contaminant levels.

Nitrogen is another groundwater contaminant of concern in this region. Recent research has suggested that atmospheric deposition, in aerosols or precipitation, may be a significant contributor to water contamination, especially as fossil fuel use has increased. UA researchers Jennifer C. McIntosh, Armin Sorooshian, and Kathleen Ann Lohse seek to determine the sources and amounts of nitrogen deposited in a sky island ecosystem, and how it is transported to groundwater. The investigators will collect samples from soil pore water, surface waters, and atmospheric deposition at three sites that span the full elevation gradient of the Santa Catalina Mountains. The sites provide a range of climates and bedrock types to compare. This project contributes to ongoing studies of how the hydrology of mountain systems surrounding urban areas impacts groundwater quality.

Project studies nitrogen deposited in a sky-island ecosystem and its transport to groundwater. Photo: Jennifer C. McIntosh

Biochar Soil Amendments to Increase the Water Holding Capacity of Sandy, Arid Soils. Another project, led by UA researchers Janick F. Artiola, Craig Rasmussen and Robert J. Freitas, will investigate how biochar amendments affect the physical properties of Arizona soils. As Arizona enters a second decade of statewide drought, water conservation is increasingly important — particularly in agriculture, which accounts for 70 percent of the state's water use. Yet Arizona's sandy soils do not retain water efficiently and thus require more frequent irrigation. Biochar, a carbon based porous charcoal, acts as a long lasting sponge in soils. The investigators will determine how various biochar amendments alter the soil moisture, surface albedo and soil temperature over time. By increasing the soil's water holding capacity, the investigators expect biochar amendments will improve irrigation efficiency, plant growth and soil fertility.

Each project will be funded for one year, beginning in March 2010. Contact the investigators for details about their work. For more information about the Section 104(b) grant program, or how to apply for a grant, go to http://ag.arizona.edu/azwater/programs/104.

WRRC Announces, Publishes Writing Contest Winners

Following are the winning entries in the Water Resources Research Center's recently inaugurated annual writing contest. Undergraduate students at The University of Arizona, Arizona State University and Northern Arizona University were invited to submit about a 1,000-word essay addressing one of six specified topics, written in a magazine-suitable style. The contest offered four prizes, one for the winner from each university and one grand prize of $100 awarded for the best article among all the entries.

A panel of writing professionals evaluated the articles on the basis of clarity, coherence, style, grammar, interest and factual accuracy. The panel consisted of Betsy Woodhouse, former publisher of Southwest Hydrology magazine; Shaun McKinnon, the Environment, Water and Climate reporter for The Arizona Republic, and Joanna Dodder Nellans, reporter for The Daily Courier newspaper for the Prescott area communities.

Eric Betz, a student in the Department of Physics and Astronomy and the Department of Communication at Northern Arizona University, is the grand prize winner. His article on El Nino's effect on water supplies, "A Warm Wave Brings Wet Weather," also won the prize for best article from Northern Arizona University.

The prize for the best article from Arizona State University was split between Katherine Cai, a student in the Department of Chemical Engineering and John Kondziolka, in the Department of Civil Engineering. Ms. Cai wrote on the subject of water contamination by TCE. Mr. Kondziolka's article "Watching Arizona's Drought" dealt with the need for water conservation.

UA students were noticeably missing from among the ranks of contest participants; none submitted essays. Whatever the reason for the no-show, it certainly was not for a lack of water talent among UA students. Contest organizers look forward to UA students demonstrating their impressive abilities in the next writing contest, to be held in fall semester, 2010.

Along with sponsoring a student essay contest the WRRC also conducted a photo contest this past year. Both endeavors were intended as outreach efforts to encourage broader and more varied involvement in WRRC activities. Those participating in the photo contest, which was open to the public, were asked to submit photos illustrating the significance of water in Arizona. Winning photos are included on the following pages.

Warm Wave Brings Wet Weather

by Eric Betz, Department of Physics and Astronomy and the Department of Communication, Northern Arizona University

A surge of activity in the Pacific Ocean coupled with agreements between multiple computer weather pattern simulation models, led climatologists to suspect a rash of winter and spring storms was headed towards Arizona in 2010; storms born from a massive and warm ocean wave.

In April 2009, information relayed to the Climate Prediction Center in Washington, D.C. from satellites, buoys and ships in the eastern Pacific Ocean showed a marked increase in water temperature, a classical indication of a pending El Niño. To be categorized as an El Niño, there must be at least a half degree Celsius rise in ocean temperatures and when the CPC declared the winter of 2009 2010 as such, this one barely made the grade.

El Niño historically has been a mixed blessing for Arizona, while it's known to cut short summer monsoons, it can also bring an increase in fall and winter precipitation. Nothing is certain in a weak El Niño year though; the last 50 years worth of rainfall data shows that a weak or average El Niño is just as likely to bring less precipitation to the state as it is to bring more.

"If El Niño is weak to moderate," said Nick Petro, "I wouldn't hang my hat on it." Petro is the senior science advisor at the National Weather Service office in Bellemont, AZ and has compiled Arizona precipitation data from El Niño years over the last half century.

By fall, the year was fast becoming one of the driest ever recorded in many parts of the state largely thanks to the lackluster monsoon. In fact, the last decade has brought a succession of years with very little wet weather. Since 1999, the Colorado River, crucial to the water supplies of 30 million westerners, has run at above average levels only once.

The lack of persistent precipitation this decade has left Lake Powell with a "bathtub ring," showing how far the reservoir level has plummeted in recent years and pushing questions about the water supply of a state peppered with fairways, swimming pools and desert waterscapes.

WRRC Photo Contest Winner

Las Cienagas Resource Conservation Area & Santa Catalina Mountains, photo by Bill Radke

A massive warm ocean wave appeared late in fall though that has given confidence to forecasters that the winter of 2009-2010 will extinguish the dry weather in Arizona, if only temporarily.

Under normal conditions in the Pacific, fierce tradewinds force surface water from east to west. As this warmer surface water is pushed into the western Paccific, it forms what is known as the "warm pool"and cold, nutrient rich water upwells off the coast of the Americas to fill the warm water's place. This cycle creates the unstable atmospheric conditions in the western Pacific that fuel rainfall and influence weather throughout the world. El Niño reverses that pattern.

For unknown reasons, tradewinds weaken in an El Niño and shutdown the movement of warm water from east to west. The warmer waters that normally persist in the west spread back to the Pacific coasts of the Americas and rework weather in the United States and across the Earth. El Niño can carry perilous floods to Peru, Chile and California, spread ruining droughts throughout Australia, Indonesia and India, and intensify fall and winter snowfall in the Southwest.

El Niño is no guarantee of an increase in wet weather though. The last two El Niño years have brought snowfalls less than half of average to many northern parts of the state.

"Are we gonna break through this dry weather pattern?" said Petro, "it's looking like it."

Ocean temperatures off the Pacific coast of the Americas remained steady through summer and by fall a weak El Niño looked imminent. Then, throughout October ocean temperatures across the eastern Pacific increased nearly a degree, with some areas seeing as much as a 5 degree increase. The sudden rise in temperature came as a result of a dramatic El Niño event known as a Kelvin wave.

A Kelvin wave is a vast redistribution of warm water from the west caused by diminishing tradewinds. Kelvin waves stretch hundreds to thousands of miles and are indicative of El Niño activity. This particular wave has given NWS forecasters confidence that the coming winter will bring strong snowfalls to Northern Arizona. "That wave helped strengthen El Niño" said Petro. "The temperatures in the eastern pacific are now 1.5 to 1.7 degrees above normal."

That temperature increase has reclassified this winter as at least a moderate to strong El Niño and that gives scientists at the CPC historical justification to suspect an increase in precipitation through spring and possibly into early summer.

Petro differentiates Kelvin waves and even El Niño as individual factors in the much bigger picture of weather patterns though and reasons that the future is uncertain.

"It's hard enough to predict the next seven days, let alone anything beyond that," said Petro.

Even if Arizona does receive a succession of strong winter and spring storms, the state still won't be able to overcome years of drought conditions. A decade of drought as devastating as the Southwest has seen would take many years to pull out of.

What's more, climatologists only expect the pattern to get worse. Intensive studies of likely impacts from climate change show that the Southwest is likely to be among the worst hit places in the world. Conditions are likely to progressively worsen for the foreseeable future, with the Colorado river decreasing its flow to levels unseen for centuries by 2050 and dramatic die-offs of native species like Pinon and Ponderosa Pines.

In the meantime, several seasons of increased precipitation could bring a momentary breath of life to parched and precarious desert climes.

TCE, a Water Quality Threat

by Katherine Cai, Department of Chemical Engineering, Arizona State University

Water quality is one of the more commonly overlooked environmental and health issues. However, there are a plethora of pollutants that plague drinking water. Trichloroethylene (TCE) is a ubiquitous groundwater contaminant. It is a chlorinated and colorless man-made compound that has been increasingly found in groundwater due to its release in air emissions from metal degreasing plants as well as its use as an industrial solvent. Wastewater from metal, paint, electrical and rubber processing industries often contain TCE. The Toxics Release Inventory recorded a total of 320 million pounds of TCE releases in land and water in 1991 alone. Since it is such a highly toxic substance, it has become a major environmental concern.

According to the U.S. Environmental Protection Agency between 9 and 34 percent of U.S. water is contaminated with TCE. The contamination is located at over 380 different Superfund sites, uncontrolled hazardous waste sites targeted by the federal government for clean-up. In the National Toxicology Program's 11th Report on Carcinogens, TCE was reasonably anticipated as a human carcinogen. People who are exposed to TCE or drinking water containing an excess of TCE experience many health problems including liver damage and central nervous system depression.

In order to ensure safety, governmental organizations have implemented some basic standards. EPA has set maximum contaminant levels for TCE in drinking water of 5 parts per billion parts water, or 0.005 mg/L, and has developed regulations for working with and disposing of TCE. In addition, the Occupational Safety and Health Administration has set a maximum exposure limit of 100 parts per million parts of air for a standards 40-hour work week.

There are many current analytical methods used to detect TCE. The EPA, as well as the National Institute for Occupational Safety and Health, has identified a number of approved techniques that can be used for a variety of samples. This includes water and soil samples that can be measured either in situ, at the site of contamination, or in a laboratory. Gas chromatography, especially using the headspace gas above the surface of liquid samples, is very common.

Gas chromatograms have very good detection limits for TCE, generally with a lower limit of 1 µg/L for water and 1 µg/kg for soil. They can also be used in conjunction with mass spectrometers to offer even higher accuracy and lower detection limits.

Newer developments for in situ sampling and analysis are the membrane interface probe and the halogen specific probe. These use permeable membranes that, when heated, cause different volatile organic compounds or halogens to move across the membrane. At the surface, the probe uses either an ion trap mass spectrometer or downhole analyzer respectively to determine relative TCE concentrations.

Beginning in 1989, the National Primary Drinking Water Regulations began regulating and ensuring drinking water standards for TCE. The EPA now requires all water suppliers to take water samples every three months to check for TCE. If TCE is present, EPA has approved using packed tower aeration, a filter system with reverse osmosis distillation, to remove the compound from the water. However, there has been some recent groundbreaking research that shows new possible techniques for in situ treatment.

At the Biodesign Institute at Arizona State University, the Center for Environmental Biotechnology under the direction of Bruce Rittmann, has been researching a drinking water technology called the Membrane Biofilm Reactor (MbfR) that biologically degrades TCE. Jinwook Chung, with advisement from Dr. Rittmann and Dr. Rosa Krajmalnik Brown, from this lab published the only reported study of MbfR use, "Bioreduction of Trichloroethene Using a Hydrogen Based Membrane Biofilm Reactor" in *Environmental Science Technology* 2008.

The MBfR is a glass structure that contains a bundle of hollow fibers pressurized with H2, which functions as an electron donor. This gas is delivered through a bubbleless gas transfer membrane to a biofilm, a group of microorganisms forming a web structure, on the wall of these fiber membranes. Water is pumped through the reactor and the microorganisms in the biofilm oxidize the H2 and reduce the TCE to the nontoxic compound ethene. While there are many different communities of microorganisms on the fibers, the MBfR study shows that the bacteria Dehalococcoides is a part of this atutotrophic biofilm community that is capable of dechlorinating TCE. While many different bacteria can remove halogens from substances, Dehalococcoides is the only identified bacteria that is capable of removing the chlorine from 1,2 Dicholoroethene (1,2 DCE) and vinyl chloride in the final steps of dechlorination. The use of bacteria to remove TCE is very promising for future methods of water treatment.

WRRC Photo Contest Winner

Desert Flooding, photo by Esther Snow

This is a very important development because the hydrogen based membrane biofilm reactors create a natural system to remove contaminants. Bioremediation using bacteria is a biological process which is safer, cheaper, and cleaner than using a chemical or physical process to separate and remove TCE from water completely. Biological processes require nominal addition of chemicals, leaving the water cleaner for human consumption. MBfRs support efficient clean up strategies, using natural resources and alternatives for in situ purification technology.

Water quality is a timeless issue with the innumerous bacteria, parasites, and compounds that contaminate drinking water. TCE is one of the less recognized contaminants, but it still poses a major problem in terms of the health and well-being of mankind. Fortunately, EPA has already begun implementing the measures necessary to ensure clean water, and state-of-the-art research is leading the world to better alternatives to effectively clean water with lower projected costs and health risks.

Drought Threatens Our Free Water Ride

by John Kondziolka, Department of Civil Engineering, Arizona State University

Cash Cab video bonus: "drought" is (a) a prolonged period of time during which Mother Nature malevolently decides to withhold from mankind the same amount of liquid life she used to bestow, (b) a naturally occurring phenomenon, or (c) a problem. Good news! No matter which answer you chose, you are correct.

Cash Cab is a television program in which a few lucky people who happen to hail the right cab get to win money by answering trivia questions. They continue winning money until they answer incorrectly or arrive at their destination, after which they leave the cash cab with their winnings.

Arizona's water addiction follows a similar model. Some lucky people managed to settle in Arizona in the right years when there was an unusually high amount of water. We, as a population, continued using this unnaturally high amount of water and now we're starting to run out. But we refuse to leave our Cash Cab; we want to keep living the high life!

Some advance measures have been taken. Janet Napolitano's Drought Task Force assembled the Operational Drought Plan for 2006, establishing the Arizona Department of Water Resources as the head of a "Monitoring Technical Committee" (in addition to two other committees) intended to advise the governor's office on drought conditions and recommended action. As a part of this implementation the ADWR created AZ DroughtWatch, an interactive online tool intended to incorporate feedback from water users around the state. This qualitative data could then be used to make decisions about mitigation and adaptation measures. In addition to this qualitative data quantitative information could be gained from partner agencies explicitly defined as members of the Monitoring Technical Committee.

AZ DroughtWatch is not being used, and information is variable from the Monitoring Technical Committee. In an attempt to fix these issues after observing their inability to address drought problems after three years of operation, ADWR partnered during the fall semester with Arizona State University students who were to conduct a public policy and program analysis on the Operational Drought Plan and on the AZ DroughtWatch program. Recommended solutions included better environmental and drought education for both the school system and communities, explicit requirements for members of the committees outlined in the Operational Drought Plan, and better web site design. All of these will help get the ball rolling on Arizona's drought problem.

The more fundamental issue, however, is that we are currently using water unsustainably when we have more than we normally should. As the effects of climate change begin to be felt, the drought problem will be exacerbated by decreased precipitation and increased solar radiative forcing. To be plain, there is going to be less water available. If we, as a population, already face drought issues, how will we fare when our water supply is cut further? For that matter, we need a new name for a situation when our water supply is decreased. We already use "drought" to describe the current state of affairs. Perhaps "stop wasting water" can describe the new issues that we will face.

When "stop wasting water" time hits, action will need to be taken by individuals. The national government will not build any more ridiculously large canal projects (like the Central Arizona Project) to give us water from other sources. Cloud seeding is not going to become a science in the foreseeable future. Do not count on desalinization. No more water is coming.

The only solution, if our supply is diminishing, is for less water to be used. Voluntary conservation by large water users would solve the water shortage: solve, as in eliminate the problem. Conservation doesn't need to be showering only every third day, but a little xeriscaping (from the state and cities, too) would contribute, as would some low flush toilets and enforcement of laws against draining swimming pools only to refill with cleaner water. Many, many conservation efforts can be found implemented in other cities that do not have their water so easily provided, that have already hit the wall Arizona races towards. We can learn from them, and we should.

While voluntary measures are preferred, money talks. Using some basic economics, when supply decreases the price should increase. However, most cities buy their water wholesale from a provider, whose rates are set by the Arizona Corporation Commission. Many cities don't feel like increasing water rates, since raising prices bodes ill come election day. Besides, water is a necessity and must be provided to everyone. Tiered pricing incorporates these concerns by charging a minimal price for an amount of water deemed necessary for a person, and then applies additional rates for high users. This generally results in reduced water use from high users while bringing in some increased revenue to apply more water conservation efforts for low income families. Tiered pricing needs to be implemented by more Arizona counties and cities.

Arizona has been living on borrowed water for many years. While growth is an important part of the economy, no more water is coming and climate change will decrease what inputs we have. Our only solution is water conservation, whether voluntary or through tiered pricing. It's going to be difficult to leave the Cash Cab and our free ride, but with foresight we will avoid going the way of the Anasazi.

WRRC Photo Contest Winner

Awash With Color, photo by Patrick Sigl

New Online Student-Run Environmental Law and Policy Journal

The inaugural issue of the *Arizona Journal of Environmental Law & Policy* will be published this summer. AJELP is a student-run organization with a primary purpose of publishing an online journal examining environmental issues from legal, scientific, economic, public policy, and other perspectives. AJELP will create an engaging and responsive platform where pertinent environmental law and policy issues can be discussed. AJELP is a sponsored, although an editorially independent publication of the University of Arizona's Udall Center for Studies in Public Policy. AJELP's inaugural issue will focus on the 30th Anniversary of the Groundwater Management Act. For additional information about the journal check: www.ajelp.com

Public Policy Review

By Sharon Megdal

Applied Outreach Strategies, a Priority in Awarding UA Distinguished Outreach Professorship

I was very pleased to be notified in mid-March that I am to receive the highest University of Arizona honor for outreach and will officially be awarded the title University Distinguished Outreach Professor at the Winter 2010 Commencement. The nomination submission included a letter of nomination, several outside supporting letters, and a personal description of my approach to outreach and scholarship along with documentation. Following are edited and abbreviated portions of my personal statement entitled "Improving the environment and quality of lives through research-based outreach and education on water management and policy."

My life work has focused on questions related to public policy and how government can better meet its policy objectives. My training as an economist and my life experiences provide the analytical framework and background for my scholarly activity at the UA. My work, which focuses on the water management and policy challenges that confront communities, integrates the local, regional, state and global communities in a multi-directional fashion. My research, teaching and outreach are fully integrated and designed to evaluate policy practices and options, with the goal of improving practices in order to resolve water management challenges.

This integration is fundamental to my outreach practices. I regularly educate individuals who come from many different backgrounds, teaching them about water management practices and challenges. I accomplish this through participation in many types of local, regional, state, national and international forums. Knowledge alone is not sufficient for effective outreach. Effective communication and the sharing of knowledge require truly caring about connecting — engaging — with the audience. Not only do I speak to audiences, but also I empower them to learn more. In addition to the primary subject matter, I provide useful references and resources. I often make connections that are useful building blocks to carrying out and/or obtaining funding for my research programs.

Because outreach programs that effectively share knowledge and information should not be limited to presentations I conduct personally, I have endeavored to provide successful forums for others to engage with those knowledgeable about water management, both as scholars and practitioners. Since joining the Water Resources Research Center in 2002, I have planned and presided over seven successful statewide water conferences. These conferences, which have become a signature product of the WRRC, provide a unique opportunity for individuals of many different perspectives and professions to meet in Arizona to discuss a water matter/challenge of statewide importance.

I initiated the WRRC's successful Brown Bag Seminar series, whose audiences are about evenly split between the UA community and the broader community. The WRRC Brown Bag seminar series and annual conference reflect my belief that connecting researchers, policy makers, students and the public will result in better understanding of water management issues and thereby lead ultimately to better policy outcomes.

I am very much involved in outreach when training future generations about water management and policy sustainability by teaching the graduate level course Arizona Water Policy, which I have taught each spring since 2005. I offer the students a policy-based course of instruction that brings high level policy makers into the classroom. The benefits to this are two-way. The students benefit from the expertise of the guest lecturers; the guest lecturers appreciate the opportunity to interact with the graduate students. Guest presentations are connected to class readings, and the connections often extend to the students' research papers. I see a significant impact of my ability to connect course instruction and research with real world water managers and policy makers in the enhanced training I give to the future water and environmental leaders of Arizona, the nation and the world.

Of course, responding promptly to requests for information, which often involves knowledge acquired through research, is a fundamental aspect of my outreach, as is my involvement in WRRC publications. When I joined the WRRC in early 2002, I started this public policy column. I've not missed a single issue, this being column number 43. Resuming annual publication in 2007 of the *Arroyo* after a five-year hiatus is another example of my desire to take research findings and UA knowledge to the broader community. (I am gratified that the just released *Arroyo* on the water energy nexus, written by WRRC staff and a student intern, has already generated very positive feedback.)

I try to contribute to policy making through research based outreach. On my own initiative or on request, I have undertaken analytical studies that connect my academic training and real world experiences. Outreach is sometimes part of my research methodology. Several of my projects have involved interviews of water policy and management professionals, decision makers, and representatives of the business community, NGOs, and the public. In addition, my work on environmental preservation and enhancement has involved significant outreach, as has my international work related to the Middle East and to the U.S. Mexico border.

My 2008 election to a six-year term on the Board of Directors of the Central Arizona Project demonstrates how my public service complements and is therefore integral to what I do at the UA. I use my expertise to reach out and actively engage in making water policy and managing our precious Colorado River water. In the process, I gather information and make contacts useful to my research, teaching and outreach activities.

Working to make a difference through outreach is a way of life. I thank all those who work with me, and I sincerely appreciate every thank you I receive from people and organizations I've touched.

Nanotechnology...continued from page 2

of nanotechnology has raised concerns that nanoparticles might end up in water supplies ... Our research is looking at the release of engineered nanomaterials that could potentially enter water systems. We are considering nanomaterials as an emerging contaminant."

Benn mentions nano iron as an example. Used for the remediation of groundwater contaminated with organic solvents, nano iron injected into an aquifer breaks down the more toxic forms of the organic solvents. Meanwhile questions have been raised about whether iron in its nanoform is harmful to the environment and human health. Benn asks: "As we inject a nanomaterial into groundwater to remediate a problem are we simultaneously creating a new problem by injecting a material that may have adverse environmental effects?"

Nanosilver provides another example. Nanosilver's use to disinfect drinking water was noted earlier. It is effective as an absorbant media in membrane technology. It also has been used in other water quality applications including cleaning or treating water in swimming pools. Also, nanosilver serves as a tool in environmental remediation.

Nanosilver's ability to cleanse and purify is useful in other applications besides water. For example, nanosilver is used as an anti-microbial agent in clothing. When clothing with nanosilver is washed particles are released that then flow to a water treatment plant. In sufficient quantities the nanosilver could be a problem, killing bacteria necessary in the treatment process. Particles in treated water might be released directly into the environment, including streambeds, or be in the solid waste spread on agricultural lands. What, if any, environmental effects this would have are essentially unknown. Nanomaterials are already in hundreds of commercial products.

Like nanosilver, other nanoparticles used in consumer and other products could end up in the environment including lakes and streams. Many of their environmental effects are unknown. It is becoming increasingly clear that the manufacture and use of nanomaterials have broad implications, far beyond the science lab.

The Broader View

With the science of nanotechnology moving rapidly forward, some researchers argue that studies of the ethical, legal and social implications of nanotechnology lag behind. They call for catch-up in these areas to consider the effect the small world of nanotechnology will have on our larger world.

ASU's Center for Nanotechnology in Society and ASU's Consortium for Science, Policy and Outcomes has taken up this challenge. CNS works with scientists and engineers such as Jonathan Posner, an assistant professor of mechanical and chemical engineering in ASU's Ira A. Fulton Schools of Engineering, encouraging them to consider the significance the emerging technology will have on society.

In a March 2 ASU press release, Posner stated that because of nanotechnology's privileged position at the leading edge of science and engineering today "it will increasingly have health, environmental, social, political and economic implications, and raise ethical issues.

"There is a pressing need to understand the impact of nanotechnology on human health, the environment and society, to give us an informed background from which we can craft government policy and regulation, as well as legal and ethical guidelines."

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