ARIZONA WATER RESOURCE
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Student Spotlight

Reshet Gebremariam is a first-year master's student in the School of Natural Resources and the Environment's Water, Society and Policy program.

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The Water Resources Research Center produces research reports, outreach materials and regular publications, including the Weekly Wave e-news digest, the quarterly Arizona Water Resource newsletter and the Arroyo, an annual publication focusing on a single water topic of timely concern in Arizona. **Sign up online to receive WRRC newsletters, event updates and more at: wrrc.arizona.edu/subscribe**.

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Algae flows into the RAFT—Regional Algal Feedstock Testbed—in Tucson. Source: UA News

Arizona's Algae Biofuel Research Advances Understanding, Technology

Arizona is taking advantage of its open land and ample sunshine to assume a leadership position in the algae biofuel field, although farming algae can use a great deal of water. Algae shows great promise as a source for alternative fuels, as well as other useful products, and commercialization is a high priority for the U.S. Department of Energy.

Arizona is home to two national algae testbed programs for research and development, funded in large part by grants from the Department of Energy. An $8 million grant to the University of Arizona is enabling UA to try out its proprietary algae farming system in other states to see how it functions in different conditions. A previous $15 million grant to Arizona State University allowed the establishment of a national test bed, providing facilities for algae biofuel work.

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Arizona Researchers Address Water Quality, Reuse and Management

by Mary Ann Capehart, WRRC Graduate Outreach Assistant

Section 104(b) of the Water Resources Research Act, first passed in 1964, established a program for funding water research through designated Water Resources Research Institutes nationwide. In Arizona, the Water Resources Research Center has for many years awarded three to five research grants annually, of approximately $10,000 each. Investigators at the University of Arizona, Arizona State University and Northern Arizona University are eligible for this funding. The following projects, awarded for the project year 2013-14, addressed issues associated with water quality, data collection and the use of hydrological modeling in water resource management.

Extraction Methods for Engineered Nanoparticles from Aqueous Environmental Samples

This research project is a first step toward answering questions about the presence of nanoparticles in water. Nanoparticles are a class of nanomaterials sized between 1 and 100 billionth (10^{-9}) of a meter (1-100 nanometers) in at least

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Algae Biofuels continued from page 1

UA's ARID—Algae Raceway Integrated Design—is temperature controlled for year round algae growth. Source: The University of Arizona, Board of Regents

Projects that began in 2013 are promoting advances in algal technology and data collection while stimulating workforce development. But what about the technology's water footprint?

Much of the new work is in response to a report issued in 2012 by the National Research Council warning that an increase in algae-based biofuels to as little as 5 percent of the U.S. transportation fuels market "would place unsustainable demands on energy, water and nutrients." The amount of resource use depends on the method used, including what type of water the algae is grown in—salty or fresh—and whether grown in closed or open systems, where evaporation is an issue. Estimates for water use range from 3 gallons of water per gallon of algal biofuel produced to a thousand times that quantity.

Scientists are working to reduce resource use and with it the cost of production—the most significant barrier to commercialization. A gallon of algae fuel is estimated to cost more than $20, and algae fuels would have to be produced at a cost to consumers closer to the cost of gasoline, under $4 per gallon, before a market is likely to develop. Scientific advances are aimed at making the production of algal biofuel less costly. Some new designs being tested use wastewater, which provides both water and nutrients. Others capture carbon dioxide from the burning of fossil fuels to stimulate algae growth while reducing carbon emissions. Other activities focus on the type of algae and the characteristics that make it optimal for fuel production.

Algae are simple, plant-like organisms that grow all over the world in seawater, freshwater and wastewater. Although the total number of species is unknown, more than 40,000 have been identified and most use sunlight to make their own food. Half of algae's composition can be lipid oil, and algae contain protein and carbohydrates, so the plants can be used for both fuel and food. Because of their efficient use of light and nutrients, their potential for biofuel production is much greater than other crops, such as corn. Other potential advantages over the use of land plants for biofuel include algae's ability to grow where other crops are not grown and to grow in salt water or wastewater. Water use for corn-based ethanol is similar to some of the algae-based biofuel alternatives.

At ASU, a collaboration with the National Renewable Energy Laboratory, Sandia National Laboratories, Cellana LLC, Touchstone Research Laboratory, SRS Energy, Cal Poly San Luis Obispo, Georgia Institute of Technology, University of Texas at Austin, and Commercial Algae Management is supporting work on selected strains of algae in open or closed systems using various water sources. Research is also performed to improve methods for collecting and extracting the oil from algae and for processing the oil into fuel. The Department of Energy-funded collaboration is led by the Arizona Center for Algae Technology and Innovation (AzCATI) in the Polytechnic School at ASU. At this first national algae testbed, facilities support research, testing and commercialization of biofuels and other algae-based products, such as pharmaceuticals and nutraceuticals, by the algae industry and research community. Created under a Science Foundation Arizona grant in 2010, AzCATI has since developed more than $22 million in research projects.

At UA, water usage and quality issues are receiving research attention, along with design of algae production facilities and development of superior algae strains. The Regional Algal Feedstock Testbed (RAFT), a research partnership led by UA, is exploring the potential for growing algae in different climates using UA's open-air algae farming system, the Algae Raceway Integrated Design (ARID). The other RAFT partners include Pacific Northwest National Laboratory, New Mexico State University and Texas A&M AgriLife.

ARID was used to determine the optimal temperature for algae growth and has a unique design that can sustain growth year-round in a temperature-controlled environment. It recycles water through its serpentine canals and only adds water when needed to control temperature or for harvesting and cleaning. The RAFT is comparing ARID with other designs to identify the best-performing systems in different parts of the country. Results of an evaluation published in October 2013 described ARID's superior economic potential over open ponds. The ARID system located in Tucson is available for use by researchers from elsewhere for other algae projects.

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Editor: Susanna Eden
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WRRC Website: wrrc.arizona.edu
WRRC Director: Dr. Sharon B. Megdal

Arizona Water Resource
Water Resources Research Center
College of Agriculture and Life Sciences
The University of Arizona
350 North Campbell Avenue
Tucson, Arizona 85719 USA

520.621.9591 FAX: 520.792.8518 Email: wrrc@cals.arizona.edu

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SRP 2014 Snowmelt Sparse, Winter Outlook Uncertain

The Salt River Project (SRP) announced that this year's five-month snowmelt season produced only 148,000 acre-feet of runoff, making it the eighth-driest winter season since SRP started keeping records 116 years ago. It is also the fourth consecutive year with below-median winter inflows into the SRP reservoirs. The watersheds received just 2.85 inches of precipitation from December 2013 through March 2014; that is 37 percent of normal. SRP is the largest raw water supplier in the greater Phoenix metropolitan area, delivering about one million acre-feet in normal years.

When the announcement was made in July, an El Niño event appeared likely for the coming fall and winter. El Niño is characterized by warmer-than-normal ocean temperatures in the equatorial eastern Pacific. During El Niño events, a combination of factors interact, affecting weather in the southwestern United States, including the Salt and Verde watersheds. When these factors are favorable, greater-than-normal precipitation is often the result.

On September 15, the reservoirs on the Salt and Verde rivers were 48 percent full with 1.11 million acre-feet stored—7 percent lower than one year ago. The reservoir system was able to supply water customers with their full allocations in 2014 because of relatively high runoff in 2013. The first five months of that year were the most productive since the same period in 2010, although still lower than the 30-year median runoff.

A lot is riding on the outlook for the coming season. Until June, warming of the Tropical Pacific Ocean led to high hopes for an El Niño winter. Since then, however, ocean temperature has decreased and conditions have trended toward neutral. Even so, international climate model outlooks suggest perhaps a 60 percent chance for El Niño to become established between September and November, rising as high as 70 percent for the November to February period. A weak El Niño is much more likely than a strong one.

Tucson Water Plans for Recycled Drinking Water

On July 10, Tucson Water announced that it had completed a master plan for the development of recycled water as a future drinking water source. In Tucson's December 2013 Recycled Water Master Plan, Tucson Water was charged with preparing a phased multi-year implementation plan for the new indirect potable reuse (IDR) program envisioned in the Plan. IDR uses advanced treatment and aquifer recharge before recovering the water and blending it with other potable supplies.

Development of the recycled water program will take several years, but because of ongoing drought and climate change, the program is a priority. The new program's most cost-efficient design would bring recycled water from the new 32-million-gal-per-day (mgd) Water Reclamation Campus (scheduled for completion in 2015) approximately 25 miles to a North CAVSARP location. Another potential location in southeast Tucson would require 35 miles of conveyance and three booster stations to lift the water 1,200 feet. By 2030, Tucson could be recycling as much as 29,000 acre-feet each year in this way. Tucson Water is confident that available purification technology can ensure safe drinking water. Although the plan specifies the use of IDR only, Tucson is not ruling out the possibility of putting water recycled through advanced treatment directly into the potable distribution system at some time in the future.

California Moves Ahead with Historic Water Legislation

The historic drought in California has prompted legislative actions that are designed to ameliorate the state's deteriorating water situation.

A $7.5 billion water bond known as Proposal 1 will be on the ballot this fall for voters in a state beleaguered by drought, funding an array of water infrastructure projects in California. Dam and reservoir construction would claim 36 percent of the bond as authorized by the CA Water Quality, Supply, and Infrastructure Act of 2014. More than a billion dollars is to be allocated to competitive grants for watershed ecosystem protection and restoration by conservancies and state departments. Of the remaining allocations, nearly a billion dollars is earmarked for groundwater sustainability for places like the heavily polluted San Fernando Valley aquifer in Los Angeles to prevent and reduce groundwater contamination and to fund groundwater planning and implementation.

Water recycling, flood management and integrated regional water management also appear in the legislation. Lastly, $520 million is earmarked for safe drinking water to help supply all Californians, especially those in disadvantaged communities, with clean drinking water and wastewater infrastructure. This includes a State Water Pollution Control Revolving Fund, Small Community Grant Fund. The bond is 'tunnel neutral' regarding Governor Jerry Brown's promotion of building massive tunnels to divert water from the Sacramento delta to benefit Southern California.

Groundwater is also receiving unprecedented attention in the state. On September 16, Governor Brown signed into law a trio of bills for the statewide regulation of California's groundwater, marking the first time in the state's history that groundwater will be managed on a large scale. Underground basins supply 40 percent of the water used in California in an average year, and that use has gone up to 65 percent during the current drought. This groundbreaking legislation requires that "groundwater sustainability agencies" oversee the management of basins designated as at-risk and be held responsible for the adoption of "groundwater sustainability plans" to improve groundwater conditions by 2040. These plans require local agencies to regularly monitor water levels and set goals for sustainable groundwater management. The state is authorized to step in when basins are deemed to be out of compliance after the specified time limits.

Fairness issues can be expected to complicate planning because the legislation does not deal with water rights. This can be particularly troublesome where surface water is affected by groundwater pumping. An additional measure stipulates that the state's actions may be postponed for these localities.

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one dimension. To understand this scale, consider that a human hair is roughly 75,000 nanometers in diameter. Like larger particles, nanoparticles may be released into the environment during manufacturing, use, delivery or disposal. Nanomaterials, however, have the potential to remain in the environment for longer periods and may be transported over greater distances than their macro-scale counterparts. A multitude of consumer products currently use nanomaterials, and new applications of nanotechnology are increasing. Washed into sewer systems and surface waters, these materials are raising concerns about their effects on environmental and human health. Thus, an effective method for their detection and characterization in natural water bodies or wastewater is urgently needed.

Jean McLain and Channah Rock conducted much of their antibiotic resistance research on water and sediment samples collected at Gilbert Riparian Preserve near Phoenix. Source: Jean McLain

To identify an efficient method for accomplishing this, investigators Paul Westerhoff and Yu Yang of Arizona State University assessed the efficiency of several methods for extracting nanoparticles from a range of different solutions—ultra-pure water, and samples from the Salt River, the Verde River, influent and effluent from a wastewater treatment plant, Saguaro Lake, and Tempe Canal. The team used nano silver and nano gold to examine the extraction efficiency of each method in ultra-pure water, because of the common use of these materials in consumer products and concerns about their toxicity. Metallic nanomaterials exhibit chronic toxicity in biological systems.

The researchers then extracted nanomaterials from other water samples using the most efficient method and characterized the extracted materials with a combination of microscopy and spectroscopy. The most abundant nanoparticles identified were Silicon and Titanium containing particles with diameter in the range of 4-99 nm. Other nanoparticles, which ranged in size from 30-65 nm, contained major elements, including calcium, magnesium, aluminum, iron, oxygen, sulfur, carbon, and chloride. The researchers found that generally, "cloud point extraction" coupled with "transmission electron microscopy" and "energy dispersive X-ray spectroscopy" was an effective tool for extracting and characterizing nanomaterials in environmental water.

Do Simple Carbon Additions Reduce Resistance to Antibiotics in Environmental Bacteria?

In Arizona, the use of recycled wastewater is increasing to augment limited potable water supplies. Recycled water currently sustains agricultural production and riparian environments. The use of municipal biosolids on agricultural soils has also increased. Suspended in both of these resource streams are trace concentrations of commercially produced antibiotics, which add to antibiotics that naturally occur in soil microbe populations. The concern of environmentalists and public health advocates is that microbe populations will evolve a resistance to these trace antibiotics. They fear that in potential instances of human exposure to these resistant microbes, the treatment of human infections by various antibiotics will be rendered ineffective.

University of Arizona researchers Jean E. McLain and Channah Rock's research project examines the hypothesis that long-term application of recycled water and biosolids onto agricultural and riparian area soils abates the response of microbes to develop resistance to antibiotics. This hypothesis originated from a multi-year study examining the effects of the long-term (20-plus years) application of recycled municipal wastewater and biosolids on the development of antibiotic resistance in soils. The study found evidence that the hypothesis is correct. No increase in antibiotic resistance in environmental bacteria has been observed, and there was a marked decrease in multiple-antibiotic resistance in sites receiving long-term recycled water and biosolids application. A plausible explanation is that continual application of recycled water and biosolids increase organic carbon reserves in soils thereby decreasing competition between microbes. This in turn decreases the necessity for antibiotic production on the part of soil microbes. Study results may help to alleviate some concerns that environmental and public health advocates have

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Effluent enters the Santa Cruz River from the Agua Nueva Water Reclamation Facility. Source: aaees.org

regarding the use of recycled water and biosolids to augment water and soil carbon supplies in Arizona.

Sequential Advanced Oxidation and Soil-Aquifer Treatment for Management of Trace Organics in Treated Wastewater

As water supplies are threatened by the impacts of drought, climate change and the rising demand for potable water by growing populations in the arid Southwest, communities will come to rely on reclaimed water as a source of potable water. The transformation of reclaimed water to drinking water calls for a high level of water treatment. Many of the trace chemicals that enter municipal wastewater are only partially removed during conventional wastewater treatment. An assortment of pharmaceuticals, hormones, disinfection by-products and personal care products, though existing at sub-part-per-billion concentrations in water, may have negative ecological consequences. Some of these trace organic contaminants, like the unregulated substance NDMA—a byproduct of drinking water disinfection or various industrial processes—are known to cause cancer in laboratory animals.

A research project led by A. Eduardo Sáez and David Quanrud examined a potential synergy between two treatment methods coupled for the effective removal of trace organic compounds that routinely survive conventional wastewater treatment. Advanced oxidation treatment (UV/peroxide) followed by soil infiltration treatment (simulated soil-aquifer treatment) were found to be effective. Advanced oxidation processes, using solar light as the source of UV radiation, generate hydroxyl radicals that oxidize the vast majority of trace organic compounds found in treated wastewater. The infiltration of the water in the soil also removes certain trace organics due to their transformation by microorganisms living in the soil. This combination of advanced oxidation with the natural processes of soil-aquifer treatment is likely to reduce health risks for communities and species in the environment at a cost much lower than an engineered solution alone could produce.

Discrimination-Inference to Reduce Expected Cost Technique (DIRECT): A new framework for water management and stakeholder negotiation

Hydrologists and other natural scientists play an important role in supporting decisions that affect people and the environment. Environmental systems are complex and the behavior of water in these systems can be difficult to predict accurately. Given this complexity, design of data collection should be optimized to allow hydrologists to make the best predictions of interest to decision makers and other stakeholders. Scientists can no longer develop a simplified mathematical model of a natural system and suggest that predictions from this model represent known outcomes. Rather, scientists must not only make their best predictions, but also provide quantitative measures of the uncertainty of these predictions. This allows decision makers to consider the full range of possible outcomes, with associated likelihoods of occurrence, when managing water resources.

A research project of Paul A. Ferre and colleagues combined tools in hydrologic modeling with a new approach to monitoring network design to address these challenges. This collection of tools is named Multi-Model Analysis with Discriminatory Data Collection (MMA-DDC). Effort during this project was devoted to developing a solid theoretical and mathematical basis for the Data Discrimination Index that underlies MMA-DDC and developing a modular code based on this foundation. This code was applied to academic studies for the optimal design of large-scale vadose zone field studies and practical studies for water-rights acquisition to augment baseflow. Finally, it was used in the selection of monitoring points to determine whether to pursue active or passive treatment of a contaminant plume. These applications demonstrated that MMA-DDC allows stakeholders to define their priorities, hydrologists to use these priorities to target improved knowledge through data collection, and decision makers to make direct use of hydrologic models for risk-based decision making.

Guest View

Water a Key Focus of the Agribusiness & Water Council of Arizona

by Chris Udall, Executive Director, Agribusiness & Water Council of Arizona

Have you ever wondered how the countless food items you purchase from grocery stores get to the shelves? There are people who believe food is manufactured or comes from a grocery store or that milk and eggs come from cartons. I am confident that those reading this Guest View know where food comes from, and so do we. We are the Agribusiness & Water Council of Arizona (ABWC), formerly known as the Agri-Business Council of Arizona. We unveiled the name change at our annual meeting last May. Adding the word "Water" to our title better reflects our actual history and mission.

ABWC is a trade association established in 1978 to respond to proposed water legislation and to represent irrigated agriculture and agribusiness interests in Arizona. In other words, we represent Arizona agriculture from "ditch bank to dinner plate." Our members are growers, ranchers, suppliers of equipment, attorneys, university representatives, consultants, engineers, agricultural processors, financiers of agricultural enterprises, commodity groups, trade associations, and electrical and irrigation districts. Our purpose is to maintain the integrity of Arizona's water supplies and the industries that rely on these essential resources for the benefit of Arizona's economy. Our mission is to represent our membership by working to promote and protect water resources in the state of Arizona and to actively educate, support and promote all aspects of water, agriculture and agribusiness. Our goal is to alert, educate and link our members on current issues important to water, agriculture and agribusiness, including, but not limited to, federal and state legislation that impacts Arizona's water, agriculture and agribusiness; federal and state water, power and land policies and regulations; groundwater management; changes in taxation proposals and policies; and rural, state and regional economic development. We endeavor to generate support within the industry for policy positions and to speak with one voice to local, state and federal entities, as well as to the general public, in order to improve their understanding and obtain favorable action on the issues being debated.

In our efforts to accomplish our purpose, mission and goals, we also serve as the state affiliate to the National Water Resources Association, an organization of state associations and caucuses based in Washington, D.C. at which we represent western water interests including irrigated agriculture and municipal water interests with ties to U.S. Bureau of Reclamation facilities. We are also active members of the Family Farm Alliance, an organization with Arizona roots based in Klamath Falls, Oregon; similarly representing western states' irrigated agricultural interests, farmers and ranchers.

Among our many initiatives, we are focusing our attention on the development of water use studies demonstrating the positive conservation efforts of the agriculture industry. Agriculture has made and is making strides in the wise use of water resources while exponentially increasing production. We are aggressively commenting on and tracking proposed rules and regulations at the state and federal level with important impacts on agriculture. In particular, we are following various Environmental Protection Agency and U.S. Army Corps of Engineers new proposed rules redefining "Waters of the U.S." that we believe assert new expanded jurisdiction over land and water use. Also under our scrutiny are proposed U.S. Forest Service directives aimed at the regulation of ground water, in what we are convinced is usurpation of state jurisdiction. We are steadfast in opposing these and other efforts we contend will have a negative impact on food and fiber production; all this at a time when our country needs to increase supplies of food and fiber to address an ever increasing national and worldwide growth in population. In addition, we are actively involved in the pursuit of new water, be it through desalination, cloud seeding, forest thinning, or the removal of invasive species from our rivers and streams. I have just scratched the surface on issues in which we are active participants. Other issues include drought on the Colorado River and a potential shortage declaration that will impact agricultural interests first; the power and water cost implications to agriculture of decisions affecting the operation of the Navajo Generating Station; resolving the long drawn out adjudications process; addressing the issue of aging infrastructure, and more.

Workers pick lettuce in Arizona.
Source: Agribusiness Council of Arizona

Water is a precious resource; nothing happens without it, especially the sustaining of life. It takes water and power flowing to a farm to produce a crop, which, through a chain of events extending from the field to the grocery store shelf, provides sustenance to households across Arizona, the nation and beyond. We understand this chain of events and work on a daily basis to protect it and do so with sustainability and prudent use in mind. That is the purpose of the Agribusiness & Water Council of Arizona. For more information or to become a member, please visit our webpage at: www.agribusinessarizona.org.

International Hydrologic Initiative Supports Water Monitoring and Forecasting in Africa

by Mary Ann Capehart, WRRC Graduate Outreach Assistant

The UNESCO Drought Monitoring Workshop in Niamey, Niger included a visit to a women's agricultural cooperative. Source: Aleix Serrat-Capdevila

Through an initiative founded by UNESCO's International Center for Integrated Water Resources Management (ICIWaRM) and in collaboration with three African institutional partners, researchers at the University of Arizona (UA) are creating monitoring tools and forecasting applications using satellite precipitation measurements and numerical weather model results for three regions on the continent.

The collaboration began in West Africa with a partnership with the International Senegal Basin Authority (OMVS) located in Dakar, Senegal. With funding from the U.S. Geological Survey, the UA team engaged in a project that aimed at integrating existing water resources monitoring and forecasting efforts in West Africa in a meaningful and holistic manner. The project combined consolidating and validating recently developed multi-model remote sensing applications to provide 7-to-12-day streamflow forecasts in key pilot watersheds in the international Senegal basin with a number of efforts focusing on water resources monitoring.

The Senegal River basin is shared by Mauritania, Senegal, Mali and Guinea and is the second-largest perennial water course in the Sahel and in West Africa. A detailed applied research agenda was developed to help improve management tools to cope with a basin characterized by highly variable flows primarily occurring during a four-month rainy season. As in other large African basins, water management must balance competing demands between irrigated agriculture, which is facilitated by the dams on the river, and a thousand-year-old traditional flood recession agriculture, which is disrupted by the dams, as well as the demand for hydropower, urban supplies and navigation.

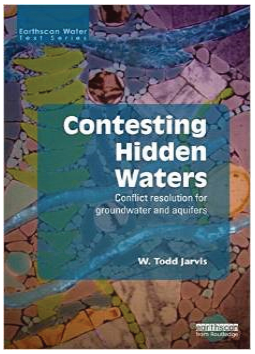
A low density of rain gauges in the region, one rain gauge for roughly every 6,000 square kilometers, makes the use of satellite precipitation measurements and numerical weather models critical for this and other African monsoon-dominated basins. Responding to specific needs reported from the field, such as the lack of quantitative tools to estimate water availability at resolutions useful to decision-making, the UA-facilitated team is developing tailored applications to fill that gap. Using rainfall estimates from satellite observations and near-term weather forecasts as inputs to hydrologic rainfall-runoff models, streamflow forecasts will be made available for the management of the basin and reservoirs. This creates a valuable application that can be easily exported to other poorly gauged basins in Africa and around the world.

Cooperation has been initiated with a second ICIWaRM partner, the AGRHYMET Regional Center, a specialized institute of the Permanent Interstate Committee for Drought Control in the Sahel (CILSS), located in Niamey, Niger. This collaboration is under the direction of Juan B. Valdes and Aleix Serrat-Capdevila of the UA Department of Hydrology and Water Resources and has been funded by a grant from the National Science Foundation. The AGRHYMET represents nine member countries in the Sahel—a semi-arid region that extends from the Sahara desert on the north to the wetter regions of equatorial Africa on the south, and from the Atlantic on the west to the Indian Ocean on the east. AGRHYMET's primary goals are achieving food security and increased agricultural production in the member states, and the improvement of natural resources management in the Sahelian region. The collaborators are committed to creating a network that pools each area's knowledge and expertise in order to quickly share and disseminate workable solutions.

In a very similar collaboration, a third partner, the Climate Services Centre of the Southern African Development Community (SADC-CSC), located in Gaborone, Botswana, provides services and outreach products in weather/climate monitoring and prediction. Fifteen member states spanning the continent, south from the Democratic Republic of the Congo to the nation of South Africa, are represented by the SADC-CSC. These states, as well as other regional and international institutions, will benefit from services and products designed to monitor and predict the extremes in climate events. Weather-and-climate-induced calamities constitute more than 80 percent of all natural disasters worldwide. SADC-CSC member states experience recurrent extreme climatic events such as floods, droughts and tropical cyclones, often resulting in negative impacts on their socio-economic development. Their populations are also susceptible to diseases such as cholera and malaria, which are influenced by climate factors. With input from academic partners like the UA, SADC-CSC's commitment to disaster preparedness and health and water management programs should help mitigate the negative impacts of weather and climate on food security and sustainable socio-economic development in southern Africa.

Resources

Contesting Hidden Waters: Conflict Resolution for Groundwater and Aquifers

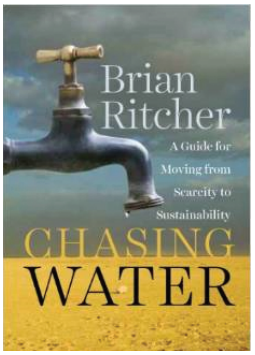


W. Todd Jarvis, Earthscan Water Text Series, Routledge, Abington (UK) and New York, 2014

In *Contesting Hidden Waters*, W. Todd Jarvis sets out a framework for approaching groundwater and aquifer governance in conflict situations and illustrates the use of this framework through detailed case histories. His goal is to promote the use of a transdisciplinary perspective on these situations; that is, to assemble a range of competencies and through joint activity arrive at a higher-order, more holistic conception of the issues. These competencies include not only knowledge of hydrogeological, economic and other technical fields, but also skills in communication, such as listening and diplomacy, and skills in morality and ethics, such as good judgment and confidentiality. These competencies are needed because problems related to groundwater and aquifers are "wicked" problems, or problems that are complex and dynamic, lack specific boundaries, and often defy solution. Wicked problems require negotiation for dispute prevention and conflict resolution.

A second goal of the book is to encourage the use of negotiation in disagreements over aquifers, where reference to science alone is often insufficient. A hydrogeologist of many years practice himself, he has learned from his experience that there is much more to aquifer management than hydrogeology. He argues for inclusion of local knowledge and respect for individual beliefs in problem solving activities. He advocates developing a sense among all the parties to disputes that "we are all in this together." His message is sometimes obscured by the dense thicket of his prose, but case studies are presented in compelling detail, and application of his framework provides insight into these conflicts and an intriguing potential solution to some truly wicked problems.

Chasing Water: A Guide for Moving from Scarcity to Sustainability



Brian Richter, Island Press, Washington, Covelo (CA) and London, 2014

As an answer to increasing global water scarcity, Brian Richter, director of Global Freshwater Strategies for The Nature Conservancy, provides tools and principles for building a framework to sustain water supplies for people and ecosystems. He begins with water budgets and the need to understand how much use is sustainable within a water system. Using the analogy of a bank account, he explains water budget accounting and goes on to provide six tools to avoid water bankruptcy. Optimal use of these tools requires a balanced approach that considers social, economic and ecosystem values. How this optimality is accomplished is through a process of governance with input from governments, business, civil society and the people. Richter's seven principles for sustainability carry this coalition from shared vision to adapting in response to lessons learned. As illustration he presents the case of the Murray-Darling River Basin in Australia, where implementation of the seven principles resulted in changes in law and practice that buffered the effects of severe drought and set the stage for a more sustainable future. He ends on a hopeful note with examples of individuals, non-governmental organizations and businesses taking the lead and working with governments to reduce water scarcity and restore river health. This readable and engaging book can serve as a valuable introduction to collaborative water stewardship.

Restoring Sacred Waters: A Guide to Protecting Tribal Non-Consumptive Water Uses in the Colorado River Basin

Julia Nania and Julia Guarina, Getches-Wilkinson Center for Natural Resources, Energy, and the Environment, 2014

Research Needs in the Colorado River Basin: A Summary of Policy Related Topics to Explore Further in Support of Solution Oriented Decision Making

Colorado River Governance Initiative, University of Colorado, June 2014

Two new studies were released by the Getches-Wilkinson Center for Natural Resources, Energy, and the Environment. Part of the Center's Colorado River Governance Initiative, these studies contribute to the ongoing policy discussion concerning the uses of the Colorado River. The publication, *Restoring Sacred Waters: A Guide to Protecting Tribal Non-Consumptive Water Uses in the Colorado River Basin*, seeks to foster an understanding of the legal issues surrounding non-consumptive water uses, as well as specific strategies for achieving non-consumptive water use goals. The guide reviews strategies available to tribes and surveys potential legal and political hurdles. It also offers practical strategies on how to surmount these hurdles, which were derived from the work of experienced tribal attorneys and officials. Strategies in addition to use of Indian federal reserved rights are explored, including how federal environmental laws and conservation easements have been used to create additional flows in reservation streams. *Research Needs in the Colorado River Basin* is a synthesis of ideas gained from interviews and reports assessing the state of research since the release of the U.S. Bureau of Reclamation Colorado River Basin Study. Research requirements are identified for those areas in which additional progress is most needed to aid the policy discussions. Research is recommended that could

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Reshet Gebremariam, School of Natural Resources and the Environment

Reshet Gebremariam is a first year master's degree student in the Water, Society and Policy program of the School of Natural Resources and the Environment. She received her undergraduate degree in Environmental Science from St. Cloud State University in St. Cloud, Minn.

As an international student from Ethiopia, Gebremariam has learned a lot from her studies in the United States. During her years as an undergraduate, she worked with watershed districts in Minnesota, raising awareness about watershed resources. She built a temporary portable water filter for third world countries with an instruction manual in nine languages and helped raise funds to build a drinking water well in Africa. Gebremariam's interest in water systems and water policy was triggered by the increasing competition for water resources all over the world and informed by multiple labs and case studies on the Mississippi River and surrounding areas.

At the WRRC, Gebremariam works as a Graduate Research Assistant under WRRC Director Sharon B. Megdal and Water Sustainability Program Director Jackie Moxley. She works on various outreach projects for the WRRC and assists the staff with special projects.

Gebremariam decided to pursue a masters degree in Water, Society and Policy to learn more about how environmental research is directly used in understanding and solving real world issues. The degree program provides a way to see how research scientists and policy makers collaborate to solve water-related problems and to understand how human activity and environmental processes affect watersheds. For this purpose, Arizona is a great place to study, given that it has many water challenges, and shares waters with other states and another country.

Environmental sustainability is something that is not widely acted upon in third world countries, and she believes studying at a land grant university renowned for environmental research and conservation will help her gain the proper experience and knowledge needed to bring about change. She expects to graduate in the fall of 2015. Upon graduation, Gebremariam hopes to pursue a career in soil and water resources management. She wants to focus on access to safe drinking water and the development of sustainable water systems in rural areas.

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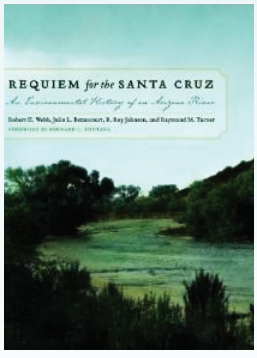
improve the level of detail, frame existing research threads or address areas often omitted from investigations because of political sensitivities. This effort incorporates an assessment of the role that the academic community can play going forward in addressing unmet needs. All reports of the Colorado River Governance Initiative can be found at the Colorado River Information Portal: http://www.waterpolicy.info/projects/CRIP/index.html.

Requiem for the Santa Cruz: An Environmental History of an Arizona River



Robert H. Webb, Julio L. Betancourt, R. Roy Johnson, and Raymond M. Turner, The University of Arizona Press, 2014

Those Tucson residents who arrived after 1970 will never have seen the Great Mesquite Forest on the Santa Cruz River south of Martinez Hill, because by then only dead stumps remained. Once a destination for bird watchers, it was a haven for tropical migratory birds and provided nesting habitat for more than 70 bird species. Mesquite trees as much as 75 feet tall, with trunks as large as 13 feet around, grew in a thicket that was probably almost 8 square miles in extent at its maximum. It boasted a richness of plant and animal species nearly unique in the region. What killed the Great Mesquite Forest? Wood cutting and agricultural clearing made in-roads, but the real cause was groundwater pumping, which drew the water table below the roots of even the largest trees. This story is the heart of the message that Webb and his colleagues convey in their natural history of the Santa Cruz River.

The result of 30 years of collaborative study, *Requiem for the Santa Cruz* is a work of comprehensive practical scholarship that encompasses what is known about the River from prehistoric times to the present. Every source of data and information has been mined to produce a book with the authority of a reference book and the appeal of a coffee table book. With language accessible to the lay reader, it provides detailed evidence on the state of the river, its past and its changes over the years, the reasons for those changes and their implications for the future. Taking an interdisciplinary approach, with authors expert in hydrology, plant ecology, geosciences and ornithology, the book documents the evolution of the river through arroyo downcutting, widening and filling, examining the potential causes that have been proposed through the years. The case is made that this evolution of the stream channel is a natural process that has occurred repeatedly on the Santa Cruz over millennia. Contrary to myth, they show that the river never flowed continuously, but was largely ephemeral with reaches where the geology supported a water table at or near the surface. Periodic floods raged down the river, creating new channel forms. Riparian ecosystems

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Announcements

Native Eyes Film Showcase: Honoring the Power of Coming Together

This fall, the annual Native Eyes Film Showcase, produced by the Arizona State Museum in partnership with the UA Department of Gender and Women's Studies, presents programs that honor the power of coming together for social change. On Friday, October 24, "Meet the Filmmakers!" a brown-bag lunch, begins the showcase with a discussion about women filmmakers, films with Native American stories, and making documentaries. LaDonna Harris (Comanche) and the late Wilma Mankiller (Cherokee) will be celebrated at an induction ceremony into the honor roll of the UA's Women's Plaza of Honor, a sculpture garden that celebrates the accomplishments of women. The public is invited to attend the induction ceremony and a reception immediately following at the Arizona State Museum.

On Sunday, October 26, the films *LaDonna Harris: Indian 101* and *The Cherokee Word for Water* will be presented followed by a Q&A with the filmmakers, a resource fair, and a panel discussion with tribal leaders moderated by Arizona legislator Sally Gonzalez (Pascua Yaqui). *LaDonna Harris: Indian 101* is a documentary that explores the political life and social activism of activist LaDonna Harris, renowned for educating Congress about American Indian Tribes and their unique relationships with the federal government. *The Cherokee Word for Water* tells the story of the struggle to build a 16-mile waterline system and a reawakening of the traditional indigenous values of reciprocity and interconnectedness from the perspective of tribal leader Wilma Mankiller and organizer Charlie Soap.

On Wednesday, November 12, the film *Oil and Water* will be screened at the Loft Cinema, the true story of two men born on opposite sides of an oil pipeline that changed the lives of the indigenous Cofán peoples in the Ecuadorean Amazon. The viewing will be accompanied by in-person commentary from the film's subjects and S. James Anaya, professor of human rights law and policy at the James E. Rogers College of Law.

Mapping Tool Shows Flood Risk of U.S. Energy Facilities

A new online map tool, available to anyone with an internet connection, provides information on flood risks to energy facilities. Weather events, such as hurricanes, overflowing rivers, flash floods and storm surges can threaten energy infrastructure, such as power plants, oil refineries and crude oil rail terminals. The new map tool matches flood hazard information with energy infrastructure locations to help users understand what energy facilities may be affected by flooding. Developed by the U.S. Energy Information Administration (EIA), the Flood Vulnerability Assessment Map combines EIA's existing U.S. Energy Mapping System with flood hazard information from the Federal Emergency Management Agency (FEMA). The EIA is the statistical and analytical agency within the U.S. Department of Energy.

The map shows areas that have a 1 percent and 0.2 percent annual chance of flooding (a 1-in-100 and 1-in-500 chance, respectively). It also contains regulatory floodways, areas with levees (reduced flood risk) and areas with conditions that might have a 1 percent annual flood risk identified in the future. To determine if a specific area is vulnerable to flooding, users can type an address, town or county name in the "find address" box, or zoom in on areas of the United States map shaded to indicate that flood hazard information is available. Flood hazard information is shown at the map's street level. The Flood Vulnerability Assessment Map is available at: http://www.eia.gov/special/floodhazard/.

Arizona Forward Honors APW

Arizona Project WET's Maricopa County program received an Award of Merit for environmental education in Central Arizona at the Arizona Forward Environmental Excellence Awards. Arizona Forward is an organization that brings business and civic leaders together for dialogue on the environmental sustainability and economic vitality of Arizona.

New Arizona Prize: $100K Water Consciousness Challenge

The New Arizona Prize is a competition organized by the Arizona Community Foundation, Republic Media and the Morrison Institute for Public Policy, Arizona State University. Its aim is creating the Arizona of tomorrow: A state in which innovation thrives, ingenuity is supported and the best thinking is harnessed to create long-term, positive solutions to persistent needs. The $100,000 prize will be awarded in the Water Consciousness Challenge to a proposal for activities raising public awareness and understanding of the issue of water scarcity, ensuring that the public recognizes the urgency of the warnings from our state leaders and other experts. Teams will propose a creative content strategy that relies primarily on digital mediums, with an emphasis on social shareability. The competition encourages teamwork, and student teams, as well as professionals from a range of disciplines, are encouraged to compete. One multi-disciplinary team will be awarded $100,000 to implement its proposal, but every team that submits an application will receive valuable feedback from credible authorities and chances to connect with others.

The Water Consciousness Challenge is described in a newly released Briefing Book that includes a detailed timeline for each phase of the competition, a copy of the application, and the Trait Scoring Rubric that judges will use to assess each completed application. Registration deadline is December 19, 2014, and the submission deadline is January 16, 2015. Additional information can be found at https://www.newarizonaprize.org/.

Collaborative Efforts Yield Numerous Publications

By Sharon B. Megdal

Because this issue of the *Arizona Water Resource* has a focus on research, I thought I'd use this space to talk about some recent collaborative work. This year has been a very busy one, with attention focused on a number of water policy and management topics at multiple geographic scales.

I have been busy guest editing, along with my Australian colleague Peter Dillon, a special issue of the journal *Wate*r on the policy and economics of managed aquifer recharge (MAR) and water banking. This special issue grew out of our involvement in ISMAR9, the October 2013 triennial international conference held on MAR. The papers published to date can be accessed at no charge at http://www.mdpi.com/journal/water/special_issues/MAR. Arizona's water banking efforts are featured in the paper, "Water banks: Using managed aquifer recharge to meet water policy objectives," which I wrote with co-authors Peter Dillon and K. Seasholes. The paper summarizes the purpose and performance of the Arizona Water Banking Authority in the context of Colorado River shortage conditions and Arizona's statutory framework for storage and recovery, along with the applicability of water banking to Australia.

Another paper that features international comparative analysis is "A Tale of Two Rivers: Pathways for improving water management in the Jordan and Colorado River Basins," coauthored with A. Chen, A. Abramson, and N. Becker. We argue that there are common factors with respect to the policy and management options of these two basins that may provide insights into the similarities and divergences of their respective future pathways. These factors are regional water supply and demand pressures, water governance, transboundary issues, and demand for environmental flows. This paper is forthcoming in a special issue of the *Journal of Arid Environments*. I draw upon the analytical framework of this paper in my invited October presentation at the international conference on "The Rehabilitation of the Lower Jordan River (Phase A) and the Development of the Border Region Between Israel and Jordan along the Jordan River."

Sustainable agriculture has been the focus of some publications. My collaborators from the Jordanian Royal Scientific Society, A. Ghrair and O. Al-Mashaqbeh, and I published the paper "Performance of a Grey Water Pilot Plant Using a Multi-Layer Filter for Agricultural Purposes in the Jordan Valley," which appeared in the July 2014 issue of the journal *CLEAN – Soil, Air, Water*. The article addresses the water quality results for an installed pilot filtration system, which was built with natural locally available materials. The results indicate that the filtration system has worked well and is potentially transferable to other locations in the developing world.

The edited volume *Convergence of Food Security, Energy Security, and Sustainable Agriculture*, with an October 2014 release date, includes the chapter, "Impact of Technology and Policy on Sustainable Agricultural Water Use and Food Security." I was a coauthor of this chapter, along with M. Alam, G. Kruger, and D. Songstad, who also served as the book's lead editor. The chapter considers the sustainability of irrigated agriculture and acknowledges the associated challenges of avoiding degradation of water and soil quality and adverse impacts on the environment. The chapter points to the need for convergence of agricultural producers, society, and policy makers to develop strategies of adjustment and acceptance of future agricultural water use.

I have continued working with University of Arizona colleagues A. Gerlak and R. Varady and graduate student Ling-Yee Huang on examining groundwater governance and management. Our paper, "Groundwater Governance in the United States: Common Priorities and Challenges," has been accepted by the journal *Groundwater*. Survey responses revealed that states' legal frameworks for groundwater differ widely in recognizing the hydrologic connection between surface water and groundwater, the needs of groundwater-dependent ecosystems, and the protection of groundwater quality. The states also reported a range in capacity to enforce groundwater responsibilities. California's recent approval of major groundwater legislation points to the crucial importance of groundwater in meeting water demands. Identifying good governance and regulatory frameworks will be evermore important as many areas experience increasing demands for water, along with diminished surface supply reliability.

Supply and demand imbalance was the focus of a policy brief I wrote for the National Agricultural and Rural Development Policy Center, entitled "Facing an Uncertain Colorado River Basin Future." This policy brief highlights key questions communities should consider as they plan for their water future. Questions include the extent to which communities control their water resources, available financing mechanisms, and how collaboration among communities and water agencies can assist in preparing for alternative water futures. The policy brief can be accessed at http://www.nardep.info/uploads/Brief20_UncertainColoradoRiver.pdf.

More locally, graduate student Nate Delano and I followed up on a recommendation of the "Tucson Regional Water Assessment Task Force Think Tank Report" by examining alternative approaches to regional water management. Our article, "Regional Water Management Collaboration," was published in the March 2014 issue of *The Water Report*. Study of four regional organizations showed that collaborative efforts typically grow out of distinctive regional needs. We concluded that efforts toward greater cooperation among regional water stakeholders should focus on the Tucson region's unique water situation, rather than an external model for water collaboration. The paper is at https://wrrc.arizona.edu/publications/other/regional-water-management-cooperation.

I look forward to continuing to foster and participate in collaborative efforts, including several not mentioned due to space limitations, so that I can do my small part to develop sound water management, policy and governance strategies. Such strategies are crucial for achieving policy objectives related to sustaining communities large and small, feeding the world's population, and supporting natural systems.

WRRC
WATER RESOURCES RESEARCH CENTER

COLLEGE OF AGRICULTURE & LIFE SCIENCES
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Water Resources Research Center
College of Agriculture and Life Sciences
The University of Arizona
P.O. Box 210437
Tucson, AZ 85721-0437

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responded and adapted to the changes in recurring patterns until groundwater pumping in the 20th century left the river high and dry.

Today's water managers face seemingly contradictory goals of water supply, flood control and river restoration. The authors trace the activities of humans in seeking to accomplish each of these goals and identify their effects on the river. *Requiem for the Santa Cruz* concludes that there will be no return of the Great Mesquite Forest. At best, flood control structures can be designed to allow for growth of riparian vegetation, which would have to be irrigated to survive.