



ARIZONA WATER RESOURCE

The Water Resources Research Center Quarterly Newsletter

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Conference

This issue of the AWR contains highlights of the WRRC 2016 annual conference. Conference agenda, presentations, and videos are posted at <https://wrrc.arizona.edu/conference-2016>.

Publications

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.**



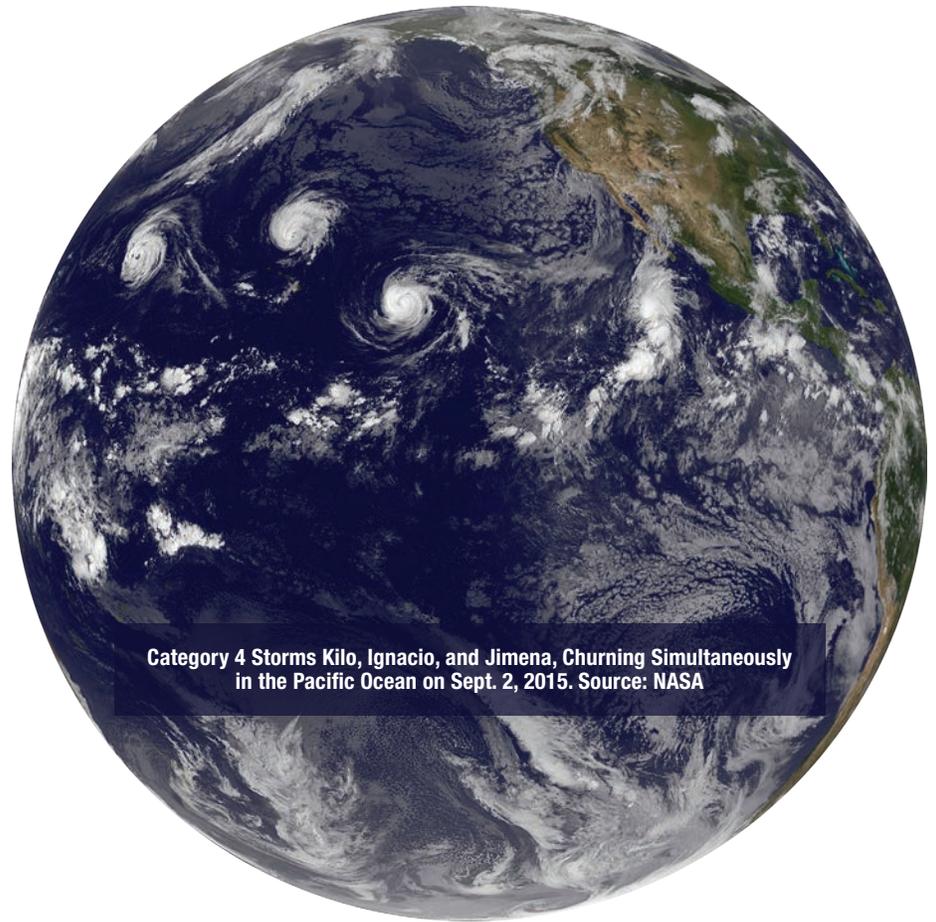
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Category 4 Storms Kilo, Ignacio, and Jimena, Churning Simultaneously in the Pacific Ocean on Sept. 2, 2015. Source: NASA

The Global Impacts of El Niño

A strong El Niño event has been taking place this year. People in Arizona generally welcome the wetter winters brought by El Niño, but in other parts of the world, El Niño can mean droughts, floods, crop failures, and looming food shortages.

Typically, during El Niño winters, a more powerful jet stream will develop north of the equator and steer storms into California and other parts of the Southwestern United States. This year, the Pacific Jet Stream was pushed north of its typical El Niño configuration. In the United States, impacts of El Niño have been felt this winter in the Pacific Northwest; Seattle is having one of its wettest winters on record and ski conditions in Oregon, Washington, and British Columbia have been the best in years.

El Niño is the warm phase of ENSO (El Niño-Southern Oscillation), which is a periodic variation in winds and sea surface temperatures over the tropical

El Niño continued on page 6

2016 Annual WRRC Conference Looks to the Future

What will Arizona's water supply look like in the future? How will the state ensure abundant water for the needs of future generations? What innovations will help achieve water sustainability and what are the choices that will have to be made? These are some of the questions addressed at #AZwaterfuture: Tech, Talk, and Tradeoffs, the Water Resources Research Center's 2016 Annual Conference.

On Monday, March 21, the University of Arizona WRRC assembled a conference of water experts, professionals, students, and the interested public to peer into Arizona's water future. With about 275 people attending from all across Arizona and the southwestern states, the conference explored novel ideas and approaches in the areas of technology, communication, education, and policy.

Conference continued on page 2

The main task of the conference was framed by keynote speakers Anne Castle, a former Assistant Secretary for Water and Science at the U.S. Department of the Interior, and Lisa Beutler, an expert in leading complex group problem solving efforts. Castle, currently a senior fellow at the Getches-Wilkinson Center for Natural Resources, Energy, and the Environment at the University of Colorado, brought the bad news that our old “security blankets” were worn and cannot be depended on to provide water security in the future. We can no longer assume that the future will look like the past and we will have to adjust our planning to changing conditions that include perhaps a 50 percent reduction in runoff to the Colorado River by the end of the century. We can no longer count on our large reservoirs to protect us from water shortages. Consistently taking more water out than is flowing in on average will, and is, depleting the water stored in these reservoirs. Finally, the laws that protected water users in the past are now too inflexible for current needs and new institutions for water banking and exchanges are needed.

These new challenges present the kinds of problems that Beutler, Public Affairs Specialist with MWH Global, characterized as “wicked”; that is, they do not have a single solution. As Beutler put it, “One and done will not work anymore.” Instead, solutions to wicked problems must be approached through a mitigation framework where people with an interest in the outcome collaborate on finding

actions that are adaptive in a world that is full of unknowns and the future is not predictable. Beutler’s prescription for addressing wicked problems provided a new way to think about the water situation. “Hundreds of people can be brought into the conversation,” she said.

Bringing people into the conversation about water was the goal of conference speakers during the communication and education portion of the conference agenda. Cody Sheehy, Video Producer of “Beyond the Mirage” introduced the project that aims to engage people of all ages in learning and sharing knowledge about water problems and potential solutions. A video-based web experience encourages internet users to watch their choice of short video clips, assemble them into their own mini-documentaries, and share them on social media. “Beyond the Mirage” is a unique platform for expanding the water conversation.

Balancing the use of social media with person-to-person communication was Lisa Shipek’s message. Executive Director and Founder of Watershed Management Group, Shipek related lessons learned from her experience in building support for a long-term watershed restoration vision. People will get involved who learn how their personal stories are part of the bigger picture, who are invited, encouraged, and connected through consistent communication.

As Kerry Schwartz, Director of Arizona Project WET observed, “Education needs to change with communication.” A panel of educators on the cutting edge of new methods



(1) Audience member, Joaquim Delgado; (2) Conference speakers and moderators, Ze'ev Barylka, (3) Lisa Beutler, (4) Guy Carpenter, (5) Michael Kotutwa Johnson and Amy McCoy, (6) Cody Sheehy, (7) Randy Snow, (8) Anne Castle
Photos courtesy of Lynn Ketchum, University of Arizona College of Agriculture and Life Sciences

in promoting learning in the next generation of leaders and citizens provided a hopeful message to conference attendees. DaNel Hogan, Director of the STEMAZing Project noted that pre-K through 8th grade is not too early to ask students how to fix problems. “No one has told them it can’t be done.” Giving students the tools of Science, Technology, Engineering, and Mathematics (STEM) will help fill the pipeline of experts who will be needed for future solutions to Arizona’s wicked water problem. Other speakers highlighted programs for providing these tools in the Pendergast School District and Red Mountain High School to enrich education for middle and high school students. The Maricopa Community College District has focused on post-secondary school students, and the conference attendees learned about efforts to create job-ready graduates who want to make an impact on community sustainability.

Technological innovation is one pathway to water sustainability, and the conference panel on the use of technology presented multiple options from drip irrigation to producing designer waters for specific uses. The water portfolio of Aurora, Colorado diversified through an innovative arrangement to share water with farmers as well as a \$700 million recycled water system, which uses a multi-barrier approach to water purification. The West Basin Municipal Water District of Southern California also looked to recycling for diversification. Recycled water is not dependent on hydrology, so it provides a measure of drought resistance. The West Basin recycling facility produces five different kinds of water “fit for purpose”: for cooling towers, for low pressure boilers, for high pressure boilers, and for recharge to a drinking water aquifer. Each purpose requires different levels and types of treatment.

High tech water conservation is another way to expand water supplies. Netafim, the company that invented drip irrigation more than 50 years ago, operates in an industry still in its infancy because the technology that directs water to plant roots and can irrigate and fertilize through the same system has not been adopted widely. It’s potential for saving water while increasing crop yields has yet to be realized. Farmer Dan Thelander has adopted drip irrigation for growing melons on 1,000 acres in Maricopa-Stanfield. The installation was more than twice as expensive as other forms of irrigation, but tillage savings and a tax credit offset some of the additional cost, and less water is used per unit produced. For other crops, the current economic equation faced by farmers works against widespread adoption.

On one end of the farming spectrum, space-age greenhouse technology is growing rapidly for specialty crop vegetables. Gene Giacomelli, Director of the UA Controlled Environment Agriculture Center, stated that there has been a 400 percent increase in greenhouse systems over the past few years. Chances are about 50-50 that the tomato in your salad was grown in a greenhouse using five to eight times less water than flood irrigated field tomatoes.

On the other end of the spectrum, Michael Kotutwa Johnson, a Hopi dryland farmer, invited the conference to think about agricultural water conservation in a new way. He uses intergenerational wisdom to gauge the needs of his plants and produces a harvest without supplemental irrigation in an area that receives six to ten inches of precipitation per

year. He practices “conservation from the point of view of caring for a relative, not from a scientific point of view of conserving a natural resource.”

Johnson’s alternative way of looking at conservation highlighted the tradeoffs involved in choosing pathways toward water sustainability. He was part of a panel on tradeoffs that looked at what these choices involve and what they may mean for the future. Brian Bennon of the Inter Tribal Council of Arizona explained tradeoffs as compromise, something that Tribal Nations have been involved in to settle water claims with real water supply outcomes. The situation of the Tribes with respect to water quantity and water quality requires many tradeoffs such as claims for certainty, an assured quantity for a lower quality, and loss of control of small local water system for the stability of larger regional systems.

On the other hand, Amy McCoy of Ecosystem Economics asked the audience to look at tradeoffs as opportunities. “Shortage has not yet arrived; how it happens remains in our hands.” One solution to shortage illustrated by the City of Las Vegas, Nevada is aggressive water conservation programs that start with public education on the nature of the problem and what they can do to help. With funny and eye-catching public campaigns they have been able to save more than eight billion gallons of water per year since the program went into effect. As a result of these campaigns, people in Las Vegas see the value of trading water-wasting practices for conservation.

So, what are major water agencies and organizations doing about Arizona’s wicked problem? A final panel of the day with representatives from the Departments of Environmental Quality (ADEQ) and Water Resources (ADWR), the Central Arizona Project (CAP), and the Salt River Project (SRP) discussed this question with the WRRC’s Director and the audience. Each organization has responsibilities for a part of the problem. ADEQ has opened a rule making process that will create a framework for water reuse that includes potable reuse and protects public health. ADWR is leading a statewide initiative announced by Governor Doug Ducey with two tracks: listening to stakeholders in the state’s 22 planning districts and public meetings of the Governor’s Water Augmentation Council. CAP is taking incremental steps toward averting shortage and preparing the CAP system for potential future arrangements, such as stored water recovery and exchanges.

Marc Campbell of SRP diverged slightly to discuss the potential for ocean water desalination. This sparked discussion, with questions about how ocean water desalination would be done, how it would be paid for, whether we need to do both desalination and water recycling, and what we do before we get to desalination, if we do get there.

Discussion continued on the role of conservation, incentives to spur more agricultural conservation, educational campaigns and how to engage and inform the public, stormwater harvesting, and public involvement in decision making. The discussion reflected the multiple components of and perspectives on Arizona’s wicked water sustainability problem. It also reflected the multiple potential solutions that may be applied in our work toward an adaptive mitigation strategy. 🏡

Conference Notes



(1) Hunter Moore, (2) Jeff Silvertooth, (3) Aloah Pope and Jean McLain
Photos 1-2 Courtesy of: Lynn Ketchum, University of Arizona College of Agriculture and Life Sciences; Photo 3: John Polle, WRRC

More Conference Highlights

- Hunter Moore, Natural Resources Policy Advisor to Arizona Governor Doug Ducey spoke during the luncheon about the Governor's Water Initiative and other policies to improve the performance of water and other natural resource related agencies.
- A poster session with 25 posters presented the latest in water research and programs across a broad range of topics. The student authors of the top three posters were awarded cash prizes. Winners included: Aloah Pope for "Effects of Policy Decision-making on Riparian Corridors in a Semi-arid Desert: A Modeling Approach"; Tirthankar Roy for "An Improved Streamflow Forecasting Platform for Better Decision-making"; and Benjamin Richmond and Saige Williams for "Water Talks!".
- The Arizona Community Foundation, creator of the New Arizona Prize, introduced their new challenge that invites community collaborations to compete for a \$250,000 prize with innovative ideas for actions that advance water sustainability.
- University of Arizona Provost and Senior Vice President for Academic Affairs, Andrew Comrie, welcomed the conference attendees on behalf of the University and commended the strength of its water expertise.
- Jeff Silvertooth, College of Agriculture and Life Sciences Associate Dean and Director of Economic Development and Extension, reminded the conference audience of the vital importance of water to society and recognized the WRRC as a hub bringing water science to the world.
- A post-conference reception featured interactive stations where conference attendees could engage with the conference Twitter conversation, the new University of Arizona Water Network website, and the "Beyond the Mirage" web experience.

Thank you to all our participants and sponsors
for making our conference such a success.



New CAP Use Agreement on Firming, Wheeling, and Exchanges Proposed

A “CAP System Use Agreement” has been drafted by the Central Arizona Project (CAP) and the U.S. Bureau of Reclamation, with input from the Arizona Department of Water Resources and the Arizona Water Banking Authority (AWBA), that provides a framework for use of the CAP system going into the future. It would authorize the use of the CAP canal system to implement the final, critical, pieces of Arizona’s water banking program in which nearly four million acre-feet of CAP water has been stored by the AWBA for later recovery and delivery to CAP customers. The Agreement also would resolve outstanding legal, financial, and operational issues to allow CAP to transport non-project water through the CAP system. It would facilitate voluntary exchanges of water between CAP’s long-term contractors, creating additional flexibility for the system. It also would establish a process for federal approval for projects to expand system capacity. The agreement can be downloaded from <http://www.cap-az.com/public/blog/482-proposed-new-cap-use-agreement-on-firming-wheeling-and-exchanges>.

UA Researchers See Drying Trends in the West

A team of authors led by Thomas Meixner, Professor of Hydrology and Water Resources at the University of Arizona (UA), synthesized the current state of knowledge about how aquifers in the western United States might respond to projected climate change. Eight representative aquifers located across the region were evaluated. For each aquifer, the authors examined four standard recharge mechanisms: diffuse, focused, irrigation, and mountain-systems recharge. Future changes in individual recharge mechanisms and total recharge were then estimated for each aquifer. Mountain-system recharge is expected to decrease in the southern and western portions of the West because of decreases in precipitation. Decreased diffuse recharge is also expected in the south. Changes in focused and irrigation recharge were too uncertain to characterize. To read the article, go to <http://www.sciencedirect.com/science/article/pii/S0022169415009750>.

Connie Woodhouse, UA Professor of Geography and Development and Dendrochronology, and her co-authors examined the influence of precipitation, temperature, and soil moisture conditions on Upper Colorado River basin streamflow over the past century. Cool season precipitation has been a robust predictor of streamflow, but over-prediction may result if warming spring and early summer temperatures are not adequately considered. There has been a marked increase in the frequency of warm years with lower flows than expected, since 1988. This suggests that warming temperatures will be increasingly important in reducing future water supplies in the Upper Colorado River basin. The full article can be accessed at <http://onlinelibrary.wiley.com/doi/10.1002/2015GL067613/full>.

NOAA’s Rapid Response Field Campaign Studies El Niño

During January through March of 2016, the National Oceanographic and Atmospheric Administration (NOAA) took advantage of an unusually strong El Niño to mount a land, sea, and air campaign in the tropical Pacific that provided the unprecedented opportunity to accelerate advances in understanding and predictions of an extreme climate event and its impacts. The El Niño Rapid Response Field Campaign deployed NOAA’s Gulfstream IV research plane and NOAA Ship Ronald H. Brown, NASA’s Global Hawk unmanned aircraft equipped with specialized sensors, and researchers stationed on Kiritimati (Christmas) Island in the Republic of Kiribati, approximately 1,340 miles south of Honolulu. Weather balloons, twice-a-day were launched from Kiritimati Island. In addition, Scanning X-Band Radar was temporarily installed in the South San Francisco Bay to fill coverage gaps in the existing radar array and provide more accurate rainfall estimates for the region. Daily briefings presented from January 19 to March 10 are archived at http://www.esrl.noaa.gov/psd/enso/rapid_response/forecasting/briefings.html.

Changing Weather Patterns Trend Toward a Drier Southwest

Researchers at the National Center for Atmospheric Research published a study that linked changes in weather patterns with drier conditions in the southwestern United States. Weather systems that typically bring large quantities of rain and snow to the region are forming less often. Analysis of 35 years of data identified common weather patterns and then looked to see whether those patterns were becoming more or less frequent. Weather patterns in which low pressure is centered in the North Pacific near Washington tend to bring wet weather to the Southwest, but between 1979 and 2014 these low-pressure systems formed with decreasing frequency. In February study results were published online in the American Geophysical Union’s journal *Geophysical Research Letters*. Although climate change is a plausible explanation for less frequent moisture-bringing weather events, more study is needed to confirm the connection. For more details, go to <https://news.agu.org/press-release/southwest-sliding-into-a-drier-normal-weather-patterns-that-bring-rain-are-becoming-less-frequent/>.

Arizona Commits to Water Sustainability Actions for White House Water Summit

On March 22, 2016—World Water Day—the Obama Administration hosted the first-ever White House Water Summit for which institutions and organizations from all sectors were called on to make new commitments to build a sustainable water future in the United States. Arizona institutions and organization answered the call as described in

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eastern Pacific Ocean. The cool phase is known as La Niña. El Niño warming occurs, on average, every two to seven years.

There were super El Niño events in 1972-73, 1982-83 and in 1997-98, the latter bringing record global temperatures alongside droughts, floods, and forest fires. The majority of climate models suggested that the 2015/2016 El Niño would be of similar strength to 1997/1998.

The 2015-2016 El Niño event comes on top of volatile and erratic weather patterns linked to climate change; 2014 and 2015 were the hottest years on record, with the Pacific Ocean already warming to an unprecedented degree. Evidence is emerging that climate change will increase the odds of stronger El Niño (and la Niña) events according to the World Meteorological Organization.

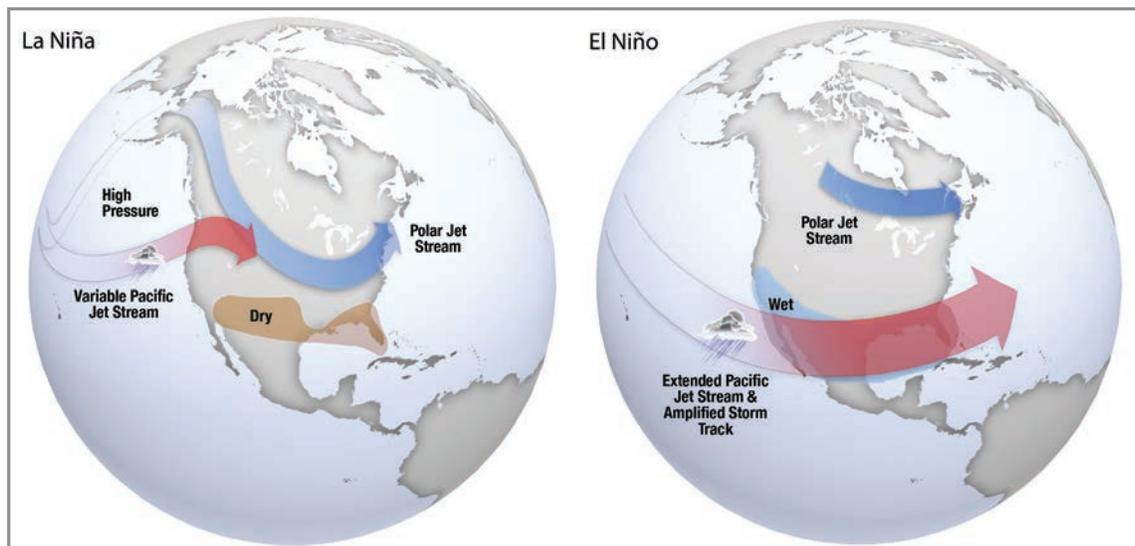
The ocean stores the vast majority of the Earth's heat. While heat storage is stable over decades to centuries in the depths of the ocean, the temperature at the surface can vary from season-to-season and year-to-year. During an El Niño event, sea surface temperatures across the Pacific can warm by 1–3°F or more and warmer conditions can last for a few months to two years. The unusual warmth is coupled with a slowdown of the easterly trade winds, as well as increased rainfall and a drop in surface air pressure in the central tropical Pacific. These disruptions to the normal air movements in the tropics affect the mid-latitude jet streams, which is how El Niño can affect weather around the world.

El Niño influenced weather systems bring more intense cyclones in the North-Western Pacific and more frequent cyclones in the South Pacific are typical. El Niño events tend to enhance the hurricane season in the Pacific and depress the Atlantic hurricane season.

Globally El Niño is associated with patterns of weather extremes. More precipitation is expected in some places, while others may receive none at all.

It must be emphasized that these impacts are likely but not certain. The stronger the El Niño, however, the more likely its impacts become. Some correlation has been observed between the strength of the El Niño and the severity of the effects, but there are no guarantees here either.

Oceanic and atmospheric indicators suggest the 2015/2016 El Niño has peaked; however, countries continue to feel its effects. In South America, southern Uruguay, Paraguay, and southern Brazil have received much more rain than their long-term December–February average.



Global images compare the position of the jet stream between El Niño and La Niña years. Source: NOAA //www.climate.gov

Thousands were displaced in Argentina and Paraguay when the Paraná, Uruguay, and Paraguay rivers overflowed in late December.

The northern portion of the continent has been dry. In Central America, El Niño was associated with serious drought in Guatemala, Honduras, and El Salvador. Some Caribbean countries have also suffered drought. This pattern is consistent with expectations in El Niño periods.

Also consistent, so far, with El Niño's typical impacts have been Africa's rainfall patterns—wet in portions of Kenya and Tanzania and dry in southeastern Africa and southern Madagascar. In addition, predicted dryness has been seen throughout Indonesia, South and South-East Asia, and northern Australia, and rains in southeastern China.

El Niño has perhaps been most pernicious in Africa, as drought ravaged much of the south of the continent. Southern Africa, including Zimbabwe, Botswana, Namibia, Angola, South Africa, Lesotho, Swaziland, and the southern half of Mozambique, tends to see a drier December–February during an El Niño. Areas of this region, especially South Africa, were already very dry, after a failed monsoon last year. In 1992, El Niño caused the region's worst drought in a century, affecting around 86 million people, 72 percent of the population. This year, Zimbabwe declared a state of emergency and an estimated 26 percent of Zimbabwe's population, around 2.4 million people, is now considered food insecure due to dying cattle and failed crops.

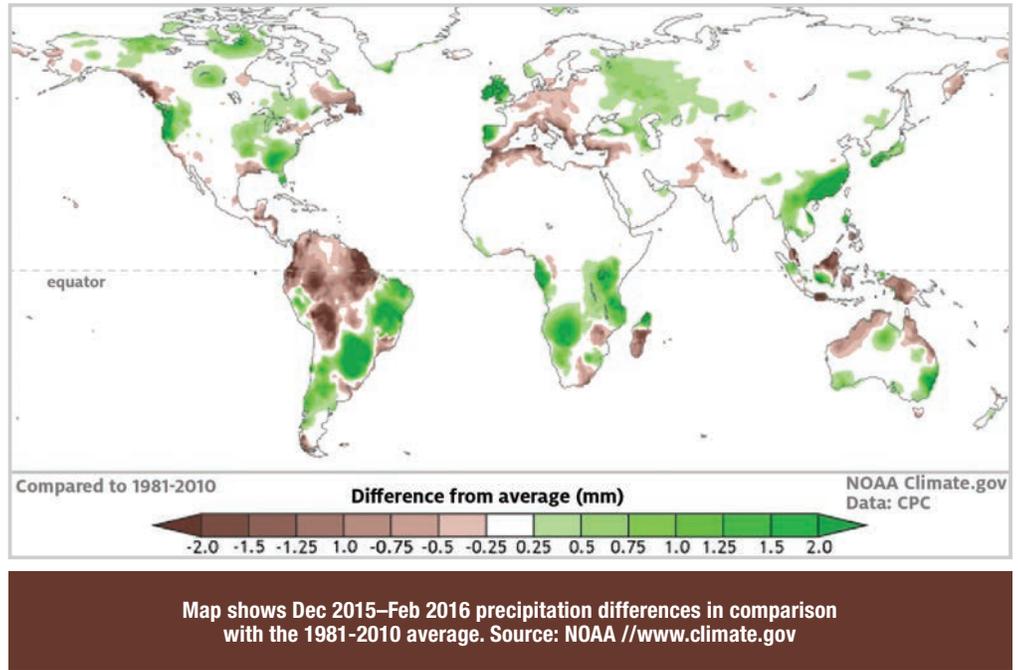
Cereal production will be significantly reduced in specific countries resulting in more volatile prices according to the World Food Programme. For instance, maize production shortfalls led to a surge in prices in Southern Africa. In highly import-dependent regions such as West Africa, consumers face food insecurity due to increased grain prices. The food security effects will be worse for regions like the Horn of Africa, which are already suffering cumulative effects of past poor growing seasons. In Ethiopia the impact of the failed spring *belg* rains was

compounded by the arrival of the El Niño weather conditions that weakened the *kiremt* rains essential for feeding 80 to 85 percent of the country. This greatly expanded food insecurity, malnutrition and devastated livelihoods. In addition, an estimated 5.8 million people require emergency water supply and sanitation.

In other areas of Africa, El Niño is causing major floods, landslides, and increased frequency of diseases that destroy cattle and crops. Excessive rainfall triggers outbreaks of waterborne diseases such as cholera, typhoid, and vector-borne diseases like malaria. Increased risk to livestock can accompany excessive rain, such as Rift Valley Fever outbreaks.

As of December 3rd, floods had already displaced 144,000 people in Somalia and an estimated 76,000 people in Kenya, according to the National Disaster Operations Center. Localized heavy rainfall resulted in flooding in parts of Mozambique and Madagascar while other parts of those countries were suffering drought. In Tanzania, flooding occurred in various regions, including Dar es Salaam, the capital city.

Historical records of previous El Niño events suggest that the likelihood of the current El Niño being followed



by La Niña is the same as a return to neutral conditions, during the second half of 2016. El Niño and La Niña events typically only last for nine to twelve months and re-occur every two to four years. Flip-flops from a strong El Niño to La Niña are not unusual. Should it occur, a La Niña could exacerbate the negative effects in countries that have experienced El Niño conditions. 🏠

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a 37-page fact sheet listing the commitments made for the Water Summit. The Cities of Tucson and Phoenix announced the next step in their 2014 exchange agreement that allows Phoenix to store some of their CAP water in Tucson’s underground recharge facilities [see AWR Winter 2015 and Summer 2015]. Over the next year, they will work together to achieve a more than five-fold increase of water stored under this agreement. Arizona State University (ASU), pledged to implement a five-year research initiative focused on water security, with components in urban landscape design and renovation; training on food-energy-water nexus issues; and testing innovative approaches to agriculture in the arid Southwest. ASU is also involved in SciStarter, which will advance citizen science by expanding the network and impact of citizen scientists and establishing a “Lending Library” of monitoring equipment. The University of Arizona is collaborating on projects to explore linked energy-water microgrids for the purpose of improving co-management of distributed water and energy systems, and to develop

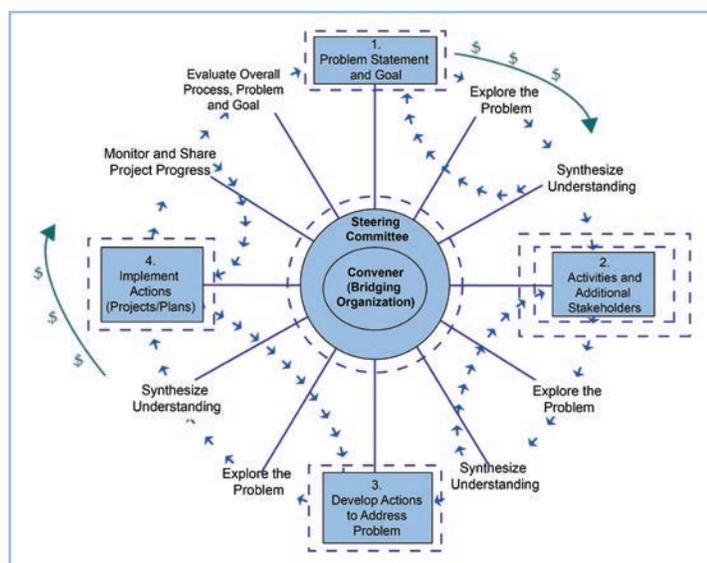
an “Ethics-Based Decision Support Tool” for guiding technology, policy, and investment decisions in the water sector. The Sonoran Institute and the Central Arizona Conservation Alliance will develop a collaborative conservation plan that will help the 24 cities and towns in Maricopa County protect local watersheds and encourage sustainable recharge of aquifers. Finally, a group made up of the Colorado River Basin States, the Southern Nevada Water Authority, the Metropolitan Water District of Southern California, the Central Arizona Water Conservation District, Denver Water, the Upper Colorado River Commission, and U.S. Bureau of Reclamation committed to launching Phase II of a program that compensates water users for implementing voluntary water-conservation projects in order to improve critical water-storage levels at Lakes Powell and Mead. The complete fact sheet can be accessed at https://www.whitehouse.gov/sites/whitehouse.gov/files/documents/White_House_Water_Summit_commitments_report_032216.pdf.

Explore, Synthesize, and Repeat: Unraveling Complex Water Management Issues through the Stakeholder Engagement Wheel

By Kelly E. Mott Lacroix and Sharon B. Megdal

Water 2016, 8(4), 118. *Special Issue: Water Governance, Stakeholder Engagement, and Sustainable Water Resources Management*

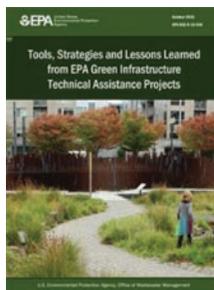
This paper presents the concept of a stakeholder engagement wheel that describes the four iterative or cyclical steps of engagement that drive collaborative water planning forward. The concept is built on evaluation of, and lessons learned from, three water management engagement



Wheel of Stakeholder Engagement. Arrows indicate the engagement cycle and dotted lines demonstrate changes/additions to the elements through iterations.

processes. In the three water management engagement processes, the study authors encountered issues, enumerated in this paper, which typically limit effectiveness. They were able to address them through a deliberate, iterative, and flexible approach, although time limitations continued to present problems. The Stakeholder Engagement Wheel circles around a bridging organization that keeps the process moving and a steering committee that guides activities as stakeholder interests and concerns emerge and evolve. The four steps around this central guidance are designed to examine iteratively these interests and concerns and expand stakeholder involvement. Cycling through activities and actions as proposed in the Stakeholder Engagement Wheel, builds the nuanced and shared understanding needed for cohesive action and robust decisions in the face of our considerable challenges. The full article is available at <http://www.mdpi.com/2073-4441/8/4/118>.

Tools, Strategies and Lessons Learned from EPA Green Infrastructure Technical Assistance Projects



U.S. Environmental Protection Agency, EPA 832-R-15-016 April 2015

The U.S. Environmental Protection Agency (EPA) has published a quick reference guide that summarizes results from EPA's green infrastructure technical assistance program, which helps cities, communities and citizens develop solutions to their stormwater challenges. This report presents lessons learned from experiences of technical assistance grant recipients. Technical assistance is a key component of EPA's investment in promoting green infrastructure for stormwater management. This 20-page report covers the why and how of implementing green infrastructure practices. Designed to capture stormwater close to where it lands, green infrastructure improves water quality by slowing down and filtering polluted runoff before it reaches waterways. It helps to recharge groundwater and irrigate plants that cool urban spaces. In addition, it can reduce the need for expensive gray infrastructure, such as pipes, storage facilities, and treatment systems. Experiences documented in this report demonstrate that green infrastructure can be successful in a variety of settings, including arid climates. EPA supported the development of Pima County, Arizona's green infrastructure guidance, which includes standard engineering drawings, a plant list, and BMP sizing guidance. The EPA report is available at

https://www.epa.gov/sites/production/files/2016-01/documents/gi_tech_asst_summary_508final010515_3.pdf

Pima County's green infrastructure guidance is available at http://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Flood%20Control/Floodplain%20Management/Low%20Impact%20Development/li-gi-manual-20150311.pdf

San Pedro River Aquifer Binational Report

By J.B. Callegary, I. Minjárez Sosa, E.M. Tapia Villaseñor, P. dos Santos, R. Monreal Saavedra, F.J. Grijalva Noriega, A.K. Huth, F. Gray, C.A. Scott, L.A. Oroz Ramos, S.B. Megdal, M. Rangel Medina, J.M. Leenhouts

International Boundary and Water Commission, January. 31, 2016

This report, which focuses on the Binational San Pedro Basin, is unique in its cooperative approach to the study of a shared aquifer. The San Pedro River basin and associated aquifer spans the boundary between the U.S. and Mexican states of Arizona and Sonora. A substantial amount of scientific work has been carried out in the basin for many years, but each country worked without full knowledge of the conditions on the other side of the border

Both countries officially recognized the need for greater scientific understanding of the aquifer system. A number of

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The El Niño-Southern Oscillation

by Mike Crimmins, Department of Soil, Water, and Environmental Science, College of Agriculture and Life Sciences, University of Arizona



The climate of the southwest United States can be a little bit deceiving at first glance. Warm and dry conditions are a pretty good bet on any given day, but if you look at precipitation records over years to decades you will notice some dramatic swings from very wet one year to very dry the next. This is what climatologists call interannual climate variability. When examining long-term precipitation records for Arizona and New Mexico, much of this interannual variability, in the winter season especially, can be tied back to a climate phenomenon called the El Niño-Southern Oscillation (ENSO). ENSO is a somewhat regular (on the order of 2 to 7 years) shift in sea surface temperatures along the equator of the Pacific Ocean basin. Normally, temperatures are cooler in the eastern Pacific and warmer in the western Pacific due to easterly winds causing upwelling of cool water in the east and the movement of warmer surface water to the west. In some years, stronger than average easterly winds will intensify this pattern of cool east—warm west sea surface temperatures, which is termed a La Niña event. During El Niño events these easterly winds weaken, causing warm water to slosh back to the central and eastern Pacific with warmer than average sea surface temperatures in these regions. The location and extent of warm sea surface temperatures (SSTs) is critical in determining where tropical thunderstorms occur and in turn their impact on global circulation patterns. Across the continental United States the impact of ENSO is strongest during the winter season when the storm track, driven by the position of the jet stream, is typically disrupted and precipitation anomalies emerge. During El Niño events, the winter jet stream often splits in the east Pacific with a stronger than average subtropical jet stream that steers a parade of storms across the southern states and subsequently above-average precipitation (see figure page 6). In contrast, during La Niña events the winter storm track is more likely to enter the Pacific Northwest, bringing above average

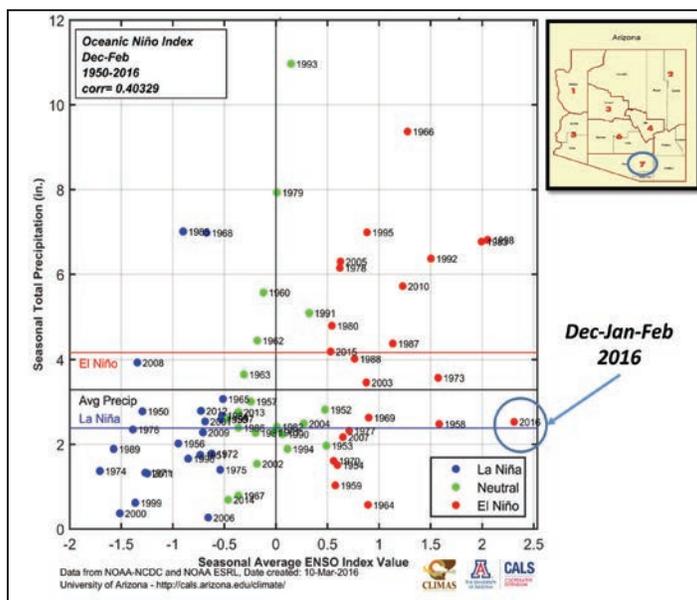
precipitation to this region and leaving the southwest U.S. with below-average winter precipitation.

Our understanding of the impact of El Niño events on seasonal climate has improved considerably over the last few decades. In particular, we can often detect the development of an El Niño event months in advance, long before it will ever have an impact on seasonal weather conditions. For Arizona and New Mexico, an El Niño event means increased probability of receiving above-average winter precipitation, generally between October and March. However, there is still plenty of variability when comparing El Niño events, and there is no guarantee that any given El Niño event will lead to wetter than average conditions. Unfortunately, knowing that an El Niño event, even a strong one, will be present over the winter is not a slam-dunk wet forecast for the Southwest. The very strong El Niño event of 2016 has been very instructive in this point.

To illustrate, the figure below is a scatterplot of total December-January-February precipitation for southern Arizona (climate division 7 to be more specific) for every year from 1950-2016 plotted against the strength of a common ENSO index called the Oceanic Niño Index (simply how different the SSTs are from average in the central-eastern Pacific Ocean). In general, you may notice a rough organization of the blue points or La Niña years on the lower end of the precipitation scale and the red with more spread and reaching into the higher values of total Dec-Jan-Feb total precipitation. Interestingly the blue-

dot/La Niña years pretty much all fall below the average level of Dec-Jan-Feb precipitation, which is consistent with our understanding of the winter storm track being shifted north away from Arizona. The red dot/El Niño years are a bit more of a mess with some below-average years and many above. The stronger events, especially 1983 and 1998, were quite a bit above-average which gave us some hope that 2016, which was even a touch stronger, would be above-average as well. Unfortunately, 2016 charted its own path and reinforced the point that the El Niño is not a guarantee of above-average winter precipitation and only tilts the odds in that direction. The winter storm track in 2016 was displaced

north, much as during a typical La Niña winter, keeping the expected precipitation in the Pacific Northwest and northern California rather than in the Southwest. It is unclear why this El Niño behaved so differently from past strong events, but will no doubt be an active area of research over the next several years. Regardless, future El Niño events will assuredly bring wet conditions, but not all of them. This is part of living in a region with large amounts of climate variability, being ready to be surprised by both the wet and the dry. 🌧️



ENSO Index Value vs. Seasonal Precipitation. Sources: NOAA and UA

Student Spotlight



Bailey Kennett, School of Natural Resources and the Environment

Bailey Kennett is a first-year master's student in the Water, Society and Policy program within the School of Natural Resources and the Environment. She received her undergraduate degree in environmental studies and economics from Eckerd College in St. Petersburg, Florida, where much of her research focused on international sustainable development, particularly in terms of drinking water supply. While at Eckerd College, Bailey interned with an estuary education non-profit, in addition to working as the Conservation Assistant for the municipal water provider.

Prior to beginning graduate school, Bailey worked for four years as a fellow with the U.S. Environmental Protection Agency in Washington, D.C. Her work focused

on building resilience in the water sector by promoting natural disaster preparedness and response among utilities. Also while in Washington, Bailey served as the Western Water Intern with American Rivers, where she examined the connection between groundwater overdraft and river conservation.

At the WRRC she works within the Water RAPIDS program on water supply and demand planning, primarily in the Upper Gila River Watershed. Through stakeholder engagement, she works to determine and communicate current and future water needs and explore potential supply alternatives. In addition to her work at the WRRC, Bailey has begun an internship working on the U.S. Bureau of Reclamation's Lower Santa Cruz River Basin Study, which aims to explore the impacts of climate change on future water supply and demand in the Tucson region.

Bailey's studies focus on water management and policy, within and beyond Arizona. After graduating in May 2017, she plans to continue her focus on stakeholder engagement and community planning around sustainable water management. 🏡

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studies and technical activities were carried out in Sonora and Arizona in a cooperative effort by institutions and organizations on both sides of the border, with the International Boundary and Water Commission coordinating the scientific dialogue and information exchange.

The study had two major objectives: first, to understand the state of knowledge with respect to geography, climate, geology, and hydrochemistry, hydrology of the aquifer system, including surface and groundwater interactions; second, to identify data needs for creating a binational hydrologic model of the aquifer system. The bulk of the report presents information from past work and new investigations on the aquifer system in its binational context. The report concludes with technical recommendations on monitoring and observations to maintain the needed records and fill data gaps. It also recommends coordination on mapping and data compatibility across the border. Finally, the report recommends building an advanced binational coupled ground- and surface water model of the San Pedro River aquifer that covers the entire study area considered in this report. The English language version of the report is available at http://www.ibwc.gov/Files/San_Pedro_River_Binational%20Report_013116.pdf.

Water: More or Less

By Stephanie Taylor and Rita Schmidt Sudman

Water Education Foundation 2016

California's water policy is changing in dramatic ways. Droughts, floods, and water quality issues cast harsh light on how water is used every day in homes and businesses, agriculture, and the environment. Artist and essayist Stephanie Taylor and the Water Education Foundation's former executive director, Rita Schmidt Sudman, co-authors of the book, *Water: More or Less*, visually and verbally cover water in three dimensions – art, history, and stories of real people. This book captures the flow of California's water history, including conflicts and moments of change, and offers solutions for the future. It includes diverse contributions from 20 top water policy leaders, who share their personal thoughts and visions for the future.

A 10-page preview is viewable at https://issuu.com/stephanietaylor11/docs/waterbook_preview_10-22-15

The book can be ordered from the Water Education Foundation at <http://www.watereducation.org/publication/water-more-or-less>

It's Spring! Time to get out in the field!



by Sharon B. Megdal

Spring Semester is always busy and exciting for me, particularly because I teach my graduate course, Arizona Water Policy. Each year the course is a bit different. Because the course attracts students from many different programs, there is always an interesting mix of student backgrounds and interests. Also, while we cover some of the same

topics every year, others vary, depending on what out-of-town experts may pay a visit or what water happenings have recently occurred. Regardless of the variations, one thing remains constant – our all day field trip, about which I have written before. This year the field trip took place on March 4.

I truly believe that getting out in the field is an extremely important way to learn about Arizona water policy and management. We can talk all day about recharge and water banking, the Central Arizona Project (CAP), and water reuse, but there is nothing like seeing these things firsthand. Indeed, the day of site visits and briefings is the first thing to be scheduled on the syllabus, and all enrolled students are asked to try to allocate the full day to the class outing.

Our day starts with a stop at Tucson Water's Advanced Oxidation Process (AOP) Plant and continues on to Tucson Water's Southern Avra Valley Storage and Recovery Project (SAVSARP). The AOP plant treats polluted groundwater to very high standards for delivery to Tucson Water's customers. At SAVSARP, vast amounts of CAP water are stored for current and future recovery and use. We then go on to CAP's Twin Peaks Pumping Plant, where the students learn firsthand about CAP's reliance on power to pump water uphill from the Colorado River all the way to Tucson. Lunch at the White Stallion Ranch, hosted by BKW Farms, provides a perfect backdrop for reflection and conversation, along with learning about White Sonoran Wheat production in our region. We then go on to Pima County's new Agua Nueva Water Reclamation Facility, which was built and is operated through a public-private partnership with CH2M. There we learn about state-of-the-art wastewater treatment, as well as effluent recharge. The final stop is Tucson Water's Sweetwater Wetlands, where wetland treatment and effluent recharge basins operate. The Sweetwater Wetlands, which is open to the

public during daylight hours, is truly an oasis in the desert and a favorite birding spot.

The field trip follows the "life cycle" of water use in the Tucson region: groundwater pumping and clean-up, groundwater recharge, water banking, Colorado River water delivery, energy requirements, wastewater treatment and reuse, and some agricultural water use. Although we start out at and return to the urban core, we are in the desert as we ride through Saguaro National Park West and parts of the Avra Valley. We interact with people who make sure we have safe and reliable water supplies and are very grateful for the expertise shared with us by the professionals who meet with us at our various stops. Some are even with us throughout the day! That professionals are so generous with their time shows the value they place on training our next generation of professionals, academicians, and leaders.

My hope is that through spending this busy day in the field, my students gain greater appreciation for the complexities of water management as practiced in our region and also see ways they might contribute to resolving the complex water challenges we face throughout our region, country, and world. The field trip experience provides this important context to my students: a student recently wrote, "...the field trip counts among the most educational days in my time at the U of A".



Arizona Water Policy Class on Their Spring Field Trip, March 4, 2016. Source: Sharon B. Megdal

During the Spring Semester, I also convene a seminar course for the master's program in Water, Society, and Policy. This one-unit course is designed to expose the students to a multitude of water topics through seminar attendance and group discussions. We engaged in lively discussions about the various seminars they've chosen to attend across campus.

Spring is also when we hold the WRRRC Annual Conference, which is covered elsewhere in this newsletter, with more coming in the Summer issue. Preparing for the conference involves a whirlwind of activities on the part of WRRRC staff and student workers. This year's topic, #AZWaterFuture – Tech, Talk, and Tradeoffs, enabled us to cover issues ranging from "wicked problems," such as Colorado River structural deficits, to innovative solutions, including drip irrigation, technology, and education at all levels and through different approaches. Speakers addressed the difficult tradeoffs associated with living sustainably in the desert and the important dialogues to address these tradeoffs, such as through the Governor's Water Augmentation Council. While one day can only touch on these important issues, I hope that the conference fostered thought and further dialogue. I sincerely thank all speakers and participants. We at the WRRRC will continue to do what we can to bring diverse voices to the conversation and exchange of ideas. 🏡



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