New Water Realities

PROPOSALS FOR MEANINGFUL CHANGE

NM WRRI Report No. 364

Proceedings of the 58th Annual New Mexico Water Conference

Embassy Suites Albuquerque
November 21-22, 2013

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58th Annual New Mexico Water Conference

New Water Realities

—Proposals for Meaningful Change—

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Embassy Suites Albuquerque
Albuquerque, New Mexico

New Mexico Water Resources Research Institute

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PROPOSALS FOR MEANINGFUL CHANGE

Attendees

Adrian Hanson, NMSU (left) and Bruce Thomson, UNM (right) deliver the last day's luncheon lecture on *Changes & Challenges: Reflections on Water Issues & Management in New Mexico* with collective knowledge and much humor.

Al Utton guest speaker, Tanya Trujillo, Colorado River Board of California (second from right) and others at the conference.

Conference registration

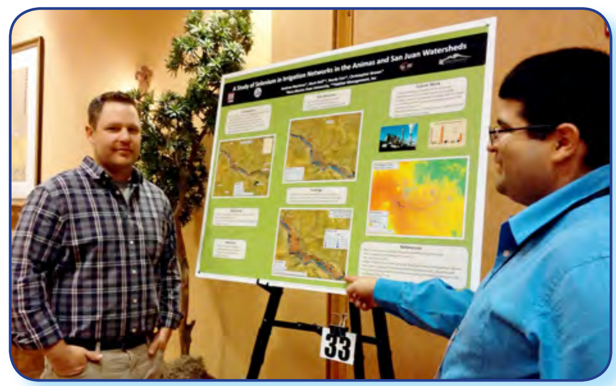
Three hundred plus people attended the 2013 Annual New Mexico Water Conference.

Poster Session

The poster session was a highlight at the conference with 40 posters displayed.

Racheal Jones of NMSU studies a poster at the Thursday, November 22, 2013 poster session.

Blane Sanchez, Interstate Stream Commission (left) and Rebecca Wacker, UNM (right) during the poster session.



Over twenty students displayed their posters at the poster session.

Agencies giving posters.

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Los Alamos National Laboratory

Sandia National Laboratories

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2013 Water Conference Advisory Committee

Aron Balok, Pecos Valley Artesian Conservancy District

Hilary Brinegar, Marron Associates, Inc.

Chris Canavan, New Mexico Environment Department

Peter Castiglia, INTERA

Gary L. Esslinger, Elephant Butte Irrigation District

Lt. Col. Antoinette Gant, U.S. Army Corps of Engineers

Dennis Garcia, U.S. Army Corps of Engineers

John Hawley, Hawley Geomatters

Matt Holmes, New Mexico Rural Water Association

Lela Hunt, Office of the State Engineer

Mike Landis, Bureau of Reclamation

Fidel Lorenzo, Acoma Pueblo

Julie Maitland, New Mexico Department of Agriculture

Nathan Myers, US Geological Survey

Bill Netherlin, Pecos Valley Artesian Conservancy District

Blane Sanchez, Interstate Stream Commission

John Shomaker, Shomaker and Associates

John Stomp, Albuquerque Bernalillo County Water Utility Authority

Jeri (Enid) Sullivan, Los Alamos National Laboratory

Bruce Thomson, University of New Mexico

John C. Tysseling, e3c, Inc.

Scott Verhines, Office of the State Engineer

Linda Weiss, US Geological Survey

Program

58th Annual New Mexico Water Conference
New Water Realities: Proposals for Meaningful Change
Embassy Suites Albuquerque, November 21-22, 2013

Thursday Morning, November 21, 2013

8:20 Welcome
Sam Fernald, New Mexico Water Resources Research Institute Director

8:35 The Future of Water in New Mexico
Lowell Catlett, New Mexico State University

9:05 Opening Remarks
New Mexico Governor Susana Martinez (video)

9:10 Moving from Policy to Solutions: Continuing to Build on Policy Ideas
New Mexico Senator Tom Udall (video)

9:15 Setting the Stage
John Shomaker, John Shomaker and Associates, Inc.

9:30 Changing Precipitation, Temperature, and Stream Flow Conditions
Dave DuBois, New Mexico State Climatologist
Greg Pederson, U.S. Geological Survey, Northern Rocky Mountain Science Center

10:30 Break

10:45 Western Perspectives
Water Transfers in the West
Nathan Bracken, Western States Water Council
The Importance of Agriculture
Dan Keppen, Family Farm Alliance

11:35 New Opportunities for Administration and Cooperation
Scott Verhines, NM State Engineer

12:00 Luncheon
2013 Albert E. Utton Memorial Water Lecture
Introduced by **J. Phelps White, III**, Albert E. Utton Memorial Water Lecture Committee Member

Hope for the Colorado River Basin – Recent Successful Agreements with the Republic of Mexico
Tanya Trujillo, Colorado River Board of California, formerly General Counsel for the NM ISC

Co-sponsored by

Thursday Afternoon
Moderated by Julie Maitland, New Mexico Department of Agriculture

1:45 Legal Realities and Solutions
Is Prior Appropriation Dead? **Em Hall**, UNM School of Law
Health of Settlements, **Steven L. Hernandez**, P.C.
Priority Administration, **Dudley Jones**, Carlsbad Irrigation District

2:45 Forgotten Rivers
Clean and Healthy Rivers, **Chris Canavan**, NM Environment Department
Healthy Watersheds & Water Quality, **Stephen Wilmeth**, Doña Ana Soil & Water Conservation Dist
Riparian Areas, **Steve Harris**, Rio Grande Restoration

3:45 Break

4:00 Stakeholders Panel: Proposals for Meaningful Change moderated by **José Rivera**, UNM
Frank Chaves, Pueblo of Sandia
Juan Garcia, El Rito Regional Water and Wastewater Association
Dan Guevara, NM Environment Dept
Steve Guldan, NMSU Sustainable Agriculture Center, Alcalde
Matt Holmes, NM Rural Water Association

Friday Morning, November 22, 2013

8:15 Legislative Perspectives, introduced and moderated by John Fleck, Albuquerque Journal
Federal View, **Kris Polly**, Water Strategies, LLC
State View, NM Senator **Peter Wirth**

9:45 Poster Session/Break

Moderated by Hilary Brinegar, Marron and Associates
10:45 Economic Impact of New Water Realities
The Relationship Between Energy and Water, **Scott Backhaus**, Los Alamos National Laboratory
Economic Impact of Western Agriculture with a Focus on NM, **Darryll Olsen,** Pacific NW Project

11:25 Solutions: El Paso as an Urban Example, **John Balliew**, El Paso Water Utilities

11:45 Conjunctive Use of Surface and Groundwater on the Pecos
Greg Lewis, Pecos River Basin Manager, NM Interstate Stream Commission

12:05 Implementation of Restoration Sites on the Lower Rio Grande
Elizabeth Verdecchia, International Boundary and Water Commission, U.S. Section

12:30 Water Data on the Web
David R. Maidment, University of Texas at Austin

1:00 Luncheon
Introduced by NM WRRI Director **Sam Fernald**
Reflections from Water Careers in the Ivory Tower
Retiring Professors **Bruce Thomson** (UNM) and **Adrian Hanson** (NMSU)

The Future of Water in New Mexico

Lowell Catlett
New Mexico State University

Lowell Catlett is a Regent's Professor and Dean and Chief Administrative Officer for the College of Agricultural, Consumer and Environmental Sciences at New Mexico State University. He is the author of numerous books and articles and won the university's highest award to a professor, the Westhafer Award. He works nationally and internationally with corporations and organizations doing futuristic planning concerning the impacts of technology on careers, lifestyles and the economy. Lowell also works with the U.S. Departments of Agriculture, Labor, Interior, Defense, Education, Energy and the World Bank. Lowell and his wife, Joni, share their home in New Mexico with several dogs and a passel of cats.

For those of you who aren't from New Mexico, welcome. We are very, very, happy that you are in our beautiful state. My wife who is a native New Mexican is always calling New Mexico, instead of the Land of Enchantment, the Land of Entrapment, because if you are fortunate enough to spend any time here, you will get entrapped by its beauty and you'll want to stay.

We are very proud of Sam Fernald as well, because in addition to being director of our state's water resources institute, that just so happens to be located at New Mexico State University, he is a distinguished professor in the College of Agricultural, Consumer, and Environmental Sciences. We are proud of Sam and appreciate the job that he is doing for the state of New Mexico's water.

I'd like to introduce one other person that if you don't know him, you need to get to know him. He is the Associate Dean of our Agricultural Experiment Station, Dave Thompson. Dave takes care of thirteen experiment stations that are scattered around the state. Although they are called agricultural experiment stations, they are experiment stations that make sure that any research that anybody comes to us with, gets done. Dave is open to any comments and suggestions.

I'm an economist by training so I know nothing about water other than occasionally I like to put it in whiskey. I can't help you much on the technical side of water at all. I can't tell you about the future of water because I am an economist. You saw that study that came out not too long ago about when you go to graduate school in economics they always try to make you take a class called econometrics, which is nothing more than throwing together a bunch of math, statistics, and economic data until the data gives you the answer you want. That is econometrics. When you do that, you naturally start thinking, well, I've massaged this data enough to where I think I can forecast the past, and so now I'm going to forecast the future. All econometrics professors tell us you can't forecast the future. Do not try to do it! But we cannot help ourselves, so we do it. They know we are not going to be able to help ourselves, so they always say this: If you are going to forecast the future, do not do it! But, if you are going to, and we know you will, give people a number or give them a date, but do not give them both. I think the interest rate will come to 11 percent. I'm not going to tell you when that will happen. I think something of economic significance will happen in 2013. It's not very helpful, but it's my profession, OK?

Despite that, of the whole bunch of us, there are some who gave people a number and gave them a date. The problem with that is that you can check our accuracy, and somebody had the gall and the audacity to do that. They went back for the last ten years, and found 7,000 right off the bat—7,000 forecasts where we gave people a number, and we gave people a date, and we forecasted everything from stock prices to the stock market to the unemployment rate. You name it, we forecasted it. And the accuracy rate? There were 7,000 forecasts, for ten years, and it turned out tragic—only 47 percent were correct. Do you understand what I have just told you? You can flip a coin, and beat us by 3 percent. I tend to make fun of my profession, but folks, trust me, every profession that we have checked, including healthcare, military, you name it, what do you think their accuracy rate is about the future? We don't know. So I am going to frame the future of water just a bit differently for that reason, because we don't know the future.

I love George Patton for many reasons. One of the things I love about him was this, he said, "No plan survives contact with the enemy." You can bet that as soon as the bullets start flying, guess what? You can kiss those plans goodbye. He also said this, "No good general ever goes into a battle." This is because they found out that we cannot predict the future, but we can prepare for it. The way you prepare for it is basically you imagine it, think about it, and you work on it because, if you do, when the future comes and there is not much of a forecast, you know how to prepare for it.

Today, I want to start with energy for just a second. Energy is an interesting one. The first class I ever had in the 1960s, was science class I never will forget. The teacher had the audacity to stand up and say, "At the current rate of consumption of gasoline, there will be no gasoline in 1980." I was thinking, I don't even have my driver's license yet! So what has happened to energy consumption since 1960? [Shoots hand up.]What has happened to the proof of known reserves of fossilized fuels? [Lingers a second and then emphasizes hand still upwards.] For three years, the number one oil and gas producing state in the United States has been North Dakota. Huh? Aren't there like three people in North Dakota? There are three very rich people in North Dakota. If you take that gas and oil reserve that they are tapping out of, and overlay that on top of Saudi Arabia, the largest proof of known oil and gas supply, it is slightly larger. Isn't it interesting as well that engineers tell us that below that bulkhead is another pool that is estimated to be three times larger? Then, somebody finally came out with a forecast that said North America, including Canada, the United States, and Mexico, now have the largest proven amount of oil and gas in the world. The estimate was—get this—was one trillion barrels of oil, but it could be as high as six-and-a-half trillion barrels. What?!

Here is the takeaway: go back ten years, and look at the annual reports by all the major gas and oil companies in the United States, and see if they had imagined a scenario that the United States would ever be energy independent again. You will find zero. They didn't even for the sake of the shareholders imagine that the world would ever be that way again. Wait a minute though, while they were saying that, they invented horizontal drilling, and they invented parabolic drilling. They were taking drilling platforms and going from sixty people that operated them to smart systems and robotics with only fifteen people operating them, while drilling three times deeper. They did this all within the last decade. Not a single scenario had said we would ever be energy independent again. We just can't do it. Hmm. Pick those reports up today and you will find that every one of them now has a scenario that says we will one day be energy independent again. They differ by days. Oh, and if you count net energy value, we reached that two years ago. The United States exported more net energy value than we imported.

What I am trying to tell you is, do not feel constrained by your thinking of what water is. I think we should remove from our vocabulary grey water and wastewater. Gee, can it be treated? There is physical scarcity, and there is economic scarcity. Gee, under most of New Mexico, certainly under where the Ogallala is by the Great Plains, is the Triassic aquifer that has how much slightly saline brackish water in it? We have no idea! Gee, you think we could be able to do molecular genetics and make some crops through agricultural experiment stations that use some slightly saline brackish water and then guess what? If we have almost an unlimited amount of it—is water an issue anymore?

All that I am trying to say is, don't be an oil company and be constrained by water. Fifteen years ago I gave a presentation called, "Energy, Energy, Everywhere." Do not be constrained because there is going to be a bunch of it, there already is. Now let's figured out what the hell we're going to do with it.

The second thing that I want you to take away is this, and it happened in 2010. I had the opportunity to be in New York, at the New York Agricultural Historical Society, which was basically the premier event in New York for the meeting of agricultural people. The Secretary of Agriculture stood before the audience in 2010 at the New York Agricultural Historical Society and said, "Do you remember in 1980 when we were at this conference, and we were told that the number one agricultural producing area of New York is Long Island? This was because Long Island produced a large and significant number of geese, turkey, poultry, and a large number of potatoes. We were very proud of that. In 1980, however, guess what? There was a whole bunch of people who wanted to buy mansions. So, all of a sudden, all of this prime agricultural real estate was being taken over for homes, and agriculture said, well, had to give it up. The highest value crop to grow is houses."

The Secretary continued, "I am very happy to stand before you as the Secretary of Agriculture of New York thirty years later in 2010 and tell you that the number one agricultural producing region of the state of New York is Long Island. No, we don't just produce a large number of common potatoes. We produce some very high value Inca Golds and Aztec Blues. We have a good wine industry, too. Yeah, we raise some geese, but it is for *foie gras*. Most of our turkeys are now free range." Agriculture did not only not vanish, it flourished when people understood that there were different markets and different ways to deal with it. All that I am saying about the future of water is, let's be creative. Let's not be constrained, and let's make it abundant.

I'll leave you with this, because it is one of the most memorable things that ever happened to me while I was at graduate school: An economist, a very famous economist from Boulder, Colorado named Kenneth Boulding—maybe you have read his works—I will never forget when I was a graduate student at Iowa State University and he was a visiting professor. He was this large man with glowing white hair and, well, just had a lot of stage presence. He got up there, and he got all of our professors that we thought were gods—because they have control of our lives—and he starts picking on all of these world class professors in economics and agriculture. He says, "I know what they are all telling you! I guarantee what they are telling you! The factors of production, the things that run an economy are land, labor, and capital. That is all there is, and they have big models to show it to you. They preach it every day, and they are wrong as hell! The only factors of production are two things: creativity and the persistence to get it done. That is all that has ever driven any society on the planet."

We do not have a water problem. We may have a creativity problem, but we damn sure don't have a water problem. Let's go make the future creative, and then let us as New Mexicans have the perseverance, and know that the world will come to be a little different, maybe even a little weird.

Thanks for coming to New Mexico, and thanks for being a part of this gathering.

Setting the Stage: WRRI 2013 Water Conference

John Shomaker
John Shomaker and Associates, Inc.

John Shomaker is President and a Principal Hydrogeologist of John Shomaker & Associates, Inc., in Albuquerque. He has over 48 years of professional experience in geological and hydrogeological studies in New Mexico and surrounding states. John holds BS and MS degrees in geology from the University of New Mexico (1963, 1965), an MA in the liberal arts from St. John's College in Santa Fe (1984), and MSc and PhD degrees in hydrogeology from the University of Birmingham, England (1985, 1995). He worked as a hydrologist for the U.S. Geological Survey (1965-1969), and as a geologist for the (then) New Mexico Bureau of Mines and Mineral Resources (1969-1973), before starting the consulting firm in 1973. Shomaker & Associates specializes in ground-water data collection and sampling, ground-water flow modeling, drilling technology and field supervision of drilling projects, water-supply planning, water-rights issues and expert testimony (including in interstate litigation before a U.S. Supreme Court Special Master), and environmental studies.

The presentations in past Water Conferences have tended to fall into two categories: they have been either explanations of some hydrologic fact, almost always accompanied by bad tidings, or arguments for one position or another in one of our on-going water controversies. This conference is going to be different—having recognized that we are facing some difficult realities in terms of future water supplies, every speaker is going to offer proposals for meaningful change. I will start to set our stage by defining a "meaningful change" as one that has some chance of being accepted by almost all of the people that would be affected by it. To propose a solution that means I get water and you don't, even if I give a very good reason, may not really offer meaningful change.

I have been tempted to say that prior appropriation is dead in New Mexico, but prior-appropriation can't really have died here, simply because it was never actually born. It is often urged that we must pursue the adjudications of water rights, and finish them, so that the rights can at last be administered according to our State law. But, of course, what we really do when things get tough is negotiate settlements that don't resemble the state-law prior-appropriation system very much at all. Simply to recognize that might qualify as a meaningful change.

Adjudication establishes a winner or winners, and a ranking of losers, which sounds like a rational way to allocate water, but what seems to have some promise of actually working an enforceable arrangement in which everybody gets most or all of what he or she needs, most of the time, or some acceptable substitute. The adjudication process provides a context in which that arrangement can be established, but simply completing an adjudication doesn't get us anywhere close to the goal, and takes up a lot of time. I admit that even the settlements are under pressure, and when real shortages do loom, we can understand that senior appropriators look wistfully at the rigid prior-appropriation system, and would like to actually try it.

Even if we finish an adjudication, we have not settled the allocation of water. There really is just no point in assuming that the losers in an adjudication, the juniors, will simply go away, or engage in some other line of work, maybe spend a few months in the south of France, because it happens to be a water-short year. As long as the due-process clause prevails, the actual distribution of water cannot be regularized, as we have learned through experience. We are in the thrall of what the economist Moises Naim refers to as "choking on checks and balances." He invented the word "vetocracy" to describe a situation like ours, in which almost everybody has the power of the veto, or at least the ability to create endless delay, and there really is no process for reaching a decision soon enough to be useful.

Most of us have read Judge Matthew Reynolds' very thoughtful paper presented to the New Mexico Geological Society last April, titled *A*

Proposal for Responding to Sustained Drought as New Mexico's "New Normal." Judge Reynolds suggests that the Legislature undertake some profound changes in our water law. When a law just doesn't seem to have worked after 106 years of trying, it is tempting to try something else.

But Judge Reynolds' paper has led me to two thoughts. One is a question: is it easier to begin all over again and try to craft a new set of laws and regulations, given the fact that we live in a vetocracy—or to negotiate comprehensive settlements within the existing legal framework as we have shown we can do. I can't help wondering what new legal structure would have brought us to the highly diverse settlements already completed, with any less struggle. In the Pecos, the Compact itself requires that New Mexico invoke priority when and as needed to meet our obligations to Texas, but what we really did was to hammer out a settlement that reduced the risk of a call by buying out a lot of farmers, and providing for augmentation pumping. That agreement hasn't solved all the problems for ever, but it's a big step toward that. In the San Juan, the settlement turns prior-appropriation on its head by giving the most senior appropriator a very junior priority in exchange for a lot of assistance for development.

Getting to the settlements so far has also provided some lessons that we can build on. For example, we might learn from the way the Lower Rio Grande operating agreement has worked out that a settlement that doesn't include the State is on an uncertain footing.

Of course, people being what we are, only a dire threat, and one that is perceived as a dire threat to all of the parties, must be in place before negotiation can be fruitful. A dire threat that just affects wildlife or the natural environment, or only junior appropriators, to choose a few random examples, is not enough. One category of dire threat is the devastating effect of a real priority call, but another fairly dire threat is the uncertainty for everybody that accompanies an endless adjudication.

My other thought related to Judge Reynolds' paper has to do with "sustained drought." What we now call sustained drought may indeed turn out to be the new normal, but that is not our fundamental problem. We have been struggling with these same issues for decades, right through the one-of-a-kind wet period of the last quarter of the 20th Century.

The drought has focused our attention, and if what we were recently calling a drought becomes the "new normal" we may have addressed our troubles a little sooner. But it had to be done anyway.

Another elephant in our living room has to do with the fact that the most senior appropriations, as you might expect, were established in the technological context of the early 20th Century, and depend on lots of surface storage, accompanied by large evaporation losses. This "storage charge" is water that simply vanishes from the system. These appropriations were made before groundwater was considered much of a resource. Rational groundwater use in conjunction with surface water supplies, what we like to call conjunctive use, is based on the premise that the groundwater reservoir will be treated as working storage, not as a separate resource that we will gradually deplete. In this way of looking at it, we will pump groundwater to make up for below-average surface-water supply, and we will allow water to accumulate in the groundwater reservoir when surface supplies are more than average. This has presumed, of course, that we actually know the average conditions. Now, unfortunately, we are beginning to see that the average itself is moving, and a conjunctive-use plan must include the ability to adjust to that.

Another elephant is that the advent of large-scale groundwater use around 70 years ago has led to a complete mismatch between prior appropriation on the one hand, and any useful way to manage water in some basins, on the other. The slow response of the groundwater system means that a priority call by a senior surface-water user is very likely to be meaningless, a "futile call" in our jargon. And in a basin with no surface water at all, prior-appropriation is more-or-less meaningless. It's hard to imagine how a priority call would work in the Estancia Basin, for example, if the most junior rights are in wells 20 miles away from the place where rights are being impaired.

I'm looking forward to our day-and-a-half of good solid proposals for meaningful change!

Changing Precipitation, Temperature, and Stream Flow Conditions: Part 1

Dave DuBois
New Mexico State Climatologist

David DuBois has been the New Mexico State Climatologist since February 2010 and located in Las Cruces. Although he is a native of New Mexico, he grew up on a farm in rural southern New Jersey. He is the director of the New Mexico Climate Center based out of the Plant and Environmental Sciences Department at NMSU. As State Climatologist, Dave teaches and trains students at NMSU as well as providing climate information and education to the public. He maintains an active research program in air quality and climate, participating in studies to understand the nature and origins of atmospheric particulates that we breathe. He is also the New Mexico Community Collaborative Rain, Hail and Snow (CoCoRaHS) state coordinator and looking for more volunteers from all corners of New Mexico to join. Dave holds physics degrees from Rutgers and NMSU, and a doctorate in atmospheric sciences from the University of Nevada Reno.

Editor's Note: The following paper represents a transcription of the speaker's remarks made at the conference. Remarks were edited for publication by the editor. The speaker did not review this version of his presentation and the editor is responsible for an errors.

Greg Pederson and I will work like a tag team this morning. We will talk about what is going on with our climate, water resources, snowpack, and so on. The first part of the presentation is going to be on the short-term perspective starting with last month and going back a few years to look at how our drought changes over time. Then Greg will talk about the longer term to put the short-term into perspective.

I like to work with visualizations and will describe each of my slides. Figure 1 shows September 2013 precipitation, which was an amazing month. A great storm came through New Mexico and we said if we have more months like September, we will be in pretty good shape. It was one of those events where everything came into place just right. The blue indicates 200-300% of what is normal for a long-term average and most of the state benefitted from this event. It was only one event, and it was rainfall, not snowpack. But coming after several years of drought, it was very welcomed. Only most of Lea and Hidalgo counties missed out on the rain.

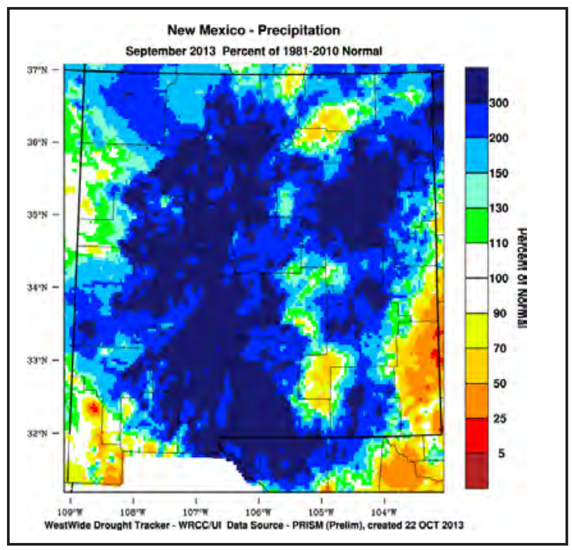


Figure 1. New Mexico - Precipitation

Figure 2 shows the monsoon for the months of July, August, and September. I chose a few of the stations and looked at the percent of average precipitation over those three months. You can see the green dots represent precipitation at more than 150% of normal, and yellow dots at 50-100%. A few places show more than 200% of the long-term average. Everywhere, except in Lea County, did really well over this monsoon. The monsoon is one of the hardest times to predict and we were very happy with the outcome.

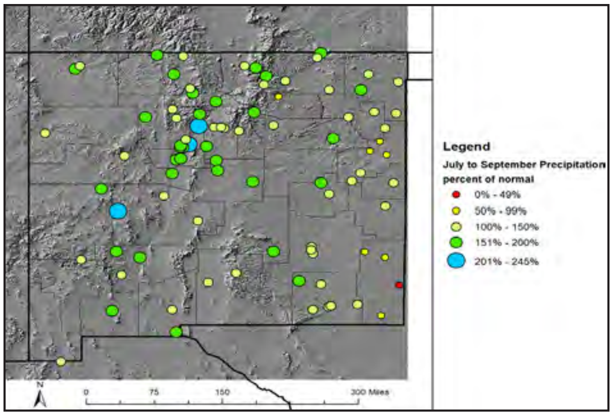


Figure 2. "The Monsoon", July-September precipitation percent of average

For at the long-term, if you look at precipitation for the first ten months of the year, from January through October of 2013, it's not too bad, but you start to see the effects of our drought. (Fig 3) Even with that really wet September, we continue to see this longer period of drought hanging over us. Only the middle of the state along the central valleys are they still in the near-average. Sierra County, Valencia County, Utero County, and a few other areas are still way over 100% of average. But anywhere that is yellow and orange represents drought lingering in the 75, 60, and 50% of average rainfall.

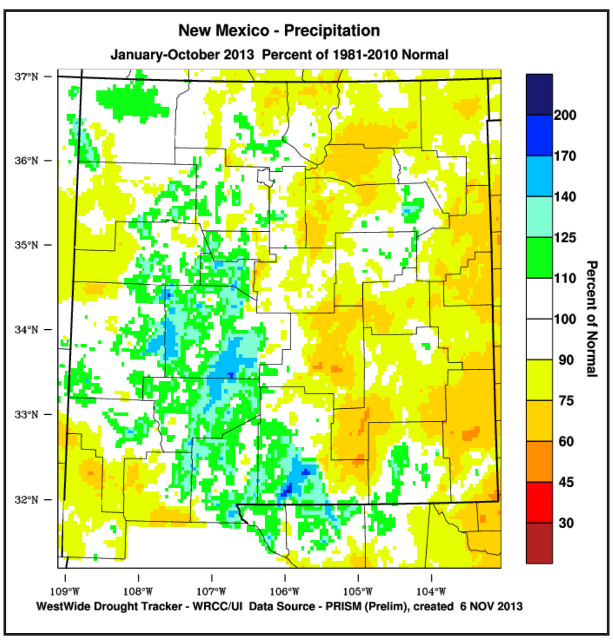


Figure 3. January to October 2013 percent of long term average - State-wide average 94%

So what about November? I plotted a graphic on the 18th. Figure 4 is already old news because we are looking outside this morning and are very optimistic about what the storm will produce. Hopefully everybody who was in the drought areas will be impacted by this storm. It does look like the storm is going to miss all those red areas again. The areas that are already doing well are going to be getting more rain, and the areas that have not been doing so well are going to be missing out on some of this storm's precipitation, but they will get some.

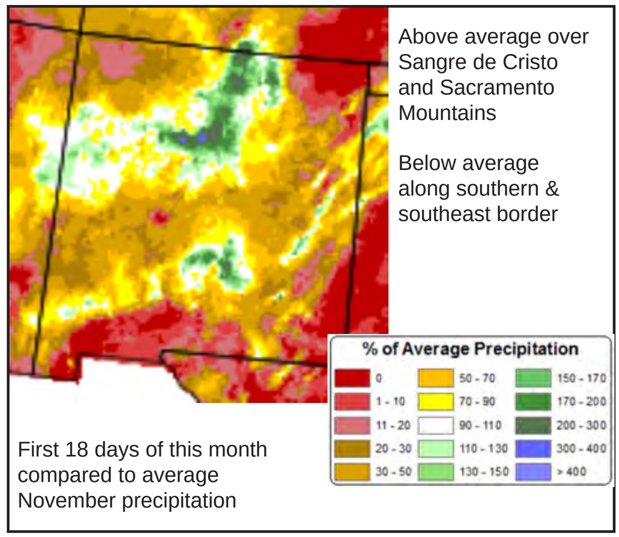


Figure 4. January to October 2013 percent of long-term average - Statewide average 94%

What about soil moisture? We look at what is coming down from the sky, how it actually infiltrates, and there is a new product I am very excited about. I have been working with the guys at NASA to produce a satellite-based model that looks at soil moisture. From two moving satellites, they can estimate how much soil moisture is below based on how much gravity is below them. Soil moisture will be calculated and put into models like this one on Figure 5. We are looking specifically at the first few centimeters of soil, and it pretty much matches what we suspected. The wetness percentiles are relative to the period from 1948 to 2009. In areas that enjoyed heavy precipitation from the September event, such as in the northern mountains, the soil moisture is continuing to look pretty good. But the areas that missed out, like in the Southeast corner, are not doing so well; they are in the 2 to 5 percentile range for that 61 year period.

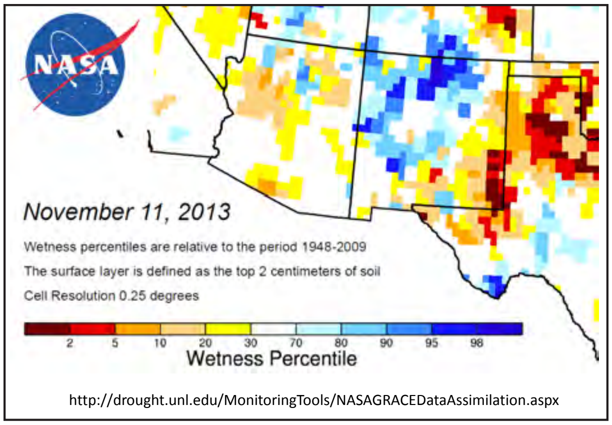


Figure 5. What about soil moisture?

How do we rate in terms of the period of record, which is about 118 years for the whole state of New Mexico? Figure 6 presents a table with the first green line representing the last two months of September and October. How does that rate in terms of all the September and October months going back to 1895? It registered as the ninth wettest on record. Since 1895, the wettest year was in 1941. The table is color-coated by how wet the year was. If the period is in green, then it is in the top ten wettest years. If it is in brown, it is in the bottom third driest in terms of precipitation. If we look at the last twelve months (average going back to 1895), we were right at about average. What about if you look back further? At two years, three years, and four years back, you can see the brown representing the effects of our long-term drought. The last three years have been the fourth driest. The four-year period has been the thirteenth driest. You can see the effects even with the large amount of rain we had in September. We are still in drought.

- The last 2 months have been the 9th wettest on record
- Past 3-yrs have been the 4th driest

Driest | ≤1/10 | ≤1/3 | Normal | ≥1/3 | ≥1/10 | Wettest

Period	Amount	20th Century Average	Departure	Rank (out of 119 years)	Record	Wettest/Driest Since
Sep - Oct 2013 2-month period	4.49" (114.05 mm)	2.73" (69.34 mm)	1.76" (44.71 mm)	111th Driest	1956	Driest since: 2012
				9th Wettest	1941	Wettest since: 1985
Nov 2012 - Oct 2013 12-month period	13.66" (346.96 mm)	13.51" (343.15 mm)	0.15" (3.81 mm)	68th Driest	1956	Driest since: 2012
	Ties: 1995			51st Wettest	1941	Wettest since: 2010
Nov 2011 - Oct 2013 24-month period	23.02" (584.71 mm)	27.03" (686.56 mm)	-4.01" (-101.85 mm)	24th Driest	2012	Driest since: 2012
				94th Wettest	1942	Wettest since: 2011
Nov 2010 - Oct 2013 36-month period	31.04" (788.42 mm)	40.50" (1,028.70 mm)	-9.46" (-240.28 mm)	4th Driest	1953	Driest since: 1956
				113th Wettest	1942	Wettest since: 2012
Nov 2009 - Oct 2013 48-month period	46.54" (1,182.12 mm)	53.94" (1,370.08 mm)	-7.40" (-187.96 mm)	13th Driest	1956	Driest since: 2012
				103rd Wettest	1988	Wettest since: 2011

Figure 6. Statewide precipitation rankings

Figure 7 is a nice visualization called the Standardized Precipitation Index, or SPI. It is widely used by climatologists to evaluate drought over many time scales. It goes from negative three to positive three with negatives being drought, and wherever it is positive, it is wetter. Zero represents the average. It is somewhat like a standard deviation with how much you are above or below the mean. Brown areas represent extended drought. The x-axis is time from the 1980s to the present. The y-axis is length of time and assesses drought from one month to five years. It is basically what the extent of drought is as it goes along in time. Green areas represent wet periods. You can see the 1985 wet period and again in the 1990s. You can see when drought comes up in this negative SPI. You have another one around 2002. It was wet around 2006–you might remember that we had a really wet period right after the summer, and you can see its effect here. This is for all counties in New Mexico. You can see that it is the darkest it has been in terms of this index going back all the way to the 1980s. You can see we exceeded this time period in the 2000s, so it is both a short-term and long-term drought. If it were a short-term drought, you would only see it in the bottom of this plot. You can see it is extended all the way in the darker three-year period. That is how we track from a perspective of the current few months, and the perspective of the last five; we then put it all the way back into the last thirty years.

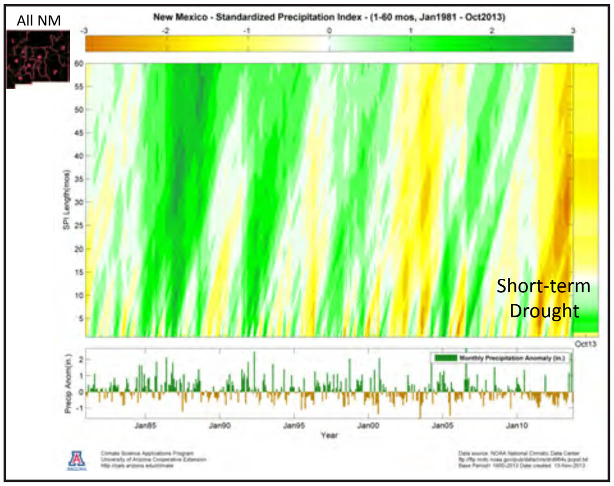


Figure 7. Standardized Precipitation Index (SPI)

Figure 7 was for the entire state and Figure 8 is for Climate Division 2. As climatologists, we like to group things. We like to separate things and find patterns. Climate Division 2 is in the northern mountains of New Mexico. Where there are high elevations in New Mexico, we like to look at what is going on with our snowpack. In Figure 8, you can see a fairly dry period in the 2000s, and we are seeing another dry period. This is actually much worse than in the last thirty years.

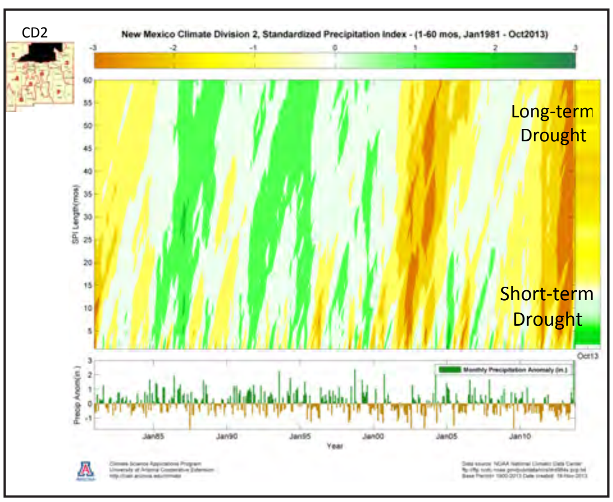


Figure 8. Climate Division 2

Now let's look at temperature. We see lots of plots like the one in Figure 9 that follows annual statewide temperatures back to the period of record in the 1890s to the present. The dots are an average yearly temperature. We can see some long trends: it was very warm in the 1950s and you see the corresponding bump; we have been slowly climbing since the 1970s or so. Then we have in 2012, the highest annual temperature in the period of record. Think of the impacts of a continuously warming state. I have been looking at all of the stations in New Mexico, and a lot of the warming we are seeing is from rising morning temperatures. It isn't in the urban areas, it is in rural areas. I kept looking at landscape changes and how that affects temperature, and how it looks compared to the entire western U.S. That is one of the questions we need to look at to solve some of our problems. Also, how and what does that impact in terms of agriculture? Snowpack is another big concern: we are seeing temperatures in higher elevations warming as well.

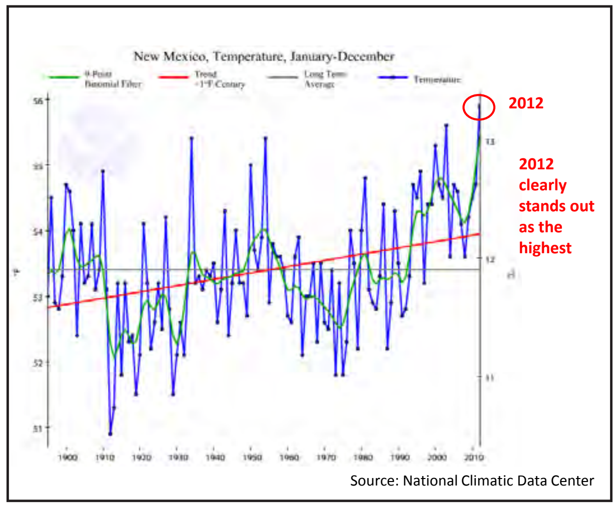


Figure 9. Annual Statewide Temperatures since 1895

Climatologists look at the drought monitor (Fig.10). It goes from a scale of zero to four with zero being normally dry and four being exceptionally dry. The return frequency probabilities as indicated on the figure start all the way back at 50-100 years.

Drought classification puts drought in historical perspective

DM Level	Name	Frequency
D0	Abnormally dry	3-5 years
D1	Moderate drought	5-10 yrs
D2	Severe drought	10-20 yrs
D3	Extreme drought	20-50 yrs
D4	Exceptional drought	50-100 yrs

Figure 10. U.S. Drought Monitor

Looking at New Mexico as a whole from around 2000, Figure 11 shows the last thirteen years. It shows percent of land area within each drought category. A lot of the D4 category came in 2003, and again in 2011, 2012, and 2013. There hasn't been any time over this period that we haven't had one area that wasn't in drought in New Mexico. That is a telling statement about our state, our climate, and the variability. You can see intense periods that come and go and predicting these deviations is hard. We are at the mercy of other cycles like the El Niño Southern Oscillation that dries our precipitation in the winter time.

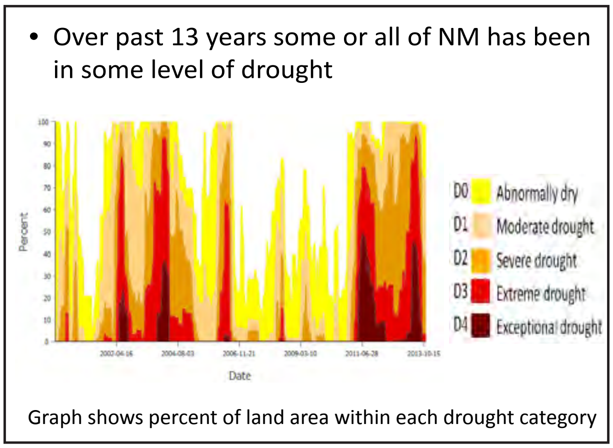


Figure 11. State-wide NM Drought Monitor

Figure 12 and 13 show the drought monitor before and after the summer monsoon. In the latest drought monitor graph, we still have a few of the D3 areas over here in Lincoln County and around central New Mexico. In effect, we are still in drought even with that big summer 2013 monsoon.

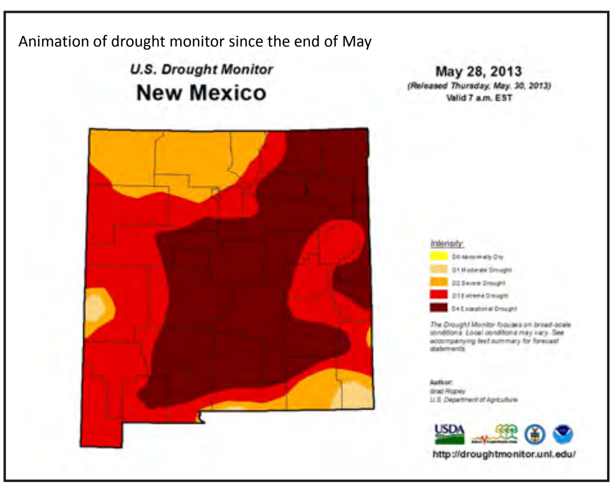


Figure 12. U.S. Drought Monitor, NM, May 2013

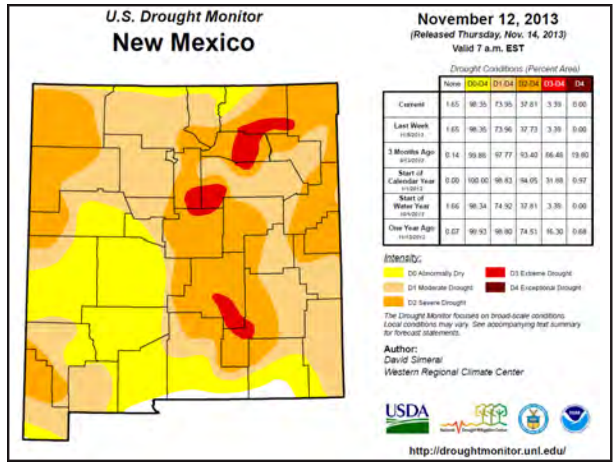


Figure 13. U.S. Drought Monitor, NM, Nov. 12, 2013

What are some of the impacts of drought? I could do a whole seminar series on drought impacts. I want to pick just one that is interesting to me. One of the questions of feedback systems in climate change as how does the landscape change affect the water cycle? I am particularly interested in the dust effects on snowpack. Figure 14 is a satellite image of an event north of Gallup in 2010. This is an event that made the snow brown up in the San Juan Mountains. Much has been written about the change of the melt cycle of snowpack in the San Juan Mountains. We are looking at the long-term effects and how it changes the overall hydrologic cycle when things melt much quicker.

Figure 14. Dust on Snow 2009 May 19. San Juan Mtns. Source from NE AZ and NW NM

Figure 15 shows current capacity at Elephant Butte. We are just shy of 10%. Last time I looked, earlier this week, we were at 216,000 acre-feet out of 2.1 million acre-feet capacity. Storage bottomed out this summer at 60,000 acre-feet. This is one of the effects of our drought.

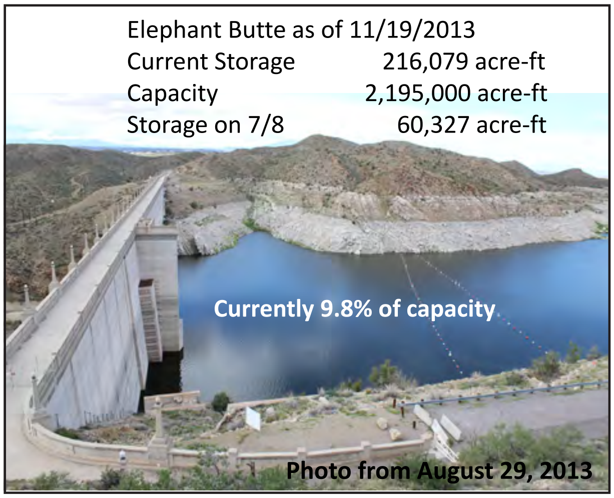


Figure 15. Capacity at Elephant Butte

Figure 16 is a picture from satellites just two days ago. The snow is represented in turquoise and I will show you the measurements of snow as indicated by the little snowflakes. Figure 17 is a plot of the amount of our snowpack as of a couple days ago. The blue line at the far left corner is our overall median from the stations in northern New Mexico and southern Colorado. The little red circle shows us where we are right now. We are just a little above the long-term median for the last thirty years, which is a positive thing, but it doesn't say how it will look this coming snow season. The green line represents 2013; it is a miserable line and hopefully we won't repeat it.

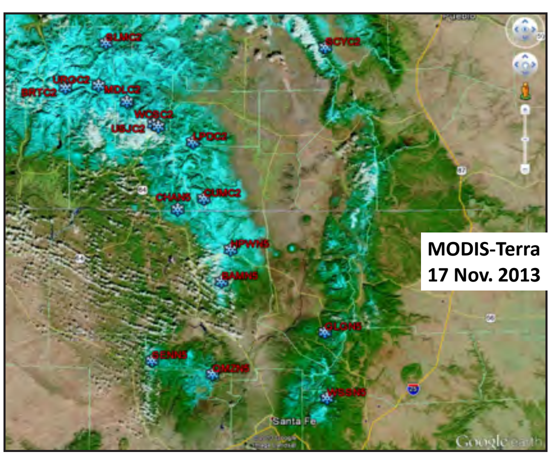


Figure 16. Satellite image of snow

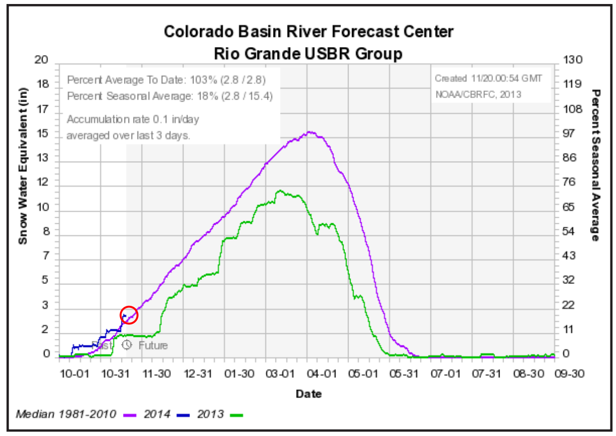


Figure 17. Rio Grande Basin + snow observations

Next are stream flow figures. The first is on the Rio Grande at the Otowi guage and shows percentiles (Fig. 18). The black line is the actual 28-day average flow in cubic feet per second. Even though we all know this is a well-managed system, you can still see the effects of drought on these wet periods. Looking at last year, 2012, you can see that we are very much down in the lower percentiles compared to other years. Compared to the Pecos (Fig. 19), you can see the real effects of flow from the Pecos before it goes into Santa Rosa Lake. We had some very low periods in 2003 and 2004, and then did fairly well until 2012. We were off the charts in terms of percentiles and were probably at record low amounts of flow. This speaks to variability. I want to impress upon you the amount of variability and how things can change very quickly in this system. We went from 1 cfs to highs of a couple orders of magnitude in a matter of weeks.

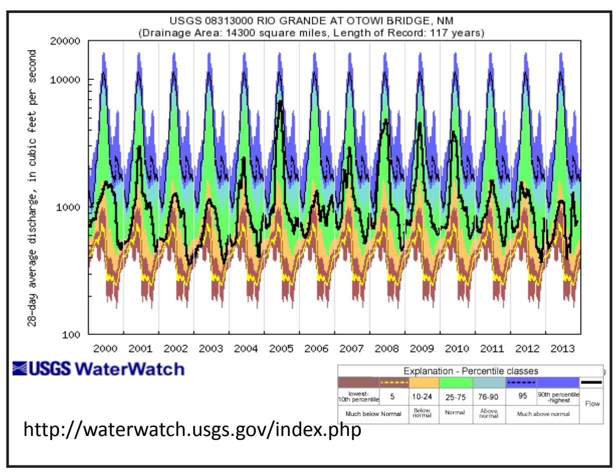


Figure 18. Stream flow on the Rio Grande at Otowi Gauge, Otowi bridge at highway 502; 28-day average flow in cubic feet per second

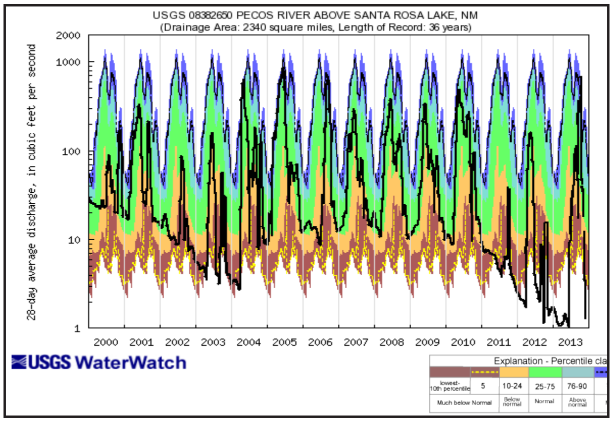


Figure 19. Stream flow on Pecos River above Santa Rosa Lake; 28-day average flow in cubic feet per second

What is the outlook? In terms of sea surface temperature, specifically in the Pacific, we are looking at what we have been calling La Niña, which is something between El Niño and La Niña. The forecast has been showing that we are probably going to be staying in that situation for a while (Fig 20). There isn't much predictability in where we are going, which doesn't help us climatologists–we are just scratching our heads. Figure 21 shows green for the probabilities that this to continue.

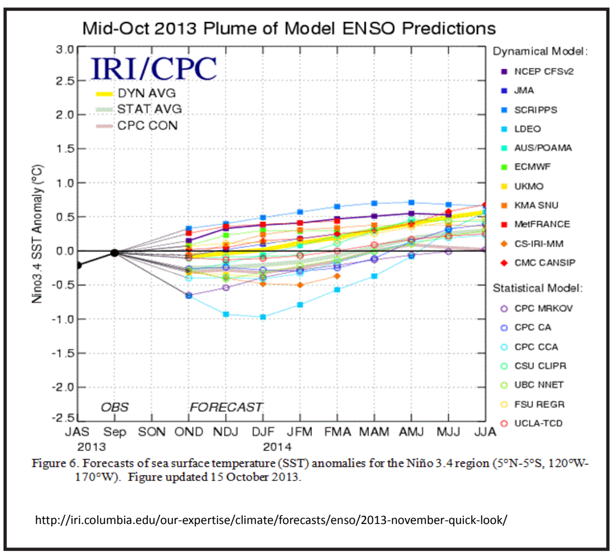


Figure 20. Forecast - ENSO-neutral is expected through Spring 2014. Seasonal predictions: Many models predict a gradual increase from slightly cooler than average to warmer conditions as the spring appropaches.

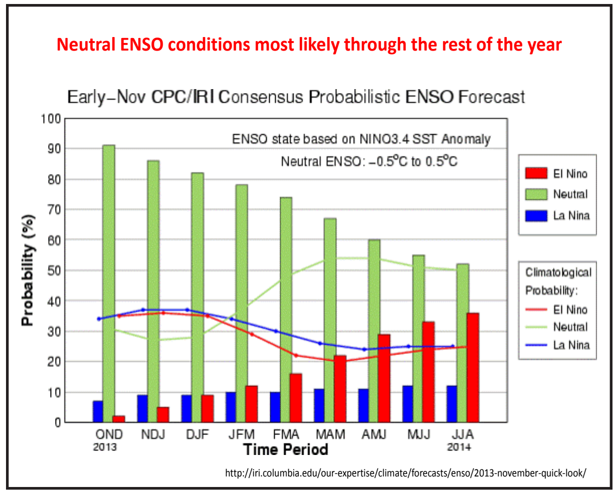


Figure 21. Seasonal Forecast

Figure 22 is the precipitation outlook for November through January. We haven't been able to predict what will happen in the wintertime, but we do have some guidance from the Climate Prediction Center. We see increased probabilities for below average precipitation and above average temperatures (Fig. 23). A good message is that it looks like the Colorado upstream will not be affected.

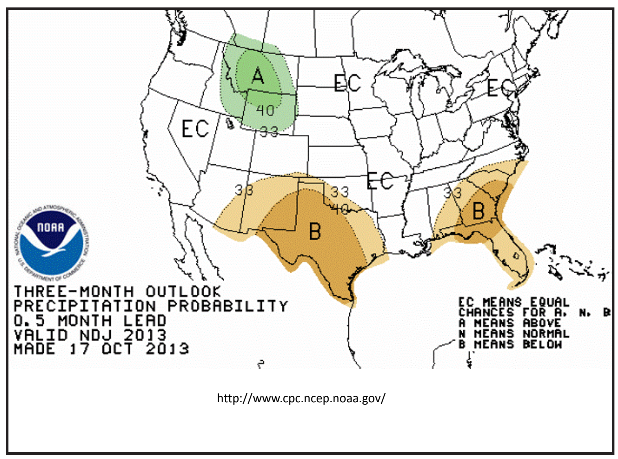


Figure 22. Nov. – Jan. Precipitation Outlook

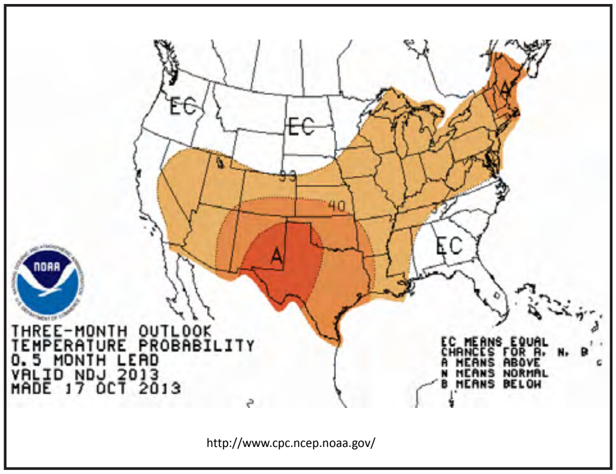


Figure 23. Nov. – Jan. Temperature Outlook

Figure 24 is the drought outlook through January 31, 2014. The brown chocolate color indicates that drought either persists or intensifies, and the lighter brown shows where drought development is likely. It is not too surprising, but as my message here is that we still have white in areas where we think drought will not intensify or appear, which is good. The bad thing is that most of the Rio Grande Basin is covered by brown.

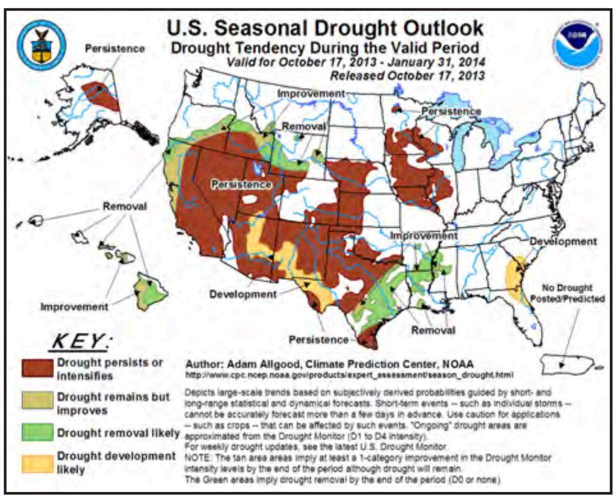


Figure 24. U.S. Seasonal Drought Outlook

Lastly, I want to plug the volunteer assisted CoCoRaHS network (Fig. 25). If you are interested in volunteering, please see me. It is one of the ways we gauge climate and drought in the state of New Mexico and across the country including Canada. It is very helpful and everybody can take part.

Figure 25. CoCoRaHS

I want to leave you with a peaceful photo from the mountains where hopefully we will be getting some snow soon (Fig. 26). My contact information is included.

Thank you.

Figure 26. Contact information

Changing Precipitation, Temperature, and Stream Flow Conditions: Part 2, the long view…

Greg Pederson
U.S. Geological Survey
Northern Rocky Mountain Science Center

Greg Pederson is currently a Research Scientist with the U.S. Geological Survey at the Northern Rocky Mountain Science Center in Bozeman Montana. His educational background includes a bachelor's degree from Michigan State University, a master's degree from Montana State University, and a Ph.D. from the School of Natural Resources and the Laboratory of Tree-Ring Research at the University of Arizona. Greg's research has focused on past, present, and projected future changes in climate and the associated changes in snow, water resources, and ecosystems of western North America.

Editor's Note: The following paper represents a transcription of the speaker's remarks made at the conference. Remarks were edited for publication by the editor. The speaker did not review this version of his presentation and the editor is responsible for any errors.

Thanks for having me back in this beautiful state again. I come from another one of our beautiful states, Montana, and I have to say I was excited to come to the Southwest because I was going to get a bit more summer before eight and a half months of winter sets in. Then sure enough, I come down and it is snow and cold temperatures here, but it is five degrees in Bozeman today, so we are much better off here in New Mexico.

That also brings up another point: Mark Twain summarized best the difference between weather and climate when he said climate is what you expect, but weather is what you get. I think that is a good thing to keep in mind as we start talking about climate change projections. Even in some of our best climate reconstructions, we anchor people with where this region has been hydrologically and where it is going. You will notice a lot of the core tenets of what Sam Fernald talked about. Fellow speakers Lowell Catlett and Dave DuBois will come up in my talk, especially as we start discussing projections into the future.

Figure 1 is a roadmap of what I am going to discuss. I'd like to anchor everybody in the recent changes in climate at a global and then regional scale in temperature, snowpack, and hydrology. It provides very simple lessons that will carry through the entire talk. Then I will summarize much of what has been shown in past research across the western U.S., both warming across the West and its effects on snowpack, glaciers, and our water resources as well as altering our hydrographs. Then, to really anchor everybody in and make their eyes cross, we'll hop into the last thousand years because there are some very important lessons when you look at the past snowpack and stream-flow variability and we start thinking about the future. I was at a meeting in Colorado not long ago talking with water managers and the director of the Southern Nevada Water Authority was there. He summarized it best. He placed himself in a climate agnostic group because he said whether it went backwards or forwards it scares the crap out of him. The way the climate system operates presents big challenges for living in these desirable regions given growing human populations. It is that nexus of climate, humanity, and the human desire to live in these desirable places, like New Mexico, that is one of our problems as water managers. Then, I will talk about projections.

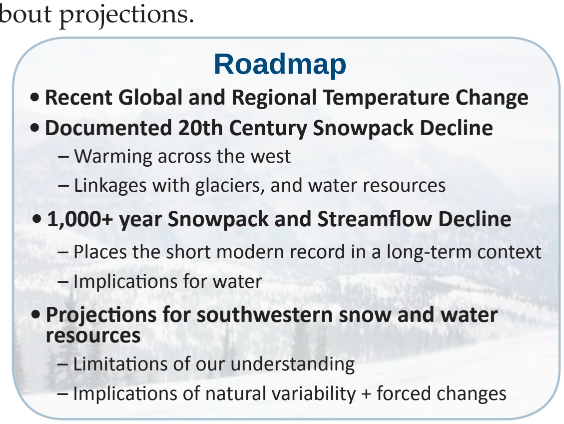


Figure 1. Roadmap of discussion

What everybody needs to keep in mind is that all models are wrong, but some are useful. In the projections category, we get a lot of useful projections out of them, but the climate system and Earth only gives us one. There is only going to be one climate realization, and none of the models will get it right, or only by chance if they do. But, hopefully they will point us down the road at how to plan for what is likely to be next.

Figure 2 provides a recent global update. Dave DuBois talked about this. The year, 2012, wasn't just the hottest year in New Mexico, it was the hottest year in U.S. history, but not globally. It ranked as ninth warmest globally. Our new record of the hottest year globally was 2010. But, if you look at what happened in 2012 in terms of land surface temperatures, they are between two and four degrees Celsius above average for the whole year. We witnessed both record melt in Greenland as well as minimum ice extents over our polar areas, which is a big climate game changer because that actually does have a large impact on our predominant storm tracks and where precipitation and moisture goes across the West. It seems counter intuitive, but as ice comes off the polar regions, we will be operating under a new rule set. But, if we zoom in on the U.S. for 2012 in Figure 3, we see our spring temperatures. I bring up spring temperatures because of their importance, especially minimum springtime temperatures due to their influence on our snowpack. You will see it across much of the West and the Great Lakes region. We are somewhere between two, and up to eight and even fifteen degrees Celsius above the long-term average in the February-March time frame. This is critical because February and March are the months that we rely on for snowpack actually falling on mountains, with temperatures staying cold enough so that snow can still accumulate and stick around. Snow basically represents free storage that accumulates in our mountains and is released slowly through our summer months. We don't have to build dams to hold the stuff up there.

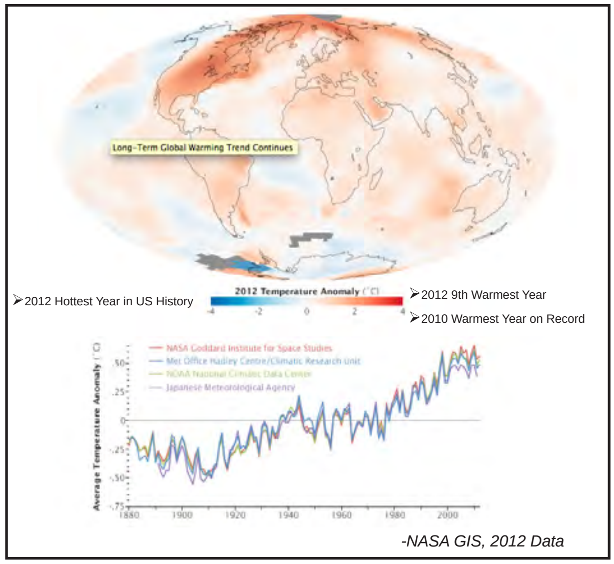


Figure 2. Historic Observed Changes: A Global Context

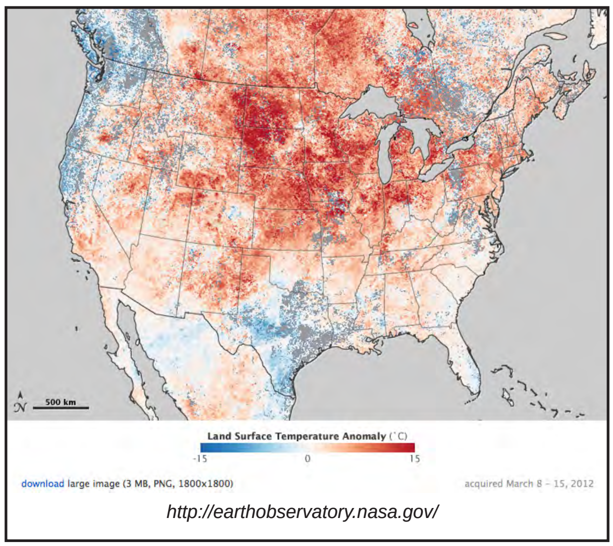


Figure 3. Historic High Temperatures

Between 2011 and 2012, we had the perfect Dr. Jekyll and Mr. Hyde years. In 2011, across most of the country except for New Mexico, we had extremely cool springs and high winter precipitation that gave us some of our record snowpack of the twentieth century into the late spring. That also led to some flooding problems in the Upper Mississippi River Basin when it melted. The white areas on the map in Figure 4 show high snow cover and basically high snow levels. In 2012, we were running temperatures far above normal. The blue areas of the map grew, you could see that temperature influence, plus an overall reduction in precipitation driving that snow out of the mountains, and leading to those big drought setups that Dave DuBois pointed toward. The interplay between temperature and precipitation, much like on our reservoirs as Sam pointed out, shows us that it is the integrating of these two parts of our climate system that generates high or low snowpack and variability from year to year.

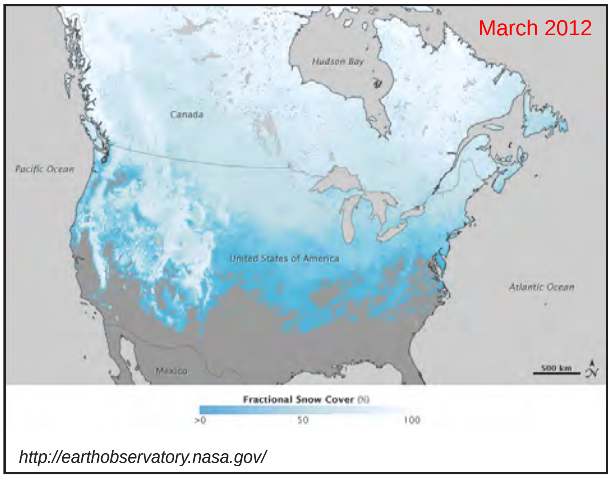


Figure 4. Drive Low Spring Snowpack

Now I will summarize the published literature about where we have been in the past century, especially in the last fifty years, with changes in temperature, precipitation, glaciers, snow, and ice across the West. Since the 1950s, we have seen our minimum temperatures warming faster than our maximums (Fig. 5). We have seen an amplitude of near a few degrees Celsius in most of the West with much of that centered in the Northern Rockies of the Pacific Northwest. The South-Southwest area has been spared somewhat; it hasn't been as rapid, and part of that is due to natural variability of the climate system. We've seen the greatest warming across the North, and in the classic detection and attribution sense of climate and climate modeling studies, you can't generate this amount of warming with natural variability alone. Again, given the warming we would expect from an El Niño event across the West versus a non-El Niño year, you have to consider the role of greenhouse gasses plus those natural influences to generate this magnitude of warming in the past fifty years.

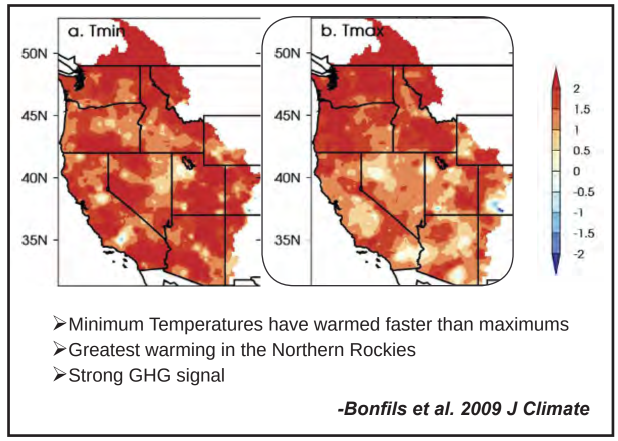


Figure 5. Recent Warming: 1950-2000

Mirroring that warming across the West, you also see general trends in the general time of year that we have peak snowpack, which is around April 1 in most of the mountains of the western U.S. (Fig. 6). At least by April 1 it is a good forecaster for how much snow we are going to have. You can see from the 1950s that snow has declined on the order of 15-60% with the worse declines along the Northern Rockies and the Columbia River Basin. The region in the Upper Colorado has seen a mixed response. The low and middle elevations have shown the same declines, but the higher elevations were showing level to increasing trends of snowpack. One of the reasons we are seeing this response is that a majority of our snow mass in the Northern Rockies fits much closer in the springtime to that zero degrees Celsius melt/freeze threshold than the high mountains of the South and Southwest. It was only about a degree Celsius over the last 30 years away from that freeze/melt threshold, so when you warm things up a little bit or cool them down a little bit, you see a big snow response much more than we are registering down here in the South and Southwest—that is both good and bad.

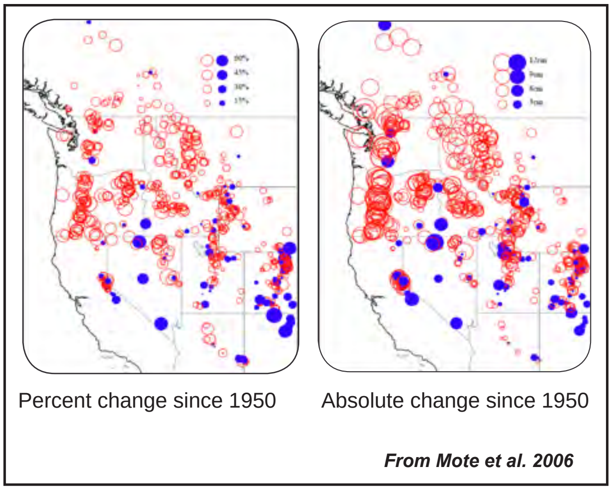


Figure 6. Trends in *APRIL 1* snow pack: 1950-2000

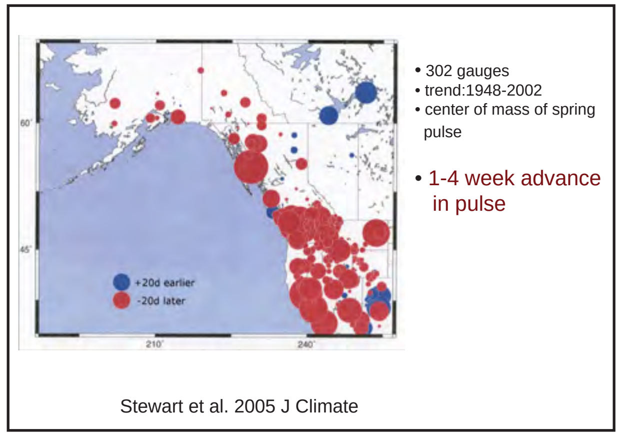


Figure 7. Trends in Snowmelt Timing

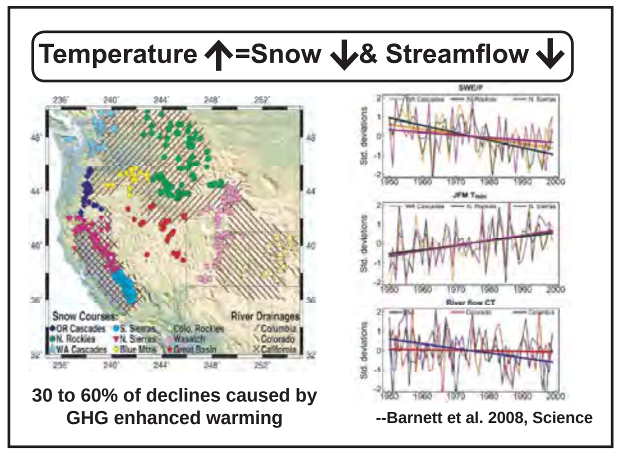


Figure 8. Increasing Temperatures Result in Less Snow and Streamflow

Going back to our snow, which is free storage, and turning to what is happening in our streams, you can see both lower peak flows in most of the West, with that mixed response across the Southwest, and about a one- to four-week advance in that snowmelt driven pulse (Fig. 7). We are seeing earlier and earlier stream flow registered at stream gauges, which leads to the problem of how to manage this resource through hot and dry summers; you have to manage this limited resource through increasingly warm, dry, and long summers. The general story line, and what the data show, is that as temperatures increase, we have seen a decrease in our snowpack with earlier melt-off of snow leading to earlier peak flows in our streams and lower base flows in the summer. It is greatest along the Cascades and Northern Rockies (Fig. 8). You'll notice that one of the more resilient basins, even as bad as this recent drought has been through these long-term trends, has been the Upper Colorado River Basin, at least on the basis of timing based on where this snow sits. The primary driver for this major response is the increasingly warm temperatures, especially the minimum nighttime temperatures in January, February, and March. Everybody who gets involved in the game of detection and attribution of what is causing this change has seen this recent change where about half of the decline of the snowpack has been amplified by natural drivers such as the Pacific decadal variability, and the El Niño Oscillation, and the remaining half seems to be due to the warming of greenhouse gasses. Study after study has parsed it out, but the exact amount is hard to say.

Figure 9 shows this hydrographically; this is middle 21st century and already similar to what we have seen in warming across most of the West. What we expect, for example, is a three-degree Fahrenheit increase. The blue line shows an historic plot where spring flows from snowpack peaking around June and early July run off into your base flows by September. What is more or less expected, and what is being detected at our stream gauges, is this shift toward diminished winter flows with more spiky winter flows due to increased mid-winter melt events of our high elevation snowpack. This shifts your hydrograph in runoff starting earlier and moving toward a lower peak that also occurs earlier. You then slide into this in early August where you are already seeing low-base flows that you used to see in September. That is a good visualization of what is happening and what is projected to keep happening. And similar to reservoirs, which are good integrators of the effects of temperature and precipitation on water balances, glaciers serve the same purpose but for the frozen part of our hydrologic system, the cryosphere so-to-speak. You can use old geologic and historical maps (everything that the USGS has been doing for the greater part of a century) and see the changes in glaciers and ice masses across the West. They tell this story better than any of the graphics I have can show you (Fig. 10) Looking at the decline in terms of a fraction of glacier area lost since 1900, you see that basically every place across the West is registering losses (Fig. 11). Some of our largest glacial losses are in areas like Glacier National Park in northern Montana where we have gone from a high of around 150 glaciers at the height of the last Ice Age to around 25 remaining today. The story is quite similar for the Yellowstone ecosystem where the 66% loss in area equates to about an 80% loss in mass.

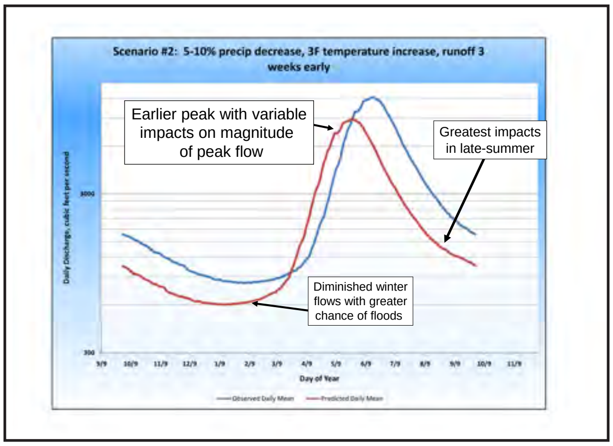


Figure 9. Projected Impacts of Increasing Evaporation & Earlier Snowmelt

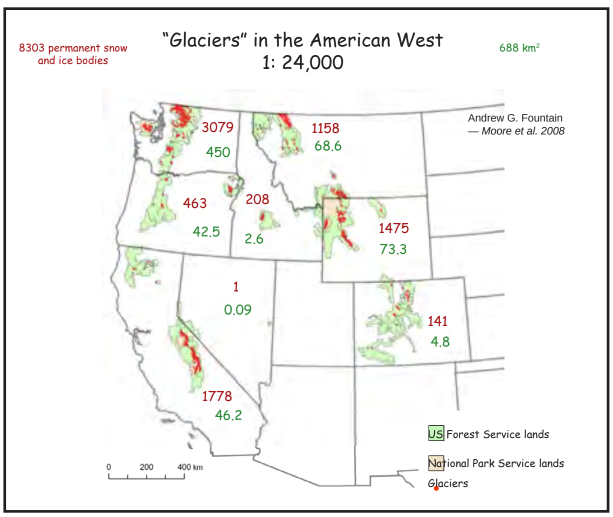


Figure 10. Glaciers in the American West

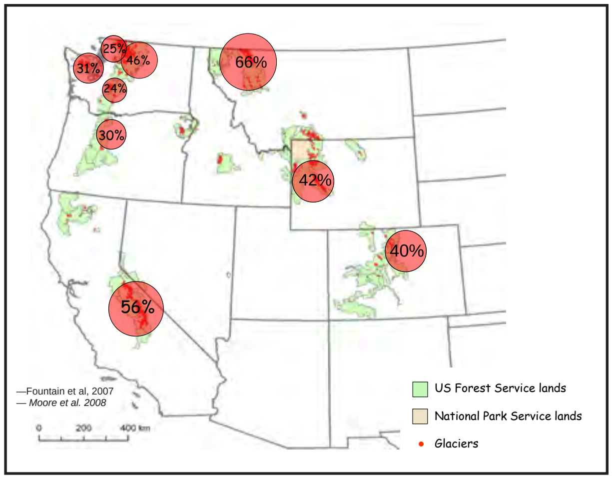


Figure 11. Fraction of Glacier Area Lost since 1900

Pictures tell the story best. Figure 12 shows these rapid and massive high elevation changes. The photos show Boulder Glacier in Glacier National Park, Montana in 1910 and in 2007. You can even see where its maximum extent once was from the entire Holocene. Sperry Glacier in 1913 and 2005 shows similar dramatic changes (Fig. 13). Massive changes have happened, and this represents our storage coefficient in the western United States. Ice masses and snowpack really sustain summertime base flows.

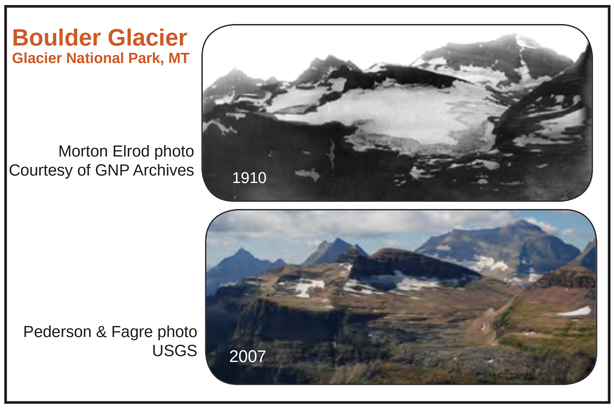


Figure 12. 20th Century Retreat, Boulder Glacier, Glacier National Park, MT

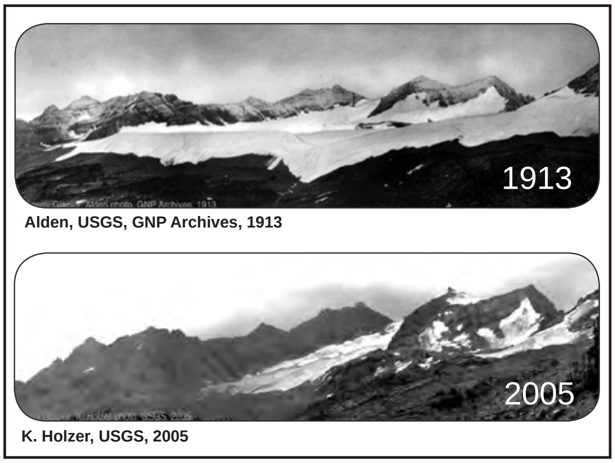


Figure 13. Sperry Glacier

We'll move on to the regionally focused part of this talk and look at the long-term history of changes of both the Upper Colorado and Rio Grande. They are both important water sources, of course, for New Mexico. We can look at this through both the recent lens of modeling studies that we have just done that run on temperature and precipitation across the basin, but also with our tree-ring study reconstructions of both snowpack and stream flow. One of the core papers that I will feature was published in 2011 and to which Sam referred (i.e., The unusual nature of recent snowpack declines in the North American Cordillera, Science, 9 June 2011, by G.T. Pederson, S.T. Gray, C.A. Woodhouse, J.L. Betancourt, D.B. Fagre, J. Littell, B. Luckman, E. Watson, and L.J. Graumlich). I was fortunate enough to work with this large group of people because we could compile all of our records from western North America where we had trees responding ecologically to changes in growth in our snowpack. I will explain briefly how they do that how that provides a reference point and a long-term history of snow change in the West.

We reconstructed snowpack in all of the basins shown in Figure 14. There is everything from level six hydrologic minutes to the entire Upper Colorado and the headwaters to the Rio Grande. We calibrated and screened all tree-ring records with long-term Natural Resources Conservation Service (NRCS) snow course records. The colored dots represent our network of tree-ring chronologies that span the West. Basically, they can tell us something about snow. There are two basic responses to how a tree tells us how much snow falls in a region. Here is the standard which everyone would probably expect; it is the "watering can" effect. The snow we get in the wintertime translates into soil moisture, trees grow on that soil moisture, and you have larger rings when the trees grow on larger amounts of snowpack. The other ecological response to snow that we captured across these basins was from many of our high-alpine trees and subalpine trees. Figure 15 is a photo from British Columbia showing Subalpine Larch at Hazeldene Lake. This is a deciduous conifer that sits at such high elevations near the upper limit of the tree line that when you get high snowpack winters, it shortens their growing seasons and they put on smaller rings. So both the timing and amount of snowpack, when it runs off, and how much is there gives you the inverse relationship at high elevations. Figure 16 is a great picture of the change in the northern Cascades just before the trees drop needles –you can pick those out from other tree species. They tell us a lot about the timing and how much snow there is along with Mountain Hemlock.

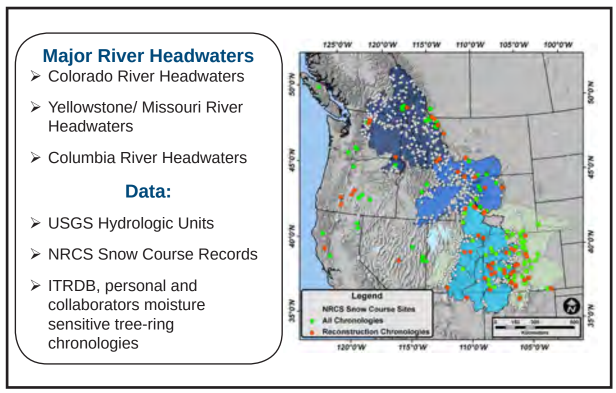


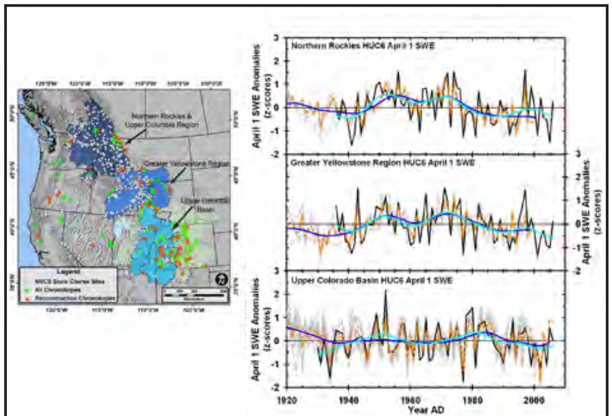
Figure 14. Primary Data for Major River Headwaters

Figure 15. Subalpine Larch

– Littell Photo

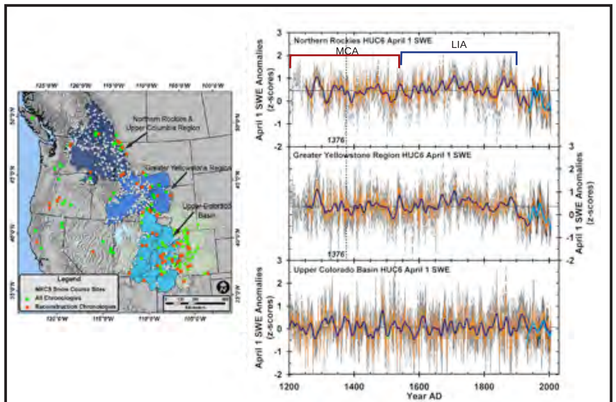
Figure 16. Northern Cascades

From those two responses, you can do a pretty darn good job at reconstructing snow. Figures 17 and 18 are classic slides where we can show how well or how poorly we actually did. We looked at our observational studies for our snow courses from 1920 to 2006. We compiled all of these records, and here are the Upper Colorado River Basin snow records. The black line is the observational record. You don't see as much of the low frequency or decadal variability in a large magnitude change like you have seen in the Northern Rockies. You do see the high snowpack events of the 1940s and early 1950s before the 1950s drought. Then you can see the latter part of the century with the 1980s high snowpack when we were stilling our dams and reservoirs. What you are seeing in the background with the light grey are these individual watershed reconstructions for basins within the larger basin. The orange is the entire basin's reconstructions. What you can pull away from this is that the trees do a pretty good job at both tracking yearly events and this low frequency change that we call the decadal variability, as well as long-term trends. They match the records well.



- Pederson et al, Science, 2011

Figure 17. Results: Calibration 1



- Pederson et al, Science, 2011

Figure 18. Results: Calibration 2

We have the backing and confidence to take this relationship and hind cast it as long as these trees have been growing at a population level, and that is what the graph shows. There are lots of squiggly lines but some summary points here. Looking at snowpack in places like the Upper Colorado River Basin, when we allocated all of our waters to the down river basins like New Mexico, Arizona, and California, it was again like our stream-flow reconstructions. It was a high snowpack and high-flow event. On a linear scale it was one of the highest. So, we started right off the bat looking at early water legislation that over-allocated water. The other thing that you see in all of these records is that bumpy ride where you can be in a wet sustained period for ten or twenty years at a time, or a sustained dry period for ten or twenty years at a time. As you will see in upcoming slides, the Upper Colorado River Basin seems to do that inversely to our northern basins. That is due to steering of our storm tracks from events like the

El Niño Southern Oscillation and Pacific Decadal Variability. When you have an El Niño event down south, you get high precipitation whereas across the upper areas of the country you get low precipitation.

I want to point out that even the paleo-records show the northern regions have seen both the cooling effect of temperatures generating higher snowpack in the last Ice Age where all the glaciers reached their maximums, and our lower snowpack at the end of the twentieth century during the 1940s to 1970s when snow was good. This gives you some perspective – at best, it was average for the period from the 1400s to the 1890s. But, years like 2011 certainly spike up into this range that gives you some idea of what little different ice conditions and snowpack conditions were for extended periods of time.

Now we turn to what has changed in a lot of these dynamics. What gave us confidence that we had succeeded in recreating winter snowpack was this tendency as we look across the record depicted in Figure 19: the Upper Colorado River Basin is in red, the northern regions are in blue. You can see that as you have high snowpack in the Upper Colorado River Basin, you typically have low snowpack in the northern regions. This represents where the jet stream is delivering moisture more or less. For the majority of these records, at least where we have continuous records for the past 800 years, that is what these records show. Very seldom do you see a breakdown in that behavior. Figure 20 shows graphically where little ice age glaciers expanded to their maximums in the North. You can see our upper basins of the northern Columbia and Missouri. We are registering extremely high snowpack. This even extends into the upper headwaters of the Colorado, but the lower part of the basin was actually dry. Going back further in time, from 1511 to 1530, you have a period of extremely low snowpack across the northern Rockies, but really good conditions in the Upper Colorado (Fig 21). But, when you look at records now, you see this synchronicity in decline. There isn't much of a dipole left (Fig 22). You have the recent decline in Colorado coupled with one up north. When you look back through the record, you only see these intervals in brief spots in the 1350s and 1400s where you see a synchronicity in declines as well. When you look at historic reconstructions of temperature, they coincide with temperatures that are nearly as warm as what we are seeing today.

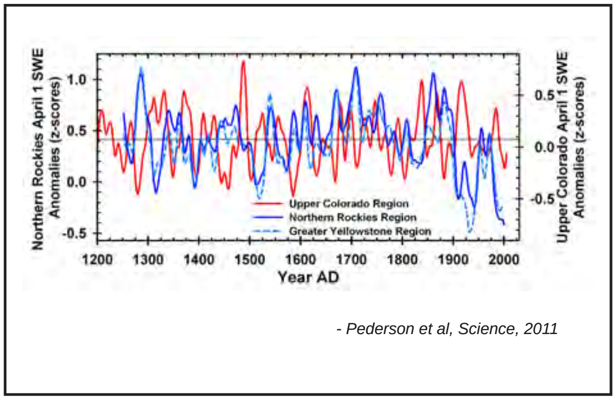


Figure 19. Stationary N-S Dipole

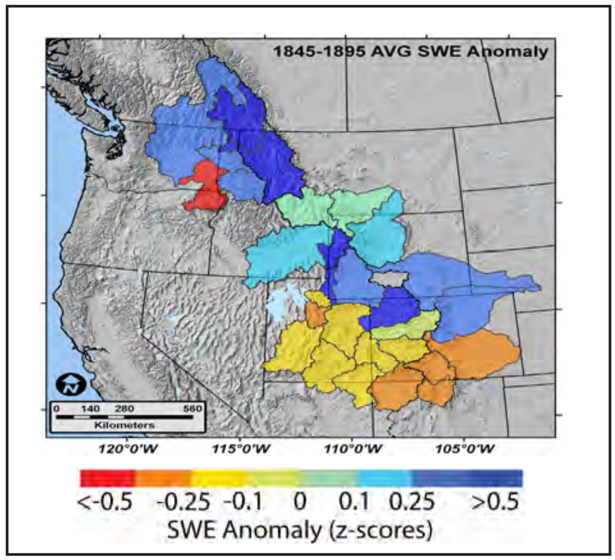


Figure 20. Little Ice Age Glacier Expansion

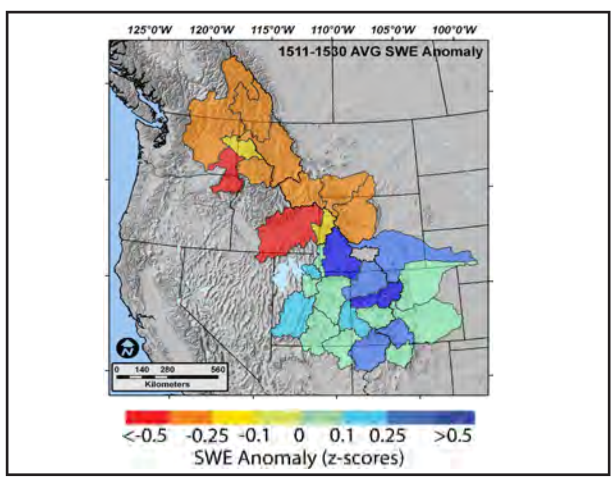
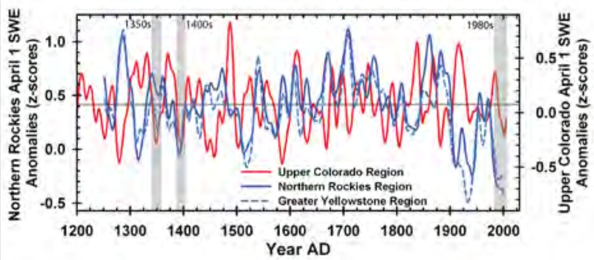


Figure 21. Little Ice Age Glacier 2

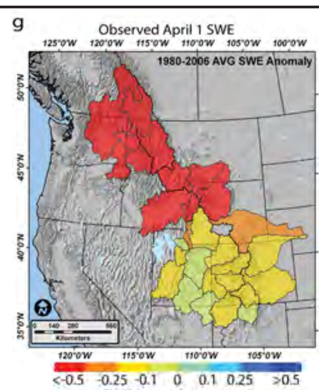


Temperature Driven Synchrony

— Pederson et al, Science, 2011

Figure 22. Stationary N-S Dipole, Temperature Driven Synchrony

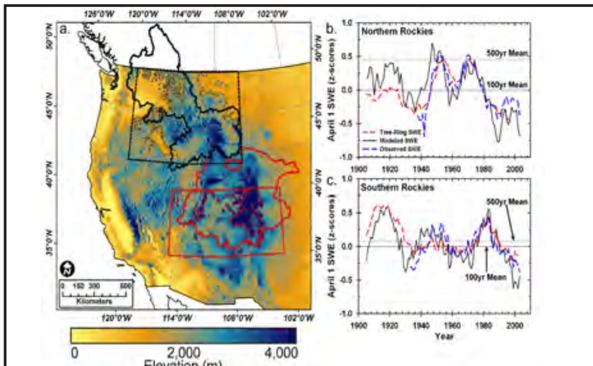
Figure 23 shows what we currently look like compared to the long-term average, even when we hit 100% of snowpack that is now based on the 1980 to 2010 mean. Again, our greatest declines are being witnessed across the northern regions due to that temperature sensitivity and degree of recent warming and the start of those temperature driven declines in snowpack across the Upper Colorado. This is not good and is part of what is talked about when you hear things like a non-stationarity climate being driven by temperature. This is one of those changing rules that would be on a hydrologic rule curve. It is fair to ask how we know that it is a temperature driven phenomenon. We looked at our paleo-record work and we modeled snowpack across the West using only temperature and precipitation. We wanted to look specifically at what portion of the snowpack changes with temperature versus precipitation change. This model yielded some pretty interesting insights into the 2010 snow and temperature relationship.



Synchronized Western Snowpack Declines

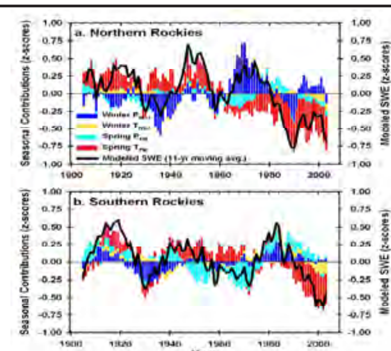
Figure 23. Recent Non-Stationarity

Figure 24 shows our tree ring reconstructions using our snow course records for both the Upper and Lower Colorado. The black lines show you how well the model did at reconstructing twentieth century snowpack. The reason we employed the model was to back out whether it was temperature or precipitation driven. Figure 23 has a lot of lines to look at, but the simple summary for these basins is: blue shows winter and spring precipitation effect on snowpack, and red and yellow show the winter and spring temperature influence on snowpack. For both basins, there has been a huge growth in the influence of temperature undercutting the accumulation of snowpack. This again is temperature driven synchronicity. High precipitation events spilling over dams in the 1980s were primarily driven by a huge influx of precipitation across the Southwest. When we allocated southwestern water resources, everything was pointing in the right direction for high snowpack and high stream flow. We had cold temperatures, shown in red above the mean line, with high precipitation leading to high snowpack and high flows that were unique in the last thousand years (Fig 25).



– Pederson, Betancourt and McCabe, GRL, 2013

Figure 24. Snow Model: Temperature Relationship



– Pederson, Betancourt and McCabe, GRL, 2013

Figure 25. Post - 1980s Synchronous Snowpack Declines

We can also use this model to look at snow cover changes over the twentieth century In both the northern and southern Rockies, the middle elevations were where the majority of the snow mass sits. It has shown about a 20% decline, with the Upper Colorado Rockies in the 1980s showing a minor 5-6% decline. There wasn't that much change in high elevation snowpack of the southern part of the Rockies, which are headwaters to the Rio Grande. This synchronous snowpack decline my imply a new point of non-stationarity of western water resources. The last few decades may in fact represent a fundamental shift from precipitation to temperature as the predominant factor in snowpack in the North America area. We continue to see across a lot of these regions increasing spring and winter precipitation, mostly a phenomenon north of here, but decreases in overall snowpack. That is an important factor to parse out, and that changes our hydrographs. Increased warming will continue to modify annual hydrograph and stream temperatures altering our aquatic habitat and challenging water resources.

There are just a few points to be made when we compare our snowpack reconstructions to stream flow reconstructions. For the most, part they are a mirror image. When we have high snowpack, historically we have high stream flows. There are very little differences. All of the major droughts, like the medieval mega-droughts of the 1450s, the 1550s, even our 1950s drought, pair out in our records. They show the predominant nature of this system to shift very rapidly from a period of low sustained flows to high flows and high snowpack.

As Dave DuBois mentioned, it's a bumpy ride and it tends to get stuck for ten to twenty years in a row, which presents interesting management challenges. We can similarly compare our reconstructions to the Upper Rio Grande, which looks a lot like the Colorado plot. Figure 26 shows the individual snowpack reconstruction for the headwaters of the Rio Grande versus another tree ring reconstruction of flows at the Del Norte Gauge. You can see the same thing where there was high 1980s flows with high snowpack, and same thing when you have drought. With the low snowpack you get low flows in the stream flow records. They all point to the large influence that snow has on stream flow in this region, at least in terms of how it modulates your total annual and water year flows that are coming out of these basins.

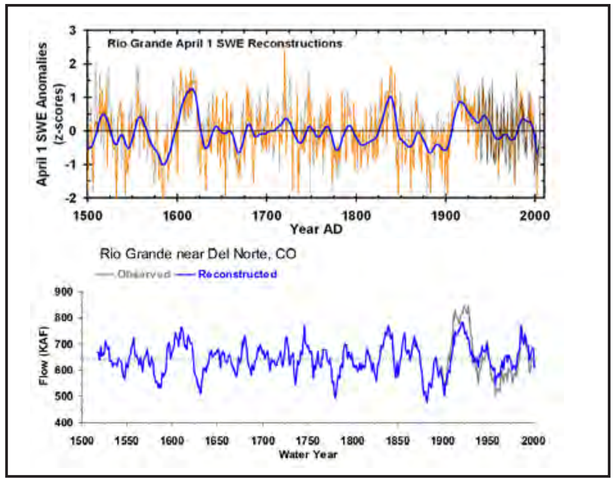


Figure 26. Snowpack & Stream Flow Reconstruction: Upper Rio Grande

Moving away from the paleo analysis, we move into the world of using big expensive models to produce really hazy and oftentimes poor forecasts. That isn't to say that they don't have some valuable information. We need to keep that in mind. Remember, all models are wrong, but some are useful. I find these models to be very useful, but they also challenge us as we work with data that have such high uncertainty when we plan for the future.

Figure 27 shows the new IPCC C55 model runs on twenty-first century precipitation projections. The vast majority of them show dry areas getting drier and wet areas getting wetter in terms of general precipitation. It is important to keep in mind that about two-thirds of these models are producing this enhanced loss of precipitation across the Southwest. It is a dynamic response that is expected from the models in which we get an intensification of Hadley cell circulation and increased subsidence across the south and southwestern parts of the U.S. This increases bridging and increases evapotranspiration; all of those processes that block storms from entering the region and also increased evapotranspiration out of the region.

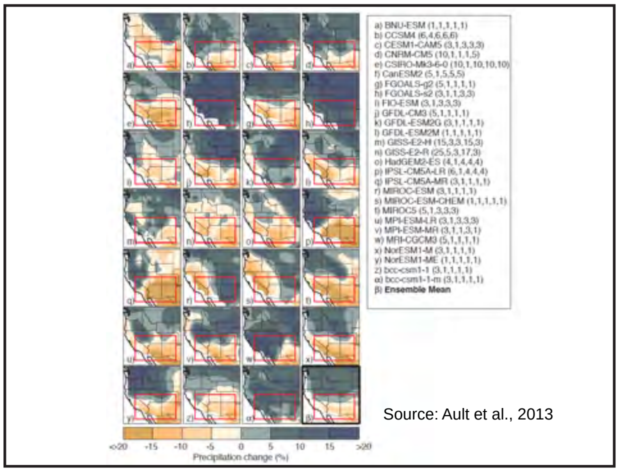


Figure 27. Near-Term Uncertainty—CAUTION: Models Disagree

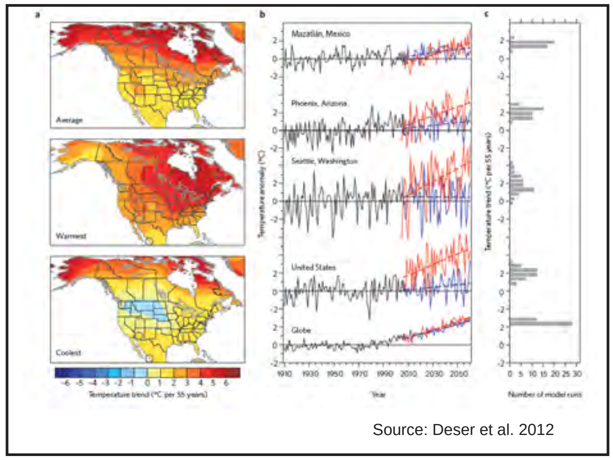


Figure 28. Near-Term Uncertainty—CAUTION: Natural Variability Still Applies

You will notice that some models produce an entire wet West and Southwest. What do you do with those models? Who is to say which model is right? I will say one thing: about a third of the models that show this wet or neutral Southwest are normally coupled with models having a tendency toward future ENSO cycles to be more El Niño like. In the climate sciences, it is hotly debated whether the future of our southern tropic sea surface temperatures variability will be more El Niño or more La Niña. So, these models are operating on a mechanism that we are not even sure will be operating in the future. Thus you have model uncertainty, and you have between model uncertainty as well as within model uncertainty. In the Figure 28 model, they parameterized a single model, the CCSM, with different sea surface start temperature conditions or boundary conditions. It was run 46 times to see how it would change twenty-first century forecasts of precipitation and temperature. Basically for temperature, it doesn't show much difference. It shows you a mean difference of two degrees Celsius globally. But, you can look at the influence of that natural variability on the mean, and the end members say the warming across the U.S. You have one end member showing extreme rapid warming and one showing very little warming, but the central tendency being two degrees Celsius. Regions like Phoenix or Seattle show the same thing. That influence of natural variability or what is happening in our basins and overlying circulation can change the end members but they are more or less predicting this mean mid-century two degree rise. Warming is expected and especially so across the South and Southwest over the next twenty to thirty years.

Figure 29 considers precipitation. The model shows that globally, it doesn't make much difference. You have around a 10% increase in global precipitation. But, if you look at our region where we are at right now, in southern North America, most areas are showing between a 10-20% decline with the most optimistic end member keeping precipitation similar to what it is today and the worst case scenario being really bad—around a 40% decline. In our northern regions, models are showing an increase in the range of 10-20%. Plus, given our natural variability and our uncertainty with precipitation, future projections of drying come from this temperature response. As you warm everything up, you melt snowpack and increase evapotranspiration.

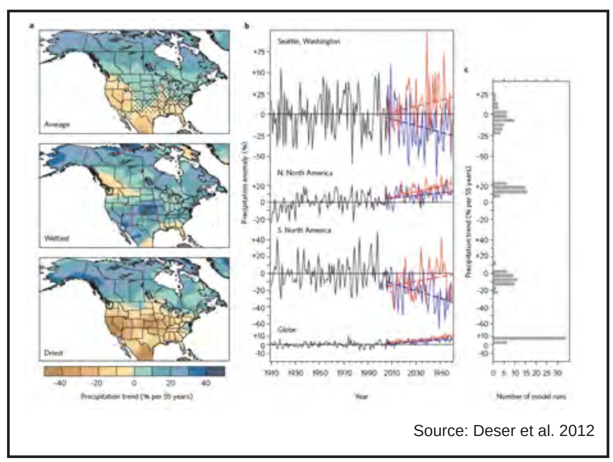


Figure 29. Near-Term Uncertainty—CAUTION: Natural Variability Still Applies

Regardless of what precipitation does, the magnitude and ubiquity of warming is expected to drive the Southwest and the West as a whole. But we can't say exactly where or how fast the West is going to dry because of errors associated with problems that Lowell Catlett pointed out earlier this morning. When you look at future model projections of increased aridity, I think we tend to think of it as some nice, linear, slow transition from today's more moist environments to tomorrow's more dry environments. What we have learned from both the paleo records and the global climate models is that our future climate is going to be a realization of natural variability in the system plus warming. We may ultimately end up with a more arid environment via a wavy path like in Figure 30 or any one of these realizations. The climate models can't tell you which one of these it is going to be. This upper threshold is a management target for when things get really bad in terms of aridity and stream flow and you have to change allocation rules. You may end up on one of these luckier paths where you approach but always avoid the worst case scenarios. Or, you might have a large amplitude swing in the future climate system where it gets really bad.

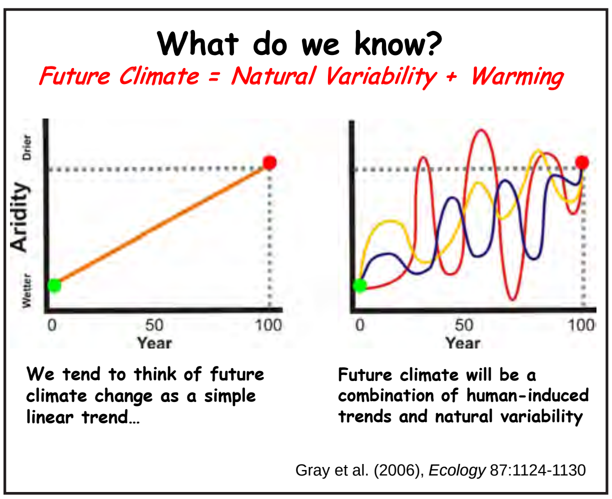


Figure 30. Climate Model Projections

What do you do when the system behaves this way? How do we think about setting up management portfolios that allow for this type of variability superimposed over long-term trends? This is the question with which I would like to leave to everyone.

Water Transfers in the West

Nathan Bracken
Western States Water Council

Nathan is the Assistant Director and General Counsel for the Western States Water Council, where he works with state water administrators and other experts appointed by 18 western governors to develop policy solutions for water challenges in the West. He has written and presented on a variety of water-related topics, including water transfers, drought, water reuse, solar energy development, Indian water rights settlements, and domestic wells, among other issues. Nathan is also a member of a number of water-focused workgroups and is the Editor of Western States Water, a nationally-circulated, weekly newsletter focused on water policy. He received his J.D. from the University of Utah, and graduated with a B.A. in English and a political science minor from Brigham Young University.

It is always a pleasure to come to New Mexico. One of the things I have learned working in the water industry is that there is no better way to bring precipitation than to hold a water conference. It seems the greater the drought or the scarcity, the greater the chance of having rain when you gather to talk about that very scarcity.

I have been asked to talk about a report that I helped put together for my organization, the Western States Water Council (WSWC), and the Western Governors' Association (WGA), which we published about a year ago. Figure 1 shows the report, *Water Transfers in the West*.

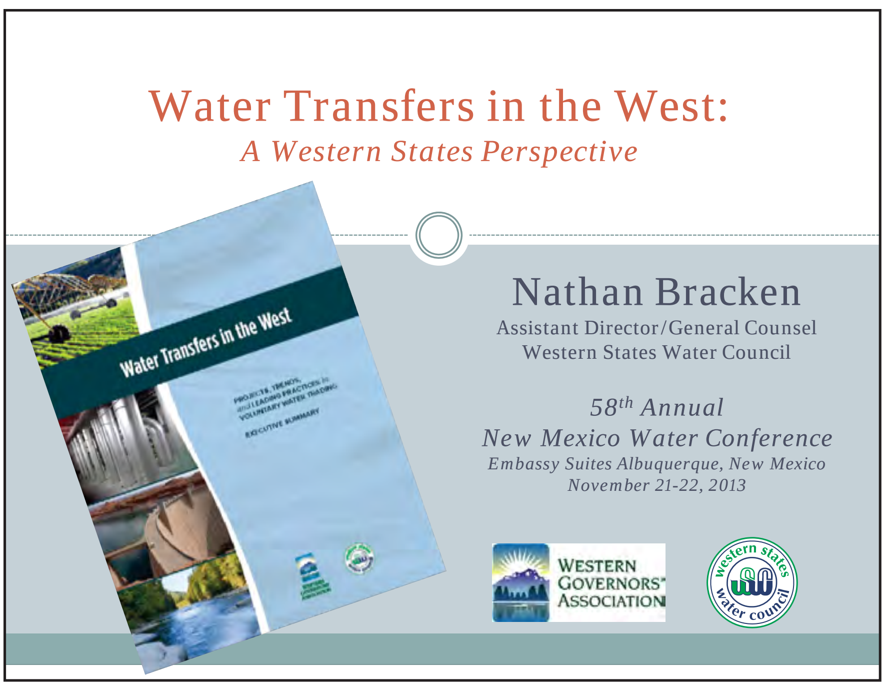


Figure 1. The Western Governors' Association prepared the report, "Water Transfers in the West: A Western States Perspective" in 2012

This report highlights a concern that we found in the West among water regulators, other policy makers, and many members of the public, about the impact of water transfers on agriculture and other values. Because agricultural water use constitutes the bulk of water use in the West, including both the water that is drawn and consumed, and as we have had changes in our economy and urban growth, agricultural water has become the de facto reservoir for much of this development. That has raised a number of concerns among policy makers around the West about the possible adverse impacts to agricultural communities and their economies, as well as environmental values and other issues.

The WSWC represents water managers from eighteen western states on water policy issues. What makes the organization unique is that our members are actually appointed by their respective western governor. Our members typically include the State Engineers, including New Mexico's State Engineer, Scott Verhines, as well as other water managers, public and private attorneys, and other water experts. Because the governors created the WSWC, we see ourselves as being accountable to the WGA and work very closely with them, essentially serving as WGA's water policy arm. For years, the WGA has had a policy regarding water transfers. It says that states should identify and promote innovative ways to allow water transfers from agricultural to other uses while avoiding or mitigating damages to agricultural economies and communities. In light of this position, WGA approached the WSWC and asked us to work with them in developing a report that looks at this particular issue. The Walton Family Foundation also provided grant funding to support the effort.

To develop the report, we held a series of three stakeholder workshops around the West. We brought together over a hundred stakeholders to get their thoughts on these issues and talked about what is working and what is not. We also did a very extensive survey with our member states and did quite a bit of independent research as well. One of the first challenges we encountered was—how do you define water transfers? It means something different to everyone. For the purposes of our report, we developed this definition:

> A water transfer is a voluntary agreement that results in a temporary or permanent change in the type, time, or place of use of water and/or a water right. Water transfers can be local or distant; they can be a sale, lease, or donation; and they can move water among agricultural, municipal, industrial, energy, and environmental uses.

While this definition is pretty general, the report does include a couple of important clarifications. One is that we are only talking about voluntary transfers. We are not talking about regulatory transfers that are a result of a court decision or other regulatory action. We are also talking about intrastate and not interstate transfers. When you represent eighteen western states, there is no better way to get yourself fired than talking about taking water from one state and sending it to another.

We also did not make any value judgments about whether transfers are good or bad. In other words, we didn't want to proceed under the assumption that one specific type of transfer should take place or that one type of transfer should not. Instead, we tried to develop an objective overview of what is happening in the West with respect to transfers and worked hard to make sure that the report was not prescriptive. As a result, we put together a resource document that provides stakeholders with an idea of what is going on around the West concerning water transfers. Hopefully stakeholders can share the information with each other.

Figure 2 comes from the report and is a snapshot of what is happening with respect to transfers in the West. We asked our states how prevalent water transfers are and about the likelihood that they would continue. The states in green are those states that indicated that water transfers were pretty common and expect transfers to continue being used to satisfy growing water demands. Obviously, the main factor that is driving many of these transfers in the West is urban development. There are other concerns and drivers, too, including transfers among agricultural uses, energy development, particularly in North Dakota, and environmental issues and concerns about instream flows.

We also found that there is no one right way of doing water transfers. Every state has very different programs with different needs and perspectives. California, for example, has the largest number of transactions in terms of the volume of water trading hands. This is due in part to the fact that California has very well-developed infrastructure, making it very easy to transfer water from one part of the state to another. California also has a well-developed regulatory structure that encourages temporary one-year transfers. It is much easier to get a temporary transfer than it is to get a permanent transfer, so most transfers there are temporary. If you look at other parts of the West, that may not be the case. If you are an urban water provider and you are looking to increase your supply to plan for anticipated population growth, a one-year water transfer is not going to work if the necessary infrastructure is not readily available because you would likely not want to spend the time and money needed to build the infrastructure needed to convey the water to where you need it for only one year.

What we have seen in many places in the West are so-called "buy and dry" transfers. These are transfers where water is permanently taken out of agriculture and used for another use, usually urban. This was probably the largest concern of many of the stakeholders with whom we

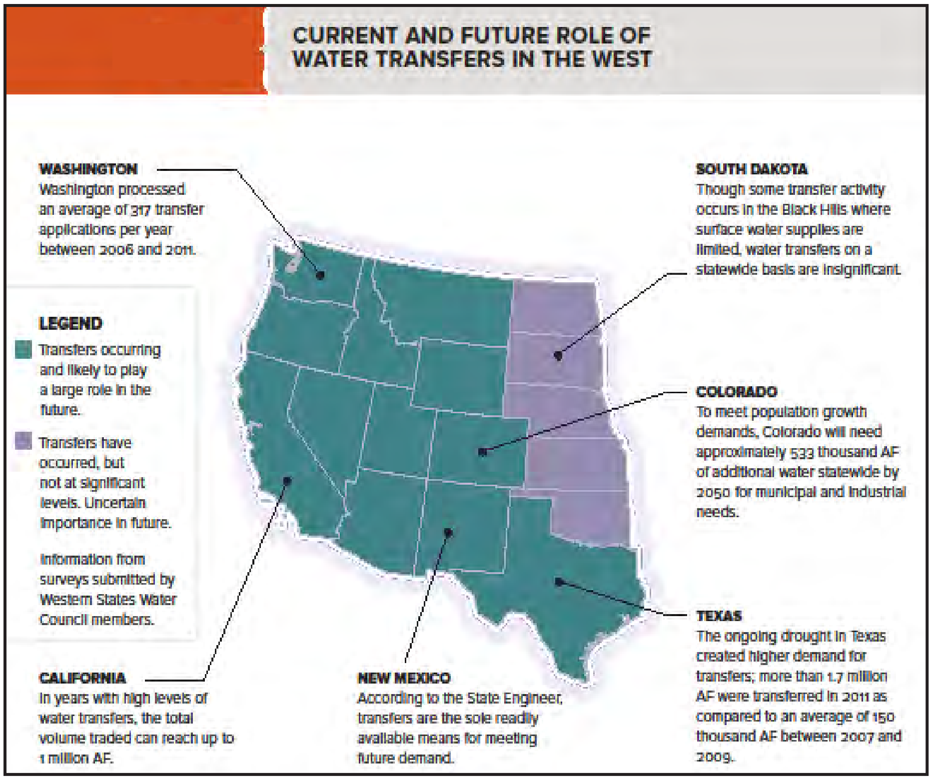


Figure 2. Current and Future Role of Water Transfers in the West

spoke. Dan Keppen will talk in a few minutes about specific impacts, but in many cases agriculture is the single largest driver for many local communities and economies in the West. If you take water out of agriculture, it can make it very hard to sustain those communities and to preserve the values associated with agriculture. For example, Colorado is in many ways the epicenter of the “buy and dry” debate. Colorado’s policies indicate that it doesn’t think that is the best way to go; they’d like to do something different.

Our report discusses alternative transfer methods including ways of sharing water between users. There are many different terms for it, but the main concept is that agricultural districts or farmers will conserve part of their water, or fallow part of their land, and then lease the savings to other users. Sometimes a supply agreement is developed where an urban user planning for future growth will tap into someone’s water every once in a while and will pay a certain amount of money for that water. The benefit of this agreement is that it allows farmers to stay in agriculture while providing them with an income they can rely on for farm improvements and other things.

Regionalism was another issue that popped up when we looked at alternative transfer methods. We found that if you are looking at local transfers, it is usually fairly easy to do because infrastructure is in place and you can often rely on natural streams. But if you are talking about moving water a substantial distance, it usually requires some type of infrastructure, and that is the hard part. For example, Montana reported that much of its urban growth is taking place in areas that are relatively water-short but located substantial distances away from where water is available to purchase or lease, which presents a challenge to water sharing arrangements.

Another issue is abandonment and forfeiture. It is almost impossible to talk about conservation and sharing water without discussing this issue. When we spoke with our state regulators, one of the first things they said was that they understood that people think there is a concern about these transfers, but they have worked hard to develop policies and regulations that will ensure that people can conserve water without being subject to abandonment and forfeiture. Our states also reported that forfeiture and abandonment proceedings are relatively rare. However, when we spoke with the user communities, they had a different perspective. They reported that the risk of abandonment and forfeiture is a huge disincentive for conservation and that there are few reasons to conserve. Part of that is due to the fact that most states only allow water right holders to transfer the amount of water they are actually consuming. If you lessen the amount of water you use, you may lessen the amount of water you can transfer, and therefore adversely impact the value of the right. So the argument is: What’s in it for me? I think the truth is somewhere in-between and probably depends very much upon the individual state and the specific circumstances. Nevertheless, this is a pretty significant area of concern for many right holders.

Another issue that always comes up deals with new approaches. Most alternative transfer methods are new concepts that haven't been fully tested in the states' legal systems. What this means is that nobody wants to be the guinea pig. Nobody wants to be the first to go and find out what happens.

So what are states doing to address these issues? For one, states have adopted general policies to facilitate water sharing. For example, California has policies designed to support voluntary transfers that do not have adverse impacts for agriculture, senior water rights, or environmental values. Moreover, California has directed its staff to facilitate conservation as well.

At the same time, many western states have some type of water bank program, sometimes specific to a particularly region. Some states also have provisions in their codes that state you can deposit water into a water bank (in the same way that would deposit money into a regular bank), and then lease that water without subjecting the underlying right to an abandonment or forfeiture proceeding. Moreover, most states allow for temporary transfers, although the specifics vary considerably from one state to another. Some of these temporary transfers are for emergencies; for example, during drought.

For most permanent transfers, most states will look at whether or not the proposed change will injure existing water rights and require a public comment period. Some states are also looking at ways to expedite this process, particularly for temporary or emergency transfers.

Funding is always a huge challenge. I mentioned earlier that Colorado is concerned about the "buy and dry" transfers. It has put its money where its mouth is and is funding a grant program that provided at least $2.8 million for stakeholders to look at this issue and figure out how they can encourage alternative water sharing efforts.

Some states are also looking at ways to address third party impacts. The general rule of thumb is that when you do a change of application, you are almost always looking at injuring other water rights. But there are people who are affected by transfers who don't have a water right. Most states have some sort of public interest review. For example, Idaho has a provision in its code that states that when considering a change of application, the state will not approve it if it will have an adverse effect on agriculture or the economy. Nebraska also has similar concerns—they will look at how the transfer impacts socio-economic and environmental issues in the area of origin.

Now I would like to talk about some specific examples of some innovative water sharing agreements. We presented three case studies in this report, the first is located in Colorado. Figure 3 shows the Lower Arkansas Valley Super Ditch. The lime-green area is the subject of this particular effort. It is an area with a pretty strong agricultural base, but it is also near Colorado's Front Range, which has been growing exponentially. This area of the state is looking at a 78 percent increase in population between 2008 and 2050. This growth has put a lot of pressure on agricultural water supplies. There have been many so-called "buy and dry" transfers in this region. In fact, according to some sources there has been a $33.5 million loss. In some parts of the state, that could result in a $2,000 per capita hit to the agricultural communities. The situation has people in these agricultural communities thinking about

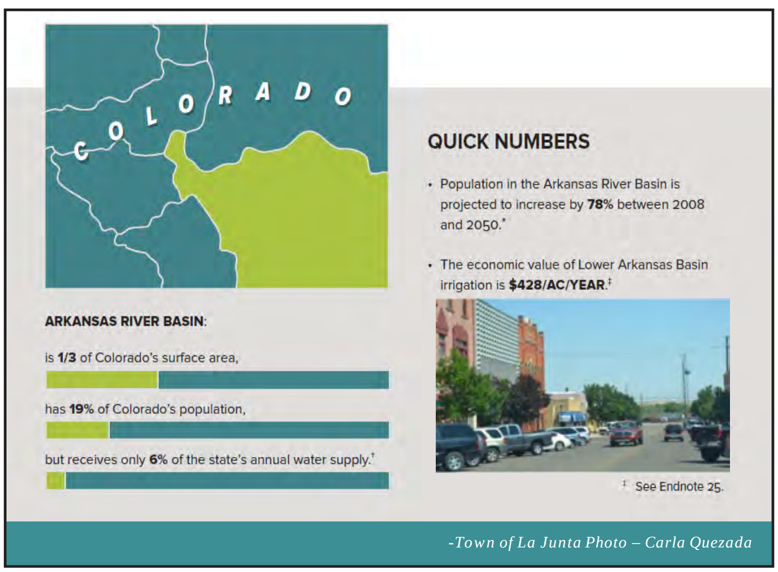


Figure 3. Lower Arkansas Valley Super Ditch in Colorado

what they are going to do. They want to preserve their communities and keep farming, but there is a constant demand for their water.

In 2002, the voters of this area approved what eventually became the Super Ditch, which is essentially a fallowing program. It is a voluntary program in which farmers can fallow a portion of their land and then lease the water saved from that land for use in the Ditch. The Ditch itself acts as a representative and negotiates these agreements on their behalf. It is still a work in progress, but right now they have built the capacity to release 24,000 to 80,000 acre-feet a year depending upon the hydrologic conditions. They have also entered into a number of agreements with citizens from Aurora and Pike's Peak. The basic structure is that they will let you lease up to a specific amount of water over a certain number of years for a set price.

One thing we learned from this example is the importance of empowering the local stakeholders. The farmers in this case were the decision makers. This wasn't an easy process and there was quite a bit of opposition, but many of the agricultural stakeholders involved felt that this was a good way for them to stay involved in agriculture, get some money, and help satisfy some of the growing urban demand for their water.

Next, I would like to talk about the Deschutes Water Alliance in Oregon near the city of Bend. This is a case that in many ways deals with a combination of urban growth and environmental pressures to put water back into the streams. In the early 2000s, Bend and surrounding area experienced a huge influx of people moving to the area. At the same time, a combination of Clean Water Act requirements, Endangered Species Act requirements, and state groundwater mitigation efforts began putting pressure on stakeholders to find ways to leave more water in the streams. The irrigation districts, the City, tribes, and other stakeholders realized that they needed to come together and address these issues. If they did not, someone else was going to make a decision for them, and it probably wasn't going to be something that they could live with.

As a result, these various interests created a "gentleman's agreement" to put 260,000 acre-feet back in the stream. Roughly 50 percent of that amount will be accomplished through conservation, while the rest will come through transfers (both sales and leases) and reservoir management. Figure 4 is a picture of how one irrigation district piped about 3.8 miles of their existing canals to help reduce the effects of evaporation. This allowed their farmers to pump less. In some cases, farmers were able to see an increase in the amount of water delivered to their farms of up to 25 percent. So far it has been very successful and they have been able to restore 200 cubic feet per second to the stream. If you visit Bend, you can go to the river and see that water is actually there. Historically that hasn't always been the case and the river often ran dry in the summer.

Figure 4. Deschutes Water Alliance in Oregon near the City of Bend

One of the interesting about this example is that the State took a hands-off but supportive approach and basically allowed the parties to develop this arrangement on their own. That being said, this type of arrangement would not have been possible had Oregon not adopted a regulatory structure that allows this type of agreement.

The last example I want to talk about is in California. Figure 5 describes a fallowing agreement between the Metropolitan Water District of Southern California and the Palo Verde Irrigation District. The goal of this agreement is to provide between 30,000 and 120,000 acre-feet/year from Palo Verde to Metropolitan to satisfy urban needs for the next 35 years. What is interesting about this particular program is what the parties did to mitigate impacts to the local community. This arrangement required a number of years to build the necessary relationships that are in place. Early on, the parties carried out a pilot fallowing program in the 1990s that later served as the basis for the larger, final agreement. One of the things they learned from this initial pilot project, which transferred about 115,000 acre-feet/year, was that the fallowing provided $25 million in payments to local farmers, but also included the temporary loss of roughly 60 full-time agricultural jobs and an estimated $4 million loss in farm-related services.

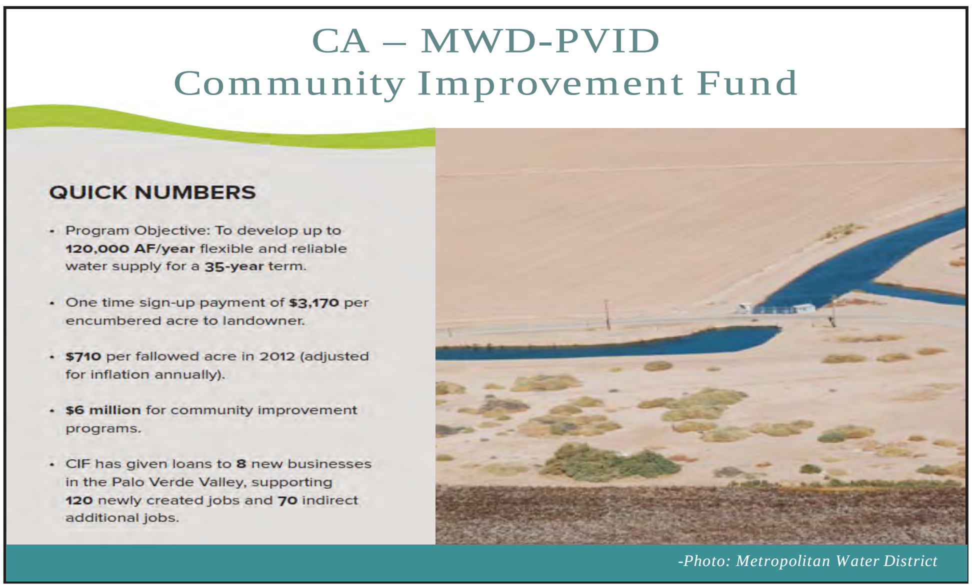


Figure 5. Metropolitan Water District, Palo Verde Irrigation District in California

So, when the parties developed the larger deal, Metropolitan agreed to provide $6 million for the local community to mitigate potential adverse impacts. The community used this money to create a Community Improvement Fund that provides small business loans and other assistance to businesses in the area to help offset the impacts of the fallowing arrangement. The Fund has been pretty successful and has supported around 120 new jobs, 70 indirect additional jobs, and saved a number of other jobs that were threatened. Examples of businesses the Fund supported include an existing nursing center, a pharmacy, and a furniture store. These were not "big box" stores. The community realized early on that they would see the best bang for their buck by focusing on local businesses. Perhaps my favorite was a truck driving school they developed. The school had an inaugural class of twelve graduates, six of whom had lost their jobs due to the fallow program.

One of the key messages from our report is this: The State creates the framework, the State establishes the ground rules, but it is ultimately up to the local folks to develop bottom-up approaches. I think it is very important for agricultural stakeholders to feel that they are in the driver's seat. They must feel that any water sharing arrangement is their choice, that they are making the decision, and that they are the ones retaining control over their water resources. It is tough to be a farmer these days because they are beset on all sides by a host of problems. A top-down approach that tries to take water from them won't work; an approach that empowers them and allows them to stay in business may.

Another point I want to make is that transfers are just one tool. In the studies we did, transfers weren't the only option that urban areas could use to obtain potable water. Transfers are part of a larger portfolio that will likely need to include conservation, reuse, new infrastructure, and a number of other measures depending upon the circumstances at hand. The point is that transfers and water sharing agreements represent an important tool that will likely be used to satisfy future water demands throughout much of the West, but they aren't the only tool.

In closing, I want to mention that the report has a number of resources you may find useful. It has a detailed appendix that discusses various types of transfers with pros and cons and summarizes the western states' regulations, policies, case law, and other policies governing transfers. The WGA also maintains a website with copies of the report and other related information at: http://www.westgov.org/initiatives/water/373-water-papers. The WSWC's website is: http://www.westernstateswater.org/. Thank you.

The Importance of Irrigated Agriculture in the West and Recent Developments

Dan Keppen
Family Farm Alliance

Dan Keppen is Executive Director for the Family Farm Alliance, a non-profit association that advocates for family farmers, ranchers, irrigation districts and allied industries in 17 Western States. He has 24 years experience in water resources engineering and policy matters. Since the mid-1990s, he has worked primarily in advocacy positions representing Western irrigators, including over three years as executive director of the Klamath Water Users Association (KWUA), where he was intimately involved with one of the most contentious water crises in the West. Prior to that time, Dan was a water resources engineer for Tehama County, California and a water resources engineering consultant in the Portland, Oregon area.

Dan is a Registered Professional Civil Engineer in California and a past Civil Engineer and Certified Water Rights Examiner in Oregon. He has testified before Congressional environmental and water committees fifteen times on water resources, environmental and climate change matters. In his eight years at the Alliance, the organization has been asked to testify before Congress 40 times.

Dan was awarded a "Resolution of Commendation" by the California State Senate and was appointed by Governor Kulongoski to serve on the Oregon Climate Change Integration Group. In 2009, he received the first ever John Keys III Memorial Award from the Bureau of Reclamation for "Building Partnerships and Strengthening Relationships." In 2010, he received KWUA's "Distinguished Service Award."

Dan received his MS in civil engineering (water resources) from Oregon State University and his BS in petroleum engineering from the University of Wyoming.

Good morning everybody. I want to talk about the importance of irrigated agriculture in the West, recent developments, and focus on the importance of our recent economic report.

First, a bit about the Family Farm Alliance. We are a non-profit organization of irrigators in seventeen western states. We advocate for protecting and enhancing irrigation of western agriculture. That is our focus. I am an advocate, and you are going to have to take that with a grain of salt. Some of the initiatives that we have been working on the past couple years include the report entitled, *The Importance of Western Irrigated Agriculture to the U.S. economy.* The last topic that I will discuss—streamlining of low-head hydro projects—is something I normally wouldn't even bring this into the presentation, but it is very relevant because there are people in this room that made really important progress in this arena in the last couple years.

Two bills have passed recently that were signed by the President that makes it much easier for irrigation districts, farmers, and ranchers to permit the development of low-head hydro in existing canal systems. This issue was primarily elevated by Gary Esslinger from the Elephant Butte Irrigation District who is here and even helped pay for me to come to this conference today. I would like to thank him for that. Gary brought up the low-head hydro effort, and it should be a no-brainer. Say you have a canal system and you want to put in a little low-head turbine. You learn it only takes $10,000 - $20,000 to fabricate these facilities, but it takes years to obtain a permit. The purpose of these bills, without getting into a lot of detail, is that they greatly streamline the permitting involved with the Federal Energy Regulatory Commission or FERC, and the Bureau of Reclamation on developing these no-brainer kind of projects. Tanya Trujillo, who is here in the front row, also played a role in this legislation. When we began with this idea, she was counsel to the Senate Energy and Natural Resources Committee, and she helped with the House and the Senate to get oversight provided on this topic. This is hugely important. I mean, how many laws has President Obama signed this year with this contentious Congress? There haven't been many, but two of them are ours and had origins here in New Mexico. We are very proud of those bills.

Dr. Darryll Olsen will talk tomorrow about our economic report. I want to go over some of the highlights that came out of this report. We did a similar report back in the 1990s with Dr. Olsen, who is an economist from Washington State. We updated the report last year and developed a preliminary white paper because the Environmental Protection Agency was making a lot of noise about focusing on the role of water on the U.S. economy. As we saw their press releases roll out and saw the scope of their initial work, it didn't seem that agriculture was getting the sort of attention that recreational use, or fish and wildlife use, and such were getting. We wanted to demonstrate that there was a definite value associated with water going to irrigated agricultural use in the West. We commissioned our report and we were the only non-governmental agriculture association invited to testify at a workshop the EPA held last September of 2012. We travelled to D.C. and rolled our report out. It was well received because it was just so real. Darryll Olsen does a great job of talking about how important this economic engine of irrigated agriculture is, and we have seen this resonate with other audiences. The Farm Foundation in Chicago peer-reviewed the report. We also updated last year's numbers with 2011 commodity prices. We rolled out a report in conjunction with the Irrigation Association this last September and incorporated the peer-reviewed findings.

I want to outline some of the key findings, and Dr. Olsen will provide more details tomorrow. First, for the 17 western states, when you look at the impact to the economy and household income associated with the irrigated agricultural sector—which we call the irrigators, farmers, producers, ranchers, the service industry, and even food processing and packaging industries—it is $156 billion. When you break it down, more money goes into the irrigated agriculture industry than goes into Intel and Nike in my homestate of Oregon. I am going to leave Figure 1 up for the rest of my presentation. The graph is very telling and has implications for policy makers dealing with water issues.

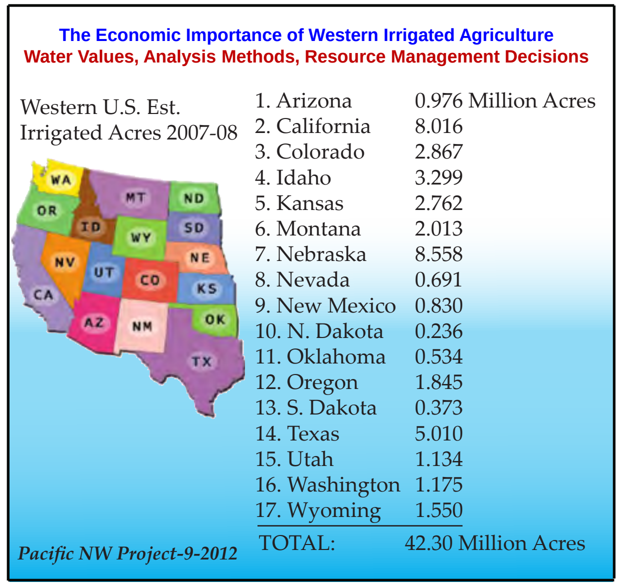


Figure 1. Western U.S. Est. Irrigated Acres 2007-08

There are some key take-aways that came out of the economic study. Basically, the importance of irrigated agriculture's contribution toward the U.S. economy is huge. The $156 billion is not a small figure and should get people's attention. The other thing that is really interesting is the so-called silent opportunity costs associated with decisions that may take water away from irrigated agriculture and move it to other sectors. One of those silent opportunity costs has to do with Figure 2. This figure shows the percentage of disposable income that Americans have that is dedicated to food spending since WWII. In the late 1940s, it was up around 25%. Now, we are at about 7%. A typical Chinese consumer spends 21.3% of their disposable income on food. Can you imagine spending four times the amount that you do now on food? That would take away people's ability to spend money on all the other things that consumers like. The consumer spending component is the most important part of our economy. Nobody ever seems to talk about that when it comes to making decisions about water resources. We put together a great focus on impacts to fish and wildlife, impacts to growth, impacts to energy development, and so on. We don't see a focus on these so-called silent opportunity costs.

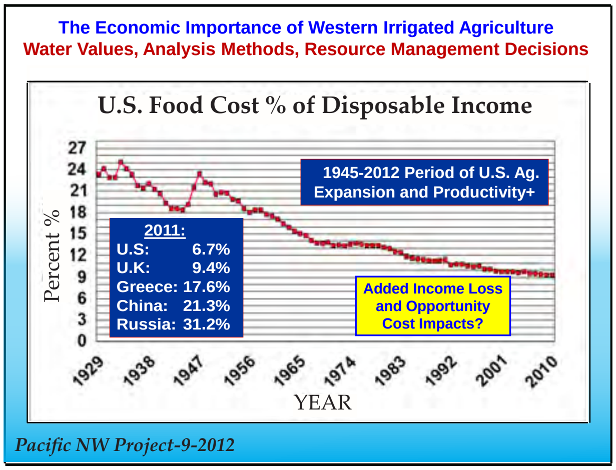


Figure 2. U.S. Food Cost % of Disposable Income

There is another factor to consider as well, and that is that by 2050 we are going to have to double our food production capacity to keep up with the growing population. That means that we are going to have to increase our ability to produce food on the order of around 1.75% a year. This is happening at a time when many of our own government policies are encouraging agricultural lands to go out of production and that water be used for other purposes. The report we put together shows that we have good arguments for protecting agriculture. We have a great need to feed the world and our country, and this is happening at a time when only 6% of our farmers nationwide are age 34 years or younger. We are in danger of losing a generation of farmers at a time when we need them to feed the world more than ever. Again, this has a huge impact to our overall economy.

I want to talk about other silent opportunity costs that nobody wants to discuss. First, I am sure that many of you are familiar with the principles and guidelines that are being developed in the agencies right now. Has anybody heard of the PNGs? Anybody? I hope you are following these developments because they are hugely important. Since the last Water Resources Development Act, there are new guidelines to reevaluate how the Corps of Engineers and the Bureau of Reclamation assess and determine whether a water project is feasible or not. Some proposed principles and guidelines have been developed by the White House Council on Environmental Quality. They will apply not just to the Bureau and the Corps, but to every federal agency that deals with water except for emergency repairs, development of regulations, and research. That is how the rules are currently written. This has huge ramifications; it isn't like the good ol' days when you simply look at a potential project, do a cost-benefit analysis, and take that to Congress to find out if you meet certain requirements to get funding. Now you will have to look at things like environmental justice, social justice, climate change, impacts to fish and wildlife, and all the things that probably should be looked at, but which are probably already dealt with through agencies such as the EPA. This will require managers to develop a whole new layer of criteria as they assess water projects. It isn't just water projects. I participated in a conference call with the White House CQ and a bunch of other folks from around the country last week. Right now, it is so subjective and hard to figure out what exactly is going to happen. We are asking the agencies to develop specific examples to show how they would currently assess projects versus how they would assess projects in the future with these PNGs to give us an idea how the agencies will deal with issues like environmental justice, social justice, or climate change.

With that said, we are saying that if you are going to look at those sort of issues, you also need to take a hard look at the impacts to agriculture with every water project decision that you make. We have examples of why that needs to happen. If you look at what is happening in the Central Valley of California, you see how the decisions made there have almost destroyed communities in the San Joaquin Valley. Another example has to do with the EPA. The Clean Water Act and the definition of U.S. waters are being looked at. Guidance was being proposed but got pulled back at the last minute; now there will be a rule-making process that accompanies the new definition of waters in the U.S. This has huge implications for agriculture. I think the rules being talked about could definitely have more agriculture activity brought in under EPA jurisdiction. The Clean Water Act originally had some exclusions that were intended for agriculture, but we hear that is probably going to change.

As part of the rollout of the new rules, there are two reports that the EPA has released. One is the conductivity report that looked at how groundwater and surface water are related and how wetlands tie into surface water. EPA also came out with a "value of water" report, which is what triggered our efforts long ago to develop our own economic report. I just looked at this value of water report that was released about a week or two ago. Consultants hired by the EPA put it together. I don't want to be critical of the EPA, but their report doesn't really say a lot. Basically, what it says is that it is hard to determine what the value of water is and more study is needed. But, water is important, clean water is important, and the EPA is important because we care about clean water. That is basically the take on the report that I have received from several folks. These two reports have come out around the same time that more aggressive rule making is being proposed and I don't think that it is a coincidence. We think our report could be used in that forum to show that agriculture is just as important as some of these other uses.

Finally, I want to talk a bit about the Colorado River Basin Study. The Bureau of Reclamation just released a study that looks at future demands and needs for water in the Colorado River Basin. It looked at a lot of scenarios out to the year 2060. From an agricultural perspective it is very concerning because the models were run based on different types of assumptions. Every single scenario shows that there will be a water shortfall of irrigated agriculture by the year 2060. Up to one million acre-feet of water might be required to be conserved according to the Reclamation's report to make up this difference. This represents 6-15% of existing irrigated agriculture in the basin would be taken out of production. Again, there are ramifications there. Reclamation is looking at scenarios that assume certain population growth, or certain environmental needs, or hydropower needs, and then running its model, which spits out how many irrigated acres will need to be taken out of production based on other demands.

We are saying that Reclamation also needs to assume that we will need to keep all of our agricultural land to feed the world, and maybe even increase that acreage. What happens to the other sectors if you make those assumptions? There is a paradigm in use that looks at modeling future water planning. I'm not blaming Reclamation, it is how many agency planners do things in the West. Planners plug in inputs, and the output is how many acres of agriculture we are going to take out of production to meet those demands. We would like to see Reclamation or other water policy officials run another scenario, one that assumes that Basin irrigated acreage will not be diminished, and may, in fact, need to be expanded. If it is going to be water transfers to meet these needs, then they need to be short-term transfers that properly mitigate impacts to communities. We also need new infrastructure as well as to continue to do great conservation work.

I will close by saying that you will learn more about our report tomorrow during Dr. Olsen's presentation. He is a very compelling, interesting, and entertaining speaker and he will handle some of the economics in more detail. I have to say, too, that we are pleased that the Bureau of Reclamation is conducting a huge river basin study. But they and other policy makers need to understand the importance of western irrigated agriculture and the implications of drying up land that is currently producing food in the West and elsewhere. The Family Farm Alliance will continue to advocate to that end.

Thank you.

New Opportunities for Administration and Cooperation

Scott Verhines, State Engineer
New Mexico Office of the State Engineer

Prior to his appointment as State Engineer, Scott Verhines served as program manager for the Eastern New Mexico Rural Water Authority, overseeing a $500 million regional water supply project that provided municipal and commercial water to communities throughout Eastern New Mexico. He has extensive experience with water issues both in and outside New Mexico. Verhines has managed and participated in over 200 hydrologic and hydraulic studies ranging in size from individual residential lots to over 500 square miles of watershed and has planned and designed over 60 major transportation projects. He earned his B.S. in civil engineering from Texas Tech University, as well as his M.S. in civil engineering and M.B.A. from the University of New Mexico.

Editor's Note: The following is an unedited, direct transcription of the presentation by State Engineer Scott Verhines.

Thank you for the invitation to come back this year. We certainly appreciate WRRI's continued sponsorship of this conference. Before we begin, I want to say kudos to the Western States Water Council. I think they are the unsung heroes—they do an absolutely fabulous job of looking after western water issues. They are on the frontlines with us, with Congress, and with others in the states. So thank you, Nathan Bracken, for that effort.

Good morning, and thank you for the impending snowfall. It will be good for all of us, a good running start to the year if we have what they are predicting is going to happen over the weekend.

My talk focuses on water administration, new opportunities for water administration, and cooperation. I am two years on the job this month, and I've learned a lot. It has been a pretty steep learning curve and I have a lot more to learn. I can tell you that the last 30 months in New Mexico have been the hottest and driest that we have had in a long time. It has not been without challenges, to which all of you can attest.

On day one of my new job, I inherited 18 lawsuits. We cleared a couple along the way, and I think we added a couple. We are going to try to hold the line and not add to that number. My mantra coming in was to solve problems and not fight, and I have to say, we have an absolutely fabulous staff working with me in the assumption that we are all better off if we can solve problems instead of continuing to fight. My father Jack, who was a Roswell native and long-time civil engineer in New Mexico, often said to be careful not to back someone into a corner, because the only way out is on top of you. There is a lot of truth to that, so whenever we are trying to resolve issues around the state, I think we all ought to be conscious of the fact that if we back a person into the corner, there is not an easy way to get them back to the table. As we sit around the table, I think about that, and I also think about the times that we are backed into a corner and how we find a way back to the table.

I would like to share with you a couple of things from the last legislative session, and I'm going to pick on the legislature in a very respectful, friendly way. To their credit, in the last 60-day session, we were in constant hearings on water and in front of committees and joint committees for nearly all 60 days. Legislators were engaged, they were involved, and they wanted to talk through water issues. When the session was over and done, how did they help us resolve these problems? They cut our budget by $750,000. The point is that we are not quite there yet. Legislators were engaged, they were trying, but a lot of issues are facing New Mexico that they are trying to balance, and that is where we found ourselves at the end of the session.

In July of this year, at the organizing meeting of the Interim Water and Natural Resources Committee—the largest legislative interim committee that we interact with as agencies—I provided the following remarks to the committee. We were in the depth of the drought in July, and were starting to see some rain from the monsoon but not out of the drought yet. Here are my comments to the Interim Committee

First of all, you want the Office of the State Engineer (OSE) to protect New Mexico's water from aggressive action by our neighboring states—so do we. You want us to efficiently and effectively spend tax-payers' dollars on critical infrastructure. You want us to identify and provide the government resources of water, if they exist. You want us to protect senior water rights. You want New Mexicans to be able to maximize the benefit of their valid water rights, or you want mechanisms in place to provide others to do so if they cannot. You want a strong economy with New Mexicans back at work. Water is an element of almost any activity that gives us those benefits. You want us to drive forward effective planning for the future with a focus on implementation. Implementation is the hard part. We have done a lot of planning around New Mexico. Turning those plans into something that is implemented is the hard work—not just a planning document that gathers dust. You want locally derived solutions and plans that fit the uniqueness of the region that the state can come in and endorse.

You want OSE to have administrative programs in place that allow us to react collectively to conditions that present themselves in the current year—not down the road, years later, or not at all. Some of the discussions have acknowledged the variability that we see in New Mexico on a yearly basis. You want us to finish adjudications for water rights so that New Mexicans have certainty in their share of the $15 billion plus back-of-the-envelope estimate of what water rights are worth in New Mexico. You want us to enforce water rights when we must and keep the system legally functioning. To all of the above, we do too.

The theme I'd like to try to work with you on today, as I have over the last couple of years, is the connectedness of all of these issues. We change hats all day every day, from being in front of chambers of commerce, to being in front of an agricultural community, to being in front of the Interim Legislative Committee, to addressing the legislature. We look at how to fund projects. How do we plan for them? How do we consider the ecosystem? All of these things are connected. I will give some examples of how these are connected from what I have seen over the last couple years.

We have talked a lot about living in a year of extremes, and I don't think that is lost on anybody. By June, we had the hottest, driest 30 months we had ever seen, and it was hard on New Mexicans. We lost 40 percent of the cattle herd, and it had a huge impact on agriculture. We were seeing an agricultural community that is used to having feet of water to apply to their land having inches in these years. We had communities where water tables had dropped below their wells, and suddenly we had emergencies we had to deal with in many places around the state. We had a priority call on the Pecos River—there was no water, how do we address the shortage? The Lower Rio Grande Valley had the shortest irrigation season ever.

In July, as predicted by our scientists, we began to see a monsoon season. It was slow at first, then cranked up by September to something we had not seen in a long time. Back in June, I had literally been talking on the phone with Mike Hamman from Reclamation on amending a prior state engineer's order on how to manage Sumner Reservoir for drought conditions to getting another phone call from Mike saying I needed to start exercising the gates—we were in flood operations. It was an incredible swing between June and September with flood conditions in four reservoirs on the Pecos system: Avalon, Brantley, Fort Sumner, and Santa Rosa. The anecdote was that within 36 hours, Santa Rosa came up roughly 30 feet, peaking at a foot an hour. It was an incredible amount of water coming into the system. The Pecos River basin actually benefitted from the rain the most of all the basins around New Mexico.

Let me start by talking about one of the connections—water planning. A favorite quote of mine, from Albert Einstein, is "In theory, theory and practice are the same, but in practice, they are not." Certainly we see that all over New Mexico. Planning must respect that we are a big rural state. We have very different situations and conditions throughout the state. In the eastern part of the state, they get 100 percent of their water from the Ogallala, all groundwater, and that is a different situation from the Lower Rio Grande, where a river runs through the basin, with groundwater and surface water being used. In the Middle Valley, we have the largest concentration of citizens in New Mexico. This year is the perfect backdrop for the importance of doing water planning. Most of you are aware that the legislature approved, and the governor signed, a $400,000 appropriation to reinvigorate state regional water planning around New Mexico. Water planning had been languishing for years. There has not been much support for planning the past five or six years. The new appropriation got us off and running.

The Interstate Stream Commission (ISC) is charged with implementing state regional planning, and in a series of meetings, over days and weeks, the ISC planning commission sat down and said, let's look at the records for the last 15 to 20 years of planning, what worked and what didn't work, and how are we going to roll this out for the future. We came up with a different approach after much thoughtful input on how we should proceed. This is one of those places for opportunity. Here are some of the changes, and they are not without detractors, but to me they make a lot of sense.

First is that the state, through its various commissions, the ISC, the OSC, the Environment Department, and the legal teams is going to provide to the regions, a common technical platform from which to start the planning process. The technical platform will provide supply and demand projections, and the legal framework that New Mexico needs to work within, for the 16 planning regions around the state. The charge to the regions will be to start from that place. We know there will be some give and take that needs to occur over the supply and demand projections, and that is part of the process. But instead of spending too much time and effort getting to that place as happened in prior efforts, we want to provide that information to the regions and let the regions go from there. Then, the hardest part is what to do with the projections. If there is a supply and demand imbalance, what does the region propose to do in terms of policies, programs, and projects to deal with the imbalance within the available legal framework? We then need to decide what to do about it. How do we implement what regions have come up with? That's part of the connection—the best planning cooperation.

Now I want to talk about how this relates to the funding connection. Before I move off this topic, I want to provide a couple of other examples for opportunities. First, I ask you to consider the magnitude of the effort in the Colorado Basin where there are seven states, Mexico, two compacts, an agricultural community, hydro-power, and the environmental community. The magnitude is not insignificant. Work is being done to look at supply and demand, and what the future ought to look like. Probably for a lot of us, that is a model for cooperation. It is not easy, it is contentious, and it has a ways to go. But it is an example of an effort where tools have been developed that I believe we can all capitalize on.

Also, I want to talk a bit about the Gila program, and the Arizona Water Settlement Act. Through the Act, New Mexico has the opportunity to develop up to 14,000 acre-feet of additional water in a given year, with some funding to back that up. I have seen articles in the paper lately about this—with the assumption that the ISC has already predetermined what the outcome of that effort is going to be. I can assure you that is not true. I am the secretary for the ISC and I can tell you we are not conspiring among ourselves. We are waiting for work to be done in order that the recommendations can be considered by the commission for a decision that must be delivered to the Secretary of the Interior by the end of next year. The presumption that we have already decided on projects is wrong. We have 15 project proposals still on the table. They fall into five categories: watershed improvement, municipal conservation, diversion and storage, community ditch improvement, and wastewater reuse.

We would like to change the connotation of wastewater effluent. One of the things we are doing with the State Water Plan is that we are trying to coin the term "recoverable water." We are trying to change the thinking behind brackish water, potable, and non-potable wastewater reuse, and produced water. We are attempting to change the connotation that we had in the past where these uses were thought of as a liability—that we needed to find a way to get rid of this water. Instead, this water can be an important asset to New Mexico down the road. It is being considered in each of the 15 remaining Gila proposals being evaluated for technical feasibility, environmental impact, cultural consideration, economics, and water supply. The plan is to deliver the final reports back to the commission for a preliminary decision in August of 2014 with the goal of delivering a final decision to Interior by December 31, 2014.

An exercise in perseverance that is particularly difficult in the Middle Valley is the Recovery Implementation Program, and the Biological Opinion for endangered species—the Silvery Minnow and Southwest Willow Flycatcher, in particular. It is hard work. Many folks in this room are at the table trying to work through this. Again, these are opportunities for collaboration.

An issue that everybody is talking about, because I think it is part of our future in this administration, is New Mexico's Active Water Resource Management (AWRM). You will recall the *Tri-State* case that was decided by the New Mexico Supreme Court a year ago concerning priority administration. To me, AWRM boils down to three components. One is pure priority administration with a fully adjudicated basin where you have certainty regarding everybody's rights. That is part of the process. AWRM asked what happens if you do not have a fully adjudicated water basin. Either it is not fully adjudicated, or is partially adjudicated, or we just haven't gotten to it yet. In water-short years, how should the state engineer administer that water? And AWRM, according to the New Mexico Supreme Court, is based on a hierarchy of data, and that will do the same thing. Thus you could administer in priority based on this hierarchy of information. Lastly, the ruling provided for an alternative administration. We have heard today that parties say that pure priority administration does not make sense for us—let's work through a way to alternatively administer what would be a locally generated solution that the state can support. I want to point out a couple of very specific examples that took place this year. In April, we had the two largest groundwater user groups in the Lower Rio Grande come see us. To their credit, they brought this local initiative to us, and said now that *Tri-State* has been decided and AWRM is implementable, we would rather not litigate for the next 50 years. Let's sit down and work together through an administration scheme that is locally directed. That got us off and running. They are leading and working together with us. A lot of discussion has occurred since April, and I think we are getting close.

In the early stages of water resource management, which includes things like expedited water leasing, a water banking arrangement, placement of plans [tape ends and new tape is inserted with a loss of some recording] that is a really significant step, and I think what we're learning we'll be able to roll out to other parts of New Mexico.

Last Thursday, Steve Vandiver—who some of you know and who has been around a long time including as a state engineer from Colorado—made a presentation to the interim water committee in Santa Fe. In his retirement now, running the closed basin project in the San Luis Valley of Colorado, and he is doing a great job. Steve talked to our legislators about the project being a locally generated solution to help stave off a priority call by senior surface water users in their valley. Steve talked about the triggers that led to the effort. He talked about the importance of the modeling effort in order to avoid a competing modelling problem that we see all over the West. They actually went to court and had the court adopt a model that would be used to manage it. It made a lot of sense. Steve talked about the importance of having the adjudication completed in that basin and how that served as the underlying framework for how it would be administered. He talked about how it wasn't a "slam dunk." It took a lot of work and was very contentious, but it was locally generated. They taxed themselves in order to do certain things and it seems to be very effective right now. The New Mexico legislative interim committee comprised of nearly a third of the entire legislature, was very engaged in this discussion and they were saying "Hey, this makes sense for New Mexico." What we, from OSE, were sitting back thinking was, "This is what we are doing in New Mexico." Almost every western state—and I think Nathan Bracken would agree with this—is utilizing some form of what we refer to in New Mexico as AWRM. In most cases, it is some sort of alternative administration scheme.

I will wrap up by talking about infrastructure. On Tuesday, the governor announced a challenge to the legislature to consider using 60 percent of the state's capital outlay program for water infrastructure statewide. This request was not done in a vacuum. We have been traveling around New Mexico and have heard communities tell us about their needs. New Mexico's Water Trust Board's capital outlay program was created about 13 years ago. The Board uses 10 percent of the state's severance tax capacity for funding five categories of water-related infrastructure projects. This year we had 120 applications for over $140 million worth of funding. We will have about $30 million to spend that links into the capital outlay program. That is not enough. The governor's challenge is to do it right this year. It will be very interesting to see if the legislature supports this request.

A bill concerning public-private partnerships was introduced last year, but it did not get very far in last year's 60-day session. Nathan Bracken and several others talked about where the money comes from for this work across the West. We have a lot of experience around the country with public-private partnerships. There will likely be renewed interest in connecting the private sector and public needs as we go into the upcoming session.

Another connection I wanted to talk about is the Rio Chama Acequia Association that developed a shortage sharing agreement this past year. Right where the Rio Chama meets the Rio Grande in New Mexico are some of the oldest water rights in the state as well as the whole country. Those old water rights go back to the 1600s and 1700s. What do you do when there is essentially no native water left in the river, and acequia users with the oldest water rights in the state watch imported San water go by? They are saying, “We have senior water rights, that water should be ours.” And we are saying that it is not native water; that is not part of the management deal. I give kudos to Frank Hill with the Rio Chama Acequia Association and our staff for coming together and working through a shortage sharing agreement to get through the year. They have recently been on the circuit talking about how the shortage sharing agreement was accomplished. Lots of other opportunities exist for us to work on together.

As a new state engineer working with the staffs of both the ISC and OSE, I can tell you that these agencies have very professional, very smart, hard working groups of people working on your behalf. These agencies are probably two of the most beat-up agencies out there. Everybody takes a lot of heat for trying to do the right thing. They are a really good group of folks and you should be proud of them.

Thank you all very much.

Hope for the Colorado River Basin — Recent Successful Agreements with the Republic of Mexico

Tanya Trujillo
Colorado River Board of California

Tanya Trujillo is the executive director of the Colorado River Board of California. She previously served as counselor to the Assistant Secretary for Water and Science with the Department of the Interior in Washington, D.C. From 2009-2011, she served as counsel to the Senate Energy and Natural Resources Committee, overseeing the Subcommittee on Water and Power. From 2004-2009, she served as general counsel to the New Mexico Interstate Stream Commission in Santa Fe, New Mexico. Prior to working for the State of New Mexico, Tanya was a partner at Holland & Hart in Santa Fe with an emphasis on natural resources issues. She received a B.A. from Stanford University and a J.D. from the University of Iowa College of Law.

Thank you for the introduction and it is a pleasure to be here today to make this presentation in honor of Al Utton. Unfortunately, I did not have the pleasure of meeting him, but I read as much information as I could find about him and I spoke with many people about him. There is no doubt that he was much loved and admired and that he left an important legacy for anyone interested in water policy, and in particular transboundary issues. It is great to have the Utton Transboundary Resources Center at UNM and the *Natural Resources Journal* to carry on his great work.

One of the tributes to Al Utton that I came across was written by another renowned water law professor, David Getches, from Colorado. David Getches wrote: “His legacy is teaching us how to reach across political boundaries, to convene people around ideas, and how to use the synergy of their intellect and values to improve the way law and policy operates.”

I understand that he felt strongly about the importance of interdisciplinary solutions—and he thought that mixing law and technical expertise is good for policy decisions.

What I heard about most was Al Utton’s emphasis on an ability to maintain and foster relationships and to bring people together to avoid conflicts. He would always look for opportunities to socialize—he had a great sense of humor and was full of humility.

The best advice I received in preparing for this talk was from Rose Utton, the wife of John Utton, Al’s son, who advised me to emphasize Al Utton’s important quest for the best margarita. I am very pleased to know the Utton family and am honored to have been asked to make this presentation.

Today I am going to focus on the Colorado River, and in particular, issues relating to our relationship with Mexico. I will talk about how some of the themes that Al Utton focused on relate to the issues we are dealing with today. I came across Al Utton’s 1994 UNM Research Lecture titled, “Water in the Arid Southwest—An international region under stress” and thought that the same title would be appropriate for the Colorado River Basin 20 years later.

We have been dealing with extreme drought, divisive litigation associated with water development and environmental issues, and contentious political issues relating to water issues—and border issues. The additional pressures are on top of the “normal stresses” of trying to balance agricultural, urban, and environmental water uses in an arid land, which are issues that exist on both sides of the border.

To focus briefly on the Colorado River Basin drought, as was mentioned by some of the other speakers, from 2000-2013 we encountered a severe drought, and experienced the worst conditions over the past 100-year record. Our reservoir levels have dropped to 50 percent, and the last two years have been particularly dry. Next year, 2014, will be historic due to its low level of release of water from Lake Powell. But, as was also mentioned this morning, we have a highly variable system, and in 2011 we had over 200 percent of the average snowpack. We are crossing our fingers for a good winter, but it will take time to recover.

Stresses in the basin include a potential imbalance between supply and demand as was mentioned in connection with the supply and demand analysis that the Basin States and Reclamation undertook. That imbalance could affect areas outside the basin like the Middle Rio Grande area that relies on San Juan-Chama project water coming over from the Colorado River Basin. To address these concerns, the Basin States and Reclamation are working on short-term drought plans and long-term strategies to be able to address what may be coming at us in the future.

The Colorado River Basin also involves Mexico. Part of the background that Al Utton would have taught us is that much of the Colorado River Basin used to be Mexico—until the Mexican/American war in the 1860s that resulted in the acquisition of California, Arizona, and New Mexico by the U.S. This history likely matters with respect to how we approach negotiations with Mexico and how we think about moving forward.

It wasn't until 1944, that a Treaty determined our water sharing arrangements with Mexico, which addressed the Colorado River and the Rio Grande, and I will spend a few minutes talking about that as well. On the Colorado River, the U.S. delivers 1.5 million acre-feet annually.

Jumping forward to 1973, 30 years later, the U.S. and Mexico entered into Minute 242. It is my understanding that Al Utton was responsible for bringing people together from the U.S. and Mexico for a symposium to address the problem of salinity in the river that eventually led to Minute 242. The Minute requires a set of detailed calculations about the quality of water to be delivered to Mexico that must be implemented on an annual basis, and also provided a water supply from the U.S. to a wetland area called the Cienega de Santa Clara that remains an important area for Mexico.

In addition to salinity concerns regarding the deliveries of water from the U.S. to Mexico, certain projects undertaken within the U.S. have had an effect on Mexico, and the lining of the All American Canal is a good example. The project was seen as a positive step in the U.S. to help California reduce its reliance on unused water that was available from Arizona and Nevada. But the project was seen as a negative project from a Mexican perspective because lining the canal would result in reduced groundwater seepage that had been utilized by Mexican farms. That tension resulted in litigation, and was ultimately resolved through Congressional action, but it also led to diplomacy, and a commitment from both countries to look for innovative water management tools to benefit both countries. That commitment became the foundation for some of the recent agreements.

Focusing on the events since 2010, there have been four important agreements with Mexico. All of these Minutes have built off each other:

- In 2010, the U.S. and Mexico entered into Minute 316. Minute 316 was an agreement regarding the operation of the Yuma desalting plant, which was authorized by Congress in 1974 but was not actively utilized. Water users and Reclamation undertook a pilot project to test the plant's ability to help more efficiently use water in the U.S. Because the project may have had effects in Mexico, we worked with the Mexicans to provide for alternate means to get water to the Cienega de Santa Clara.

- Also in 2010, we signed Minute 317, which developed a framework for additional cooperative measures. It is a process document, establishing work groups and methods of moving things forward.

- Finally in 2010, Minute 318 was adopted to respond to the Easter earthquake that severely damaged Mexico's water delivery infrastructure. Minute 318 allowed Mexico to defer delivery of some of its water so that Mexico could repair its infrastructure and would not waste water because it could not use it. This also resulted in a benefit to the U.S. because the water stays in Lake Mead and helps keep the reservoir levels higher.

- In 2012, we finalized Minute 319. The anniversary of the signing of Minute 319 was yesterday, November 20, 2012 and Figure 1 shows a picture of the signing. Minute 319 involved many long hours of negotiations and includes several components. Each of the components was a necessary element of the agreement. I would like to describe the elements of Minute 319 and some of the important steps that are underway to implement Minute 319.

Figure 1. November 20, 2012 signing Minute 319

Minute 319 extends Minute 318 and allows Mexico to continue to defer deliveries in order to continue to make repairs to its infrastructure. Minute 319 extends the shortage and surplus provisions of the agreements that have been implemented within the U.S. to Mexico, such that Mexico will share in shortages if shortages are imposed in the U.S. and similarly, if the hydrology turns around, Mexico will be able to take additional water. Mexico will also be able to create an "Intentionally Created Mexican Allocation," which allows Mexico to bank water it has saved as a result of conservation projects. Specific rules were developed for this program that are similar to the program developed among the Lower Basin states for intentionally created surplus. Mexico is allowed to create up to 250,000 acre-feet per year and can ask for a release of up to 200,000 acre-feet per year as determined through the normal water ordering and allocation process.

Minute 319 also addresses salinity issues and we agreed that the salinity requirements from Minute 242 would still be in effect. I will go into a little more detail about the "water for the environment" provisions and the "international projects" sections of Minute 319.

The water for the environment provisions of Minute 319 build off decades of work by entities on both sides of the border. The Minute allows Mexico to utilize some of its water allocation for environmental flows. Implementation of these provisions has been an example of great collaboration among representatives of the Basin States, the federal government, and NGOs in both countries to develop a plan for a pulse-flow release. The pulse flow will consist of approximately 105,000 acre-feet of water that is anticipated to be released this spring that will be supported by water in future years that will create base flows. The restoration efforts consist of plans for active and passive restoration efforts in seven reaches of the river corridor south of Yuma. We are also in the process of developing monitoring plans for the project so that we will be able to measure the effects of the pulse flow and evaluate the level of habitat benefits that were created. The project is experimental in nature so it is important to develop a monitoring plan to measure the effects and progress of the restoration efforts.

Another interesting aspect of Minute 319 is the development of "International Projects." The Minute contemplates "joint" projects that would be developed by both countries and would provide benefits to both countries. For the initial pilot project, U.S. entities have committed to provide funding for efficiency projects in Mexico or to develop jointly new sources of water. In exchange, Mexico has committed to reduce its water orders by 124,000 acre-feet and that amount of water will be converted from water saved by Mexico into water that can be used by the U.S. entities in the U.S. The efficiency projects will continue to provide long-term water savings to Mexico.

Thinking again about Al Utton's legacy, and thinking about what makes Minute 319 work, there are a few things we have learned and things we can continue working on. This agreement has been a fragile effort and we have to be very careful about respecting the understandings that went into the agreement.

Having strong leadership in both countries has been an essential element. We have had support from the ambassadors, the Secretary of the Interior, and all levels of government. Having the political will and support to get things done made a big difference, especially during some of the tough negotiations.

The Basin States also played an essential role and provided political will to bring the agreements together. The Basin States were completely aligned for Minute 319 and continue to be involved in all aspects of the implementation.

NGOs and the media have played an important role as well, again recognizing that the components of the Minute have been under development for a long time.

Perhaps the most import elements have been the qualities of patience and trust, and maybe even good luck. The negotiations took a lot of time and effort and the process is tedious and time consuming in part because of the need to work through translations. It takes time to develop relationships and to learn how to understand each other. One example of working at developing the relationships involved a tour provided for the Mexican delegation of some of the facilities in the Upper Basin, because that was an area that was not as familiar as the Lower Basin for some of the negotiators. That tour was helpful in showing our Mexican counterparts what some of our challenges are and how our system works.

The next question is "What's next?" How do we build off the foundation we have established? Minute 319 is a five-year pilot agreement, but it includes a commitment from both countries to work on a longer term agreement. The next few years will include continued work among technical, legal, and operational experts, working together and demonstrating lots of patience. We know that our relationships count and we will continue to work with our counterparts in Mexico on trying to make this a success.

We know there are several interconnected challenges that we face together in this "International Region Under Stress." We have large population growth in our border cities and elsewhere throughout the basin. That is coupled by a desire to maintain our valuable agricultural production and to continue to use Colorado River water to support economic growth and industry. Additional interconnected challenges include addressing the drought, which has an effect on the entire system.

We have common environmental issues and common goals of restoring or maintaining habitat along the river. The Lower Basin's Multi-Species Conservation Program will spend hundreds of millions of dollars on projects within the U.S. that are complemented by the restoration work in Mexico under Minute 319. We are working to benefit the same species and there may be some way of connecting the projects.

Politics is also a potential challenge. Political will is a necessary component and because of the strong benefits to both countries, there has been a will to continue to work on creative solutions. But politics can change from administration to administration and can be affected by conditions within each country or within any of the States. We were fortunate that the new administration in Mexico has continued to support the provisions of Minute 319 and we have continued to move forward, but we always have to be prepared to address what may come up. Border issues are very political and although the border is something that separates us, the river may be something that brings us together.

I wanted to touch briefly on the Rio Grande issues because the conditions present on the Colorado are not the same as the conditions on the Rio Grande. On the Rio Grande, Mexico has a delivery obligation to the U.S., and Texas has had long standing concerns about Mexico's practice of meeting the delivery obligations to the U.S. Some members of the Texas congressional delegation have sought to limit the ability to go forward with Minute 319 unless the Texans get the relief they want on the Rio Grande. This linkage has not been supported by the entities working on the Colorado River and is not in the spirit of the win-win agreements that have been reached on the Colorado River. We'll see how things continue to develop, but the Rio Grande issues sound like they would have been a perfect project for Al Utton to have been working on.

Thinking about final advice from Al Utton, I think he would urge us to continue to bring people together across boundaries, to continue to learn from each other, to continue to get to know each other, and to always remember to reserve some time for margaritas.

Is Prior Appropriation Dead?

Em Hall, Professor Emeritus
University of New Mexico School of Law

Em Hall has been since 2007 a professor emeritus at the School of Law, University of New Mexico. As a professor since 1982 he has taught courses there in property law, water law, federal public lands law, and New Mexico land and water legal history. He has published three books on New Mexico land and water including "The Four Leagues of Pecos" (1984), "High and Dry" (2002) and "Reining in the Rio Grande" (2011) and many articles on New Mexico natural resources. He is a graduate of Princeton University (1965), the Harvard Law School (1969), and Pecos Prep (1970-1981).

Editor's Note: The following is an unedited, direct transcription of the presentation by Em Hall.

Thanks very much. It's nice to be here. It's also nice to come relatively late after a series of speakers. John Shomaker said that I would answer all of the questions, and I was terrified at that prospect. Then State Engineer Scott Verhines came on and answered all of the questions that Shomaker might have had. So I am working on a blank slate, which is where I am better off, especially at this time of the day, after we all have had lunch and probably need to take a nap.

Cathy Ortega Klett asked me to speak at this year's conference. She gave me the title for the talk—is prior appropriation dead? It's hard to swallow a mouthful like that, especially in the twenty minutes provided to me, but Cathy and I decided I would focus on the priority part—the part of Article 16 Section 2 of the state constitution that simply says that priority in time should give the better right. There are only a few words there. The important part is that it is in the state constitution. That has a lot of meaning in terms of its impact.

But, even limited to the question of priority, within the doctrine part of appropriation, it's hard to think of a title like that without the nod to Mark Twain, who has been with us since before this morning. When Mark Twain was asked how he liked the fact that his death had been reported, Twain said, "Well, reports of my death have been greatly exaggerated." Also exaggerated has been the guarantee in Article 16 Section 2 that priority in time should give the better right in times of shortage. The priority doctrine flickers around in the history of water in the state, mostly in the deep background of water politics, and almost never in the actual allocation of varying and short supplies. You need to recognize that what looks like a simple command in the constitution has much deeper and harder to see meaning with respect to what is going down. So despite the fact that people are saying that we had better pick up that priority appropriation is dead, priority is back, and no fear that it ever was dead.

In my short time here this morning, I want to focus on two very recent New Mexico Supreme Court decisions, the 2012 *Tri-State* case and *Bounds* in 2013, and suggest to you how they may not have eliminated priority so much as shifted the doctrine's angle of repose in western water law, and in New Mexico law. In that posture, I think that the question that needs to be asked is not whether the two decisions have killed priority, but in what form have they resurrected a doctrine that has been moribund for a long time in this state.

When Steve Reynolds, who was my mentor and friend, used to give speeches like this, he would begin by saying, "I think it is good to start off with a little bit of history." I'd like to give you six points of priority history in New Mexico to show you how convoluted and obscure the priority doctrine has been in this state. All of them demonstrate the fact that priority isn't what it seems, and then we'll try to talk about what it will become.

Point one: pre-1848 Spanish-New Mexican water rights. Here is the thing—there was no such thing as strict priority enforcement in Spanish-New Mexican water law prior to 1848. Under pre-United States law, the priority was only one of many factors that was used in order to determine by public entities how best to distribute supplies. It wasn't the single factor that it is in the state constitution. It was one of many factors. I start here because it is historically interesting, and to try to clear up some historical misconceptions, because, of course, New Mexico said that New Mexicans have followed the doctrine of prior appropriation before Queen Isabella's will in 1493. That is not true. There have been important changes, and one of them is the doctrine of priority.

Point two: a bad Californian idea. Better legal right that priority conferred under post-1848 American law emerged only after 1848. A ferocious rule that seniors that had priority to all the water to which they were entitled before "no sharing shortages" came from the Sierra Nevada gold fields in California and was picked up here in the 1870s and 1880s, and confirmed by a series of U.S. Supreme Court cases including *Keeney vs. Carrillo* in the late 19th century. It came from California, and took hold here, but never was implemented.

Point three: priority in Article 16 Section 2 of the state constitution protecting Hispanics. Yep, here is the priority provision, but it got in late when the 1912 Constitution was being drafted, and only got in there because Dan Cassidy of Mora County (the Mora county delegate to the constitutional convention that drafted the constitution) insisted that provision be added. Before that, it was just beneficial use shall be the basis, the measure, and the limit of the right to the use of the water. Cassidy insisted on the priority provision in the constitution in order to guarantee water rights for existing, largely Hispanic, largely acequia water rights from what people knew were the rapacious plans of the United States to add to and change the water institutions of the Southwest.

Point four: priority in the 1947 Pecos River Compact. We are jumping now a long way, but it is a subject that will come up again today. Tracy, and other Carlsbad participants in the drafting of the 1947 Pecos River Compact were allocating the water between Texas and New Mexico, insisting on the insertion in the compact of a provision that said New Mexico would follow New Mexico law, including priorities, in order to make up Compact shortfalls at the state line. The reason Tracy did that was that he was terrified that existing federal law said a state can get Compact water wherever it wants. If that rule had to be applied, the easiest place to get Compact water in case of shortage, was from downstream senior Carlsbad. Carlsbad people said, we're not in favor of that Compact unless you put in a provision that says that you will enforce priorities (presumably against the junior upstream Roswell wells).

Point five: groundwater-surface priority nightmares on the lower Pecos. In 1976—and I don't know if there has ever been a priority call of this magnitude before—Jay Forbes, who was the Carlsbad Irrigation District (CID) lawyer, and who became a district judge in Carlsbad, called the priorities on the Pecos River against junior upstream Roswell wells. Forbes demanded that Roswell wells be shut down in order to guarantee the full supply of water—strict priority—to the CID and its members. Initially, and this hasn't been much noted, State Engineer Steve Reynolds said, alright, this is what I am going to do. I am going to build a well field in the northern Roswell extension where the Corn family has extensive groundwater rights in that system. If the CID, or the Pecos River Compact is short, I am going to pump those wells after the fall irrigation season, and the next spring. I'm going to shut down the Roswell wells in the amount that I had to pump the state wells in order to get the water to CID and to the Compact. This was true enforcement of surface to ground priority, and Reynolds, as smart as he was, figured out immediately one way to solve the dilemma of how you pull surface to ground priorities. It's a dilemma, but Reynolds figured it out. Reynolds, having cooked up the solution, then decided he couldn't do it. His lawyers said there was no completed adjudication, and you can't enforce priorities until your adjudication is finished, which postponed the enforcement of priority on the Pecos, well, forever I think. Later this afternoon we are going to hear what led to the settlement with Roswell and Carlsbad that produced this situation. We will hear from Greg Lewis who is New Mexico's Pecos River Basin Manager and who is in charge. The point about the well fields is in the south—in the Three Rivers area of the Roswell Basin—is that that is not priority enforcement. Reynolds' initial decision was priority enforcement. The very expensive buyout and implementation of the state well field south of the Roswell Basin was not priority enforcement. You'll notice that in the examples that I have given, there has been no actual time that priority has significantly affected distribution of water. All we have been doing is fighting about the idea of priority and how it might be implemented rather than priority enforcement.

In the last 20 to 30 years, there have been efforts to actually enforce priorities in such a way as to affect the actual allocation and distribution of water. Let me give you a couple examples of those including some situations to which State Engineer Scott Verhines referred. One that seems to have worked is on the Rio Chama as State Engineer Verhines described. It was a complicated series of adjustments that resulted in full supply to the senior rights holders without any drastic detriment to junior rights holders. It was done by local enforcement that honored priority, but developed a flexible scheme toward implementation. Much more typical in the world of priority has been a recent suit by Los Lunas farmer Janet Jarrett, who owns the prior right on the Rio Grande. Jarrett sued the Middle Rio Grande Conservancy District (MRGCD) because the district refused to distribute district water by priority and to her detriment she said. What you had was a conflict between the state constitution, priority in time, priority should give the better right, and the state statute that authorized the MRGCD to distribute water in any way it wanted. For those of us who have been to law school, it looked like the state constitution might win over a state statute. That lawsuit disappeared in smoke this year of a very difficult civil procedure. It may come back, but it is one of the few instances where you see an individual trying to enforce priority against anybody, including the MRGCD.

As I said before, the history of priority enforcement in New Mexico has shown, despite the constitutional provision, that it has never been implemented in the state and never used. The question now is what the 2012 *Tri-State* and the 2013 *Bounds* decisions, both of which seem to honor priority without doing much about it, will do to the priority doctrine in New Mexico. I think the safest thing to say is that both those decisions damn priority with "faint praise and assent with civil leer"—which is Alexander Pope's description from 18th century poetry—and leave priority in worse shape than it has ever been, but in a different place.

You'll recall that the 2003 Active Water Rights Management (AWRM) statute got the *Tri-State* ball rolling, and the grounds on which it was attacked on its face was that it conferred on the state engineer powers that were broader than he could implement. Previous cases said there could be no priority enforcement, even interim priority enforcement, unless it was based upon a court decree with respect to relative priorities, and a judicial proceeding that allowed people to protest. That was clearly not going to be true with respect to the AWRM regulations that encourage the state engineer to administer priority on the basis of best available information to him. One district court judge disagreed but the state Supreme Court reversed and said these regulations are fine. Now we will find out what the AWRM regulations mean in terms of a constitutional guarantee that priority in time should give the better right.

The takeaway from what I am telling you today is that you are going to need to pay very careful attention to how. . . given AWRM regulations, the state engineer balances the management of natural resources with the promise that priority will be protected within those regulations. I think you will see a much richer array of priority enforcement techniques in AWRM regulations than you ever did before. There will be rotation. There will be augmentation agreements. People will agree not to irrigate in order to protect the prior rights of people who will be affected by that irrigation. In other words, I think priority is going to go underground, as it should, because it is only one of many factors in the distribution of water. And no mechanical rule, which is the old priority, is going to serve either prior owners or junior owners who depend on that water as well. That is my prediction and I think that it ought to happen.

Let me just say that *Bounds*, in 2013, took a slightly different tact, because it said that the state engineer didn't have to consider priorities when it issues a domestic well permit. There is a variety of legal reasons for that, but it absolved the state engineer of the priority business. *Tri-State* put it deep into the priority business and invited a flexible honoring of that decree in those AWRM decisions. *Bounds* said, at least with respect to domestic well permits, the state engineer didn't have to consider it at all. But, *Bounds* said private people could sue to enforce priority and encouraged *Bounds* to sue the upstream domestic well owners. What you may see is what we have never seen in New Mexico—private suits to enforce priority against junior appropriators. You demand not from the state engineer but from the guy up the stream. Just like in California, you tell him to shut off his ditch or you are going to make him pay for the damages that result from you not getting your full supply. That is ultimate private enforcement of priorities.

You may see some of that, and you see it a little bit in the Janet Jarrett case in the MRGCD. There might be more private efforts to enforce priorities, and that is really what the state constitution seems to mandate.

The state engineer decentralized many controls, a flexible response to priority considerations that is from the old pre-1848 Spanish, and individual lawsuits against junior appropriators for water, which you'll never get, but maybe damages for having a short supply. This matter is pretty vague, it will be very different than it is now, and the world of priority will switch.

Thank you very much.

Health of Settlements — Two Examples on the Rio Grande

Steven L. Hernandez, Esq.

Steven L. Hernandez has practiced water law for over 35 years. He spent time early in his career with the City of Tucson dealing with CAP and the Arizona Groundwater Management Act. He also served in the Department of Interior Solicitor's Office. He is now chief counsel to Elephant Butte Irrigation District and Carlsbad Irrigation District in their various water and power issues. Steve is a member of the Best Lawyers in America, Southwest Super Lawyers, Best Law Firms and The Best of the NM Bar. He is also litigation review counsel for the National Water Resources Association and is the senior member of the NM Bar's Section of Natural Resources Energy and Environmental Law.

Good afternoon. Yesterday I attended a hearing on the priority date of the Rio Grande Project, and there were eight or nine lawyers there. Most of them were scheduled to be here and my hat is off to Tessa Davidson and Alvin Jones who were the only two who made it here with me after that long hearing that dismissed late into the wee hours of the morning.

The photo in Figure 1 was taken by one of my associates, Samantha Barncastle, and shows Elephant Butte at 2 percent of capacity. After the September rains came in, somebody from Santa Fe asked me how our water supply was looking. I said it was at 4 percent now, and they said we ought to be thrilled since our water supply has doubled.

Figure 1. Elephant Butte at 2 percent capacity

When I was given this topic, the health of the settlements, I thought, wow, there are other settlements out there than the two I know most about. One of them I had something to do with, the other one I didn't. I want to talk about the Rio Grande Compact, which is in a sense the ultimate settlement so to speak, between three states and the United States that was confirmed by Congress. Also, there are court settlements, one of which I was recently involved with.

To tell you what compacts are supposed to do, I quote from the opening pages of the Rio Grande Compact: *The State of Colorado, the State of New Mexico, and the State of Texas, **desiring to remove all causes of present and future controversy among these States** and between citizens of one of these States and citizens of another State with respect to the use of the waters of the Rio Grande above Fort Quitman, Texas, and being moved by considerations of interstate comity, and for the purpose of effecting an equitable apportionment of such waters, have resolved to conclude a Compact for the attainment of these purposes… have agreed upon the following articles…* "Desiring to remove all causes of present and future controversy among these states"—that is what was supposed to have been accomplished.

Figure 2 provides the traditional Rio Grande Compact map. You see the state of Colorado, Texas, and New Mexico and you see the district that I represent. We call it "no-man's land," EBID (Elephant Butte Irrigation District). It is always nice to come up here and visit New Mexico. As you can see in my picture, I don't live in New Mexico, I live in Compact Texas. I happen to live in Mesilla, too, in a pecan orchard that is actually on a piece of land that is part of a Spanish Land Grant, and I don't share my water with anybody.

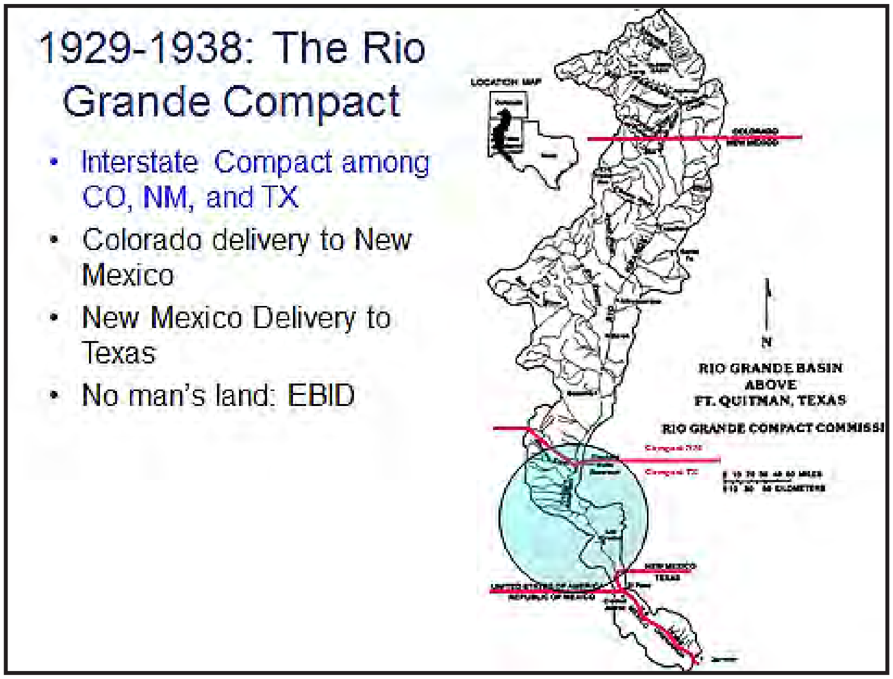


Figure 2. Rio Grande Compact map

This is a very strange situation and always hard to explain to people, including new legislators. State Engineer, Scott Verhines, has jurisdiction over our groundwater pumping, but I look to Herman Settemeyer and Pat Gordon from Texas to protect my surface water. The two district recipients of the Rio Grande Project are EBID with 90,640 acres (57%) and the El Paso district with 69,010 acres (43%). And, of course, built into an already complex interstate system, is the international part of our delivery obligations, which is to provide 60,000 acre-feet to Mexico under the Mexican Treaty of 1906.

To provide an illustration of what brought us into one of our recent litigations, I want to give you a bit of history on the Project. In 1979-1980, the two irrigation districts paid off the project construction costs of building the Rio Grande Project. Apparently, our loan payment schedule was a bit different—EBID paid off in 1979 and the El Paso district paid off in 1980. Nobody really knew what to do then because we were the first two districts in the country to have paid off its construction obligation to the United States for a Reclamation project.

We sat down and made an agreement, and we said that at some point in time we would make a contract with respect to how the United States would divide the water between the two districts. That was important because when the Bureau of Reclamation ran the project, it ignored the state line. The deliveries it made to anybody in Texas or New Mexico weren't any different—they ignored the state line. Once the districts paid off the construction costs, and they received back their drainage and distribution system with the districts running the diversions from the dam, there had to be some agreement as to how the allocation of Project Water was going to work. Well, nothing was done about it for a long, long time because we had years of full water supply. At that time, I was busy fending off the City of El Paso when it applied to drill 266 wells in southern New Mexico. We had other things on our plate.

Nothing really happened until 1997 when the United States, seeing the writing on the wall, filed a quiet title suit to rights in the Project. After the suite was filed, we went to court mediation. They wanted an answer to who owns what within the Project, and they gave money for mediation. At that point, the El Paso district started to mention concerns about pumping in New Mexico and how that pumping was affecting their deliveries. Mediation didn't go anywhere, and the parties were told to go back and proceed to argue in the state stream adjudication to see if they could sort out those issues. I'll talk more about that stream adjudication in a bit.

Drought returned, and in 2003, the State of Texas said it is very concerned about pumping in the Mesilla Valley that they said was affecting deliveries to the El Paso district. I think Texas raised $3 million to undertake efforts to look at litigation, and I think New Mexico responded with $3 million of its own. Then, Texas said, I call and raise you to $6 million. It is really hard to get in a Texas Hold 'Em game with Texas—they keep raising.

At this time, Reclamation started getting extreme pressure by the El Paso district, which said, you're the one in charge here, you need to make a decision about what you are going to do about pumping in New Mexico that is affecting the delivery of our supply. Reclamation came up with what we call the "ad hoc" allocation procedure. Reclamation tried to step in as a referee and said it would go through a series of credits that recognized carryover storage to resolve the problem. Neither district was happy with that. EBID thought they went too far, and the El Paso district thought they didn't go far enough. EBID ran to federal court in New Mexico and filed against the United States saying that Reclamation was allocating too much to the El Paso district. El Paso ran to the federal district court in El Paso and said the same thing, but the other way around, that the Bureau had lost its mind and was allocating too much to EBID, and we want you to settle it.

Since we beat them by two days, I thought we were going to have this case heard in New Mexico. Unfortunately for me, there is a mandatory mediation provision in the federal district court of Texas. So, right away, we went to mediation. We didn't think we would get anywhere, but lo and behold, we did. We actually resolved our differences in the Operating Agreement Settlement that describes how Reclamation will allocate the water between the two districts, and how EBID guarantees that supply to the El Paso district. The El Paso district abandoned its claim that EBID must account for groundwater pumping after the Compact. El Paso and EBID got carryover storage for each district. And now because the two districts get together and place their orders, the ebb and flows of water delivery from the river are much more controlled. This resulted in very good efficiency and delivery.

One of the key aspects of this is that we built in an annual operating manual review process to anticipate issues that we hadn't thought of, which now that I think about it, every compact should have. The Rio Grande Compact should have had that. The recent drought and the efficiency of the river was one of the issues picked up at the last meeting of the engineers to make sure that EBID was not unfairly punished for the decline in river efficiency. So, the Texas threat of filing in the U.S. Supreme Court was removed.

In the stream adjudication case (*NM v. EBID, et al.*, 96 CV-888 (1986)) that I was talking about earlier, we recently completed working on the issue concerning the source or sources of water for the Rio Grande Project. The court recently granted the state motion that the U.S. has no claim to groundwater as a source of water for the Project, only surface releases. What the court didn't formally recongnize was that from the release of 790,000 acre-feet, 930,000 acre-feet is actually delivered to farmers. How can that be? It is because there are 457 miles of drains within EBID that capture that water once it leaves the farm and is put back into the river system. The court indicated that it would not declare that as part of Project supply. It would let New Mexico State Engineer Scott Verhines in an administrative proceeding figure that out—it wasn't going to be easy to deal with it. Yesterday we argued what the priority date is for the Project.

NMSU Professor Phil King provided Figure 3 for those of you who don't understand how the surface water-groundwater-drain return interaction works. Note that the river feeds the diversion/conveyance to the canal. Then there is seepage from the canal. Water is put into the field; crop water use takes part of that, but the rest of it percolates down. The deep percolation hits the drains and that is the return flow. That is where the controversy is—that return product of the initial release of the Project. It makes it into the groundwater table, wells go in, the wells form a cone of depression—the red triangle in the figure. How do you manage that cone of depression? How do you make sure that it doesn't interfere with senior rights whether by Texas or New Mexico?

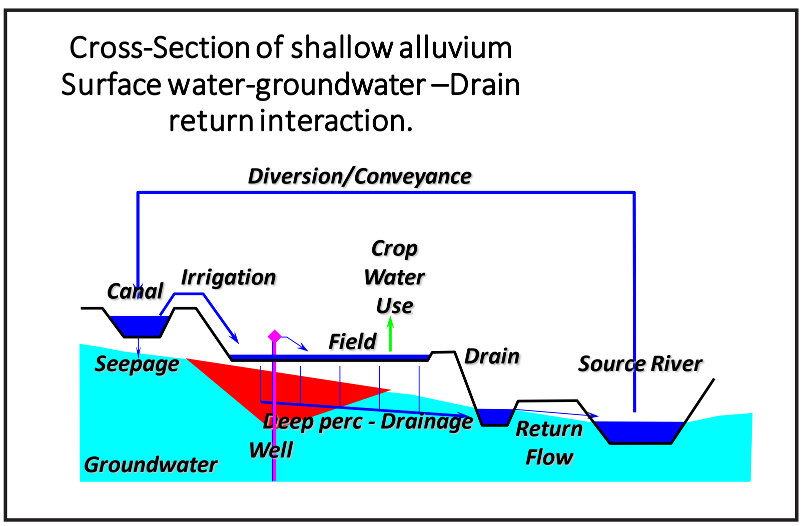


Figure 3. Surface water-groundwater drain return interaction. Courtesy of J. Phillip King

So, the New Mexico Attorney General files suit in 2011 on two grounds. The first was that the Compact accounting gave more water to Texas in a dispute over evaporation losses and the second ground was that the 2008 Operating Agreement Settlement had changed allocation of Project water in favor of Texas. There were two settlements in place: the Compact and the 2008 Operating Agreement Settlement. But obviously, nothing is ever settled because it continues in litigation and somebody will always find something that you missed.

Interestingly, that year the United States also allowed releases demanded by the International Boundary and Water Commission for Mexico under the treaty, which cost the districts 25,000 acre-feet of Project supply. The two districts believe that was a breach of the Mexican Treaty. Now that I have heard Tanya Trujillo's explanation of the deal with Mexico made from Colorado River water, I wonder if this wasn't part of the deal.

Motions to dismiss have been argued in the case, but Judge Browning has said that he is going to await the outcome of the decision by the United States Supreme Court in the January 8^{th} State of Texas filing against New Mexico. Texas complains that as a result of New Mexico's actions, Texas does not receive its share of water apportioned by the Compact and allocated by the Rio Grande Project. They go back and cite their concern over the ruling by the adjudication court that does not recognize return flows as being part of the United State's right in water that composes Project supply and instead leaves that decision to an administrative hearing before the New Mexico State Engineer. Texas has now gone back to its previous position and says it wants all groundwater pumping in southern New Mexico initiated after the Compact accounted for. Everybody jumped into that case. Responses come from New Mexico, Colorado, the City of Las Cruces, El Paso County Water Improvement District #1, the City of El Paso, and Hudspeth Irrigation District. EBID did not file anything. The United States Supreme Court has asked the U.S. for their position. Right before the sequestration, the United States was ready to file their response. It has been put off so we are all on hold waiting to see if the U.S. Supreme Court retains this case. Then we intend to jump into the case as an intervenor.

It used to be that most Supreme Court cases involving states were limited to states and the United States. But guess what happened a couple years ago? *South Carolina v. North Carolina* 130 S.Ct. 854 (2010): for the first time in a water case, the U.S. Supreme Court has allowed non-state parties to come in if they can show some compelling interest in its own right apart from his interest in a class with all other citizens which interest is not represented by the state. In the South Carolina case, you have a district serving water users in two states and Duke Energy serving electricity in both states. The U.S. Supreme Court said these two parties can come in on this water dispute. The City of Charlotte, however, was found to have been represented by its state, so they were not allowed to intervene.

Even now when we think that compacts resolve all issues between the states, they are still in litigation. What the U.S. Supreme Court has done is to open the door to allow non-state parties to enter into these U.S. Supreme Court litigations. So you will see EBID attempt to intervene in this case—because I don't know if I am in New Mexico or I am in Texas.

Thank you.

Priority Administration

Dudley Jones
Carlsbad Irrigation District

Dudley Jones graduated from New Mexico State University with a major in business. He spent 28 years with the JCPenney Company in stores, district staff work, and store management. Prior to starting with Carlsbad Irrigation District in 2008, Dudley was Vice President of The Cavern Supply Company (concessionaire at Carlsbad Caverns National Park) for eight years. He has been with the Carlsbad Irrigation District for five years and is living proof, as he says, that an old dog can learn new tricks.

Well, I do need to inform you that there is a little-known Homeland Security regulation that any time there is a gathering of real critical intellectual property that the I.Q. cannot exceed a certain number, and I am here to make sure we don't exceed that number, and I am proud to serve.

Priority administration is based on two things: one is beneficial use and the other is prior appropriation, which is first in time gets first in right. Em Hall did an excellent job of explaining all of that to us, so I don't need to try to explain that to you again. Given the likelihood that we have streams that are over-allocated due to the manipulation or use of this policy, most these streams have had no consideration of the shortage sharing agreement that was also intended to be part of that prior appropriation. You can see this with over-allocated streams and the undesirable impacts of international treaties, interstate stream compacts, endangered species flow requirements, and historic drought that we have experienced in the Southwest. In 2013 we saw how of these issues led to a stress point. Weather variability will continue and may even become more extreme in its future impacts. This potential raises the sense of urgency required to address these sensitive water issues and other critical related elements of water in the state of New Mexico.

Up to this point, I have only stated some of the obvious things that we have been talking about this morning. We, in this room, are well aware of all of the issues that we are facing and we probably have a stake in one or all of the issues in some way. The proverbial can—priority administration—has been kicked down the road for years and has been left for us to deal with or kick a little bit further down the road. We can sit and talk about what we should have done, and what we could do, and that all makes interesting conversation in the evening when we are sitting around having some drinks. But what are we really going to do about this now that we are facing a crisis? Nothing really forms a solution at this point.

Let me talk about why the Carlsbad Irrigation District (CID), specifically, and some of our partners are interested in resolving this issue. On January 8, 2013, we were faced with the third year of a severe drought impact and water availability to CID members. Through the CID Board, the directors adopted a resolution calling for immediate dialogue among the settlement parties. That includes CID, the Pecos Valley Artesian Conservancy District (PVACD), the New Mexico State Engineer, the New Mexico Interstate Stream Commission, the U.S. Bureau of Reclamation, and anybody else who felt they had issues. No really, that was about it besides the State of New Mexico. We wanted to find a way that we could all deal with this issue. Subsequently, we had several meetings after a solution was passed among those settlement parties and the governor's office that joined later. Senator Carroll Leavell and Representative Cathrynn Brown were approached about the possibility of legislation that might help us avoid litigation and a priority call, Senate Bill 462. Both Districts, CID and PVACD, testified before committees and worked at the legislature to try to get SB 462 passed, but it died in the Finance Committee and the legislative session ended without passage.

On April 2, 2013, the CID Board of Directors adopted a resolution to make a priority call to the state engineer as is provided for in Section 11 of the settlement agreement. That section basically states that if CID doesn't get at least 50,000 acre-feet of water at its Avalon Dam diversion, they make a priority call. Carlsbad Irrigation District reinforced and reaffirmed their desire for a priority call at each target settlement date subsequent to that date of the initial priority call. So the real questions for a priority administration: What are they going to look like? State Engineer Scott Verhines told us what a lot of that might look like this morning. I also have some ideas of what might be included.

First, I am sure that the facts will be checked such as what were the flows, how much water people actually had, how much was available, and who used what. Identifying that information will be an extensive process. Second, there will be exhaustive and extensive modeling taken place to determine the system capabilities, the impacts of various actions that could be implemented, and how they could produce real usable water. Third, lists of priority users by date of priority, who fits in where, and how much water they have will be compiled. Fourth, the State Engineer would probably have a plan of action that would include something like a replacement plan, curtailment, water banking, some combination of these, or new actions that could be implemented to address the shortages. Lastly, you can bet that all along the way that all of this will be challenged in court.

While few, if any, of us present today really are responsible for the challenges of this predicament, it may be our duty to resolve it and to avoid more can kicking, pun intended. But, what are the real answers? I can tell you for sure that I don't know, and I am not sure that anyone here really has all of the answers. What I do know is that we need to continue talking. Isn't this something that is really of importance to all of us and an issue that needs to be resolved for the whole state? What do we do now? Where do we go? What is the status of prior appropriation? Is it dead or does it mean anything? If it is dead, then what is it going to look like or how will it be resurrected? While these are challenging and difficult questions, we probably have more challenging and difficult questions ahead. Nothing will be resolved in any reasonable time frame without continued dialogue. There is still a need for the court system to validate any agreement, but I believe it is more our job to communicate and negotiate rather than litigate.

Water and climate change move in geologic time, while critical water issues in New Mexico move in judicial time, and I can't tell you which one is faster. But I can tell you that we need a real-time way to address these issues and to address the more current and pending conditions. What we have learned today is that a lot of things have happened, lots of things could happen, but we are not certain what will happen. However, we are sure that things will change. As Dr. Catlett challenged us this morning, we must be creative and persistent and keep the water economy of New Mexico going. Therefore, my prediction is that something significant will happen with priority administration sometime in the future.

Thank you.

Clean and Healthy Rivers: Critical Resources for a Sustainable Water Supply

Chris Canavan
NM Environment Department

Chris Canavan has worked in the environmental field for over 20 years and is currently the Field Offices Team Leader for the Watershed Protection Section of the Surface Water Quality Bureau of the New Mexico Environment Department. He was a double major at New Mexico State University where he earned a BA degree in English in 1988 and a BS degree in 1989. He earned an MS degree in interdisciplinary studies from NMSU in 1998 where his research involved examining total mercury and methyl mercury in water and sediment at Elephant Butte and Caballo Reservoirs in south-central New Mexico. As sole proprietor of Blue Heron Environmental from 1998-2004, he specialized in designing and implementing water quality studies for rivers and reservoirs. Chris has been with the Watershed Protection Section since January 2005 where his duties include writing 401 water quality certifications for 404 Dredge and Fill permits; assisting in water quality surveys; working with stakeholders on watershed planning and restoration projects producing the New Mexico Nonpoint Source Annual report; and supervising two staff.

In developing our water resources, we often forget the importance of maintaining the natural systems that provide us with our water. By doing so, we can lose or degrade the most efficient and cost effective water management tool available to us to maintain a sustainable water supply. To protect the surface water resources in New Mexico for future use, it is necessary to understand the functions and services provided by the healthy river and how the loss of function in the impaired river leads to a subsequent loss in services. By examining threats to our rivers from poor management, we can provide the context to develop approaches to maintain and restore our rivers in the future.

All healthy rivers have several basic functions. Rivers transport water and sediment, mitigate flooding, and recharge aquifers. While rivers take a variety of forms, there are common geomorphological characteristics. With minor differences, all natural rivers have either a meandering pattern or step-pool form, a floodplain, a riparian corridor, and an associated hyporheic zone. The hyporheic zone is the least understood of these characteristics and relates to subsurface flow under and adjacent to the river. Depending on the hydraulic head differences between surface and subsurface flows, water may flow into the hyporheic zone or back into the river. The exchange of water between surface and subsurface flows is critical for nutrient and oxygen exchange, maintaining base flow, and maintaining the shallow groundwater table.

In the healthy river, these common geomorphological characteristics provide a host of services. These include: mitigating flooding; storing water by maintaining the shallow groundwater table; providing abundant natural primary production in the riparian area; mitigating pollution; providing water for recreational, municipal, industrial and agricultural use; and providing aquatic and terrestrial habitat. Overbank flooding is the driver for many of these services. When a river reaches flood stage, water overflows the banks onto the floodplain mitigating the impacts from flooding by dissipating energy from floodwaters and reducing flood volume downstream. Floodwaters also irrigate the floodplain and infiltrate into the ground recharging the shallow groundwater table. The riparian corridor provides structure and stabilizes the channel and adjacent floodplain reducing erosion. Riparian vegetation also helps mitigate the impacts from flooding by slowing floodwaters and further dissipating flood energy. In-stream biogeochemical processes provide some pollutant mitigation. Further pollutant mitigation occurs during overbank flooding by filtering pollutants as floodwaters infiltrate into the floodplain. Figure 1 shows Jaramillo Creek as it flows through a wet meadow in the Valle Caldera National Preserve. The creek maintains the ability to mitigate the impacts from flooding, store water and filter pollutants on the adjacent floodplain, maintain base flow, maintain productive grasslands, provide aquatic and terrestrial habitat, and provide excellent fishing opportunities. Riparian areas are also one of the most highly productive areas on the landscape providing forage and habitat for both livestock and wildlife. The combined effects of these services provide healthy and clean water for recreational, municipal, industrial, and agricultural use. Dr. Paul Bauer, Associate Director of the New Mexico Bureau of Geology and Mineral Resources at New Mexico Tech, summed it up well in his book entitled The Rio Grande: A River Guide to the Geology and Landscapes of Northern New Mexico (Bauer 2011):

> *Rivers are essential to life and lifestyle. They are critical habitat for the vast biodiversity of the planet. They recharge aquifers, nourish floodplains and farmland, create swamps, drain swamps, dilute natural and human pollution, and transport sediments and nutrients into bays estuaries, deltas, and oceans. Rivers provide us with drinking water, crop irrigation, navigation, food, hydroelectric power, spiritual fulfillment, and many other uses – including of course, recreation.*

The river with geomorphological impairment can lose one or more functions of the healthy river. For purposes of this discussion, the relevant impairments are all related to sediment transport (sediment regime) by one or all of the following: aggradation, degradation, bank destabilization, or the loss of floodplain, and associated incision. Aggradation can occur from a change in sediment supply that leads to a depositional sediment regime as a result of events such as increased runoff and subsequent upland erosion following wildfire, increased in-stream erosion upstream of the aggradation area, and increased erosion in tributary watersheds. The result is seen in the formation of side bars, mid-channel bars, channel widening, lateral migration, and in extreme cases, channel avulsion. Aggradation also occurs behind both large and small retention structures that result from decreased flow velocities and the subsequent decreased capacity to transport sediment. Degradation can arise from a change in sediment supply to an erosional regime for a variety of reasons that include denuding of stream banks, channel modification including straightening, poorly designed in-stream structures, levees, hardened bank stabilization, and floodplain narrowing related to urban or agricultural encroachment or transportation and utility development. Most degradation is associated with some form of bank instability. In extreme cases this leads to channel incision and a disconnected floodplain.

With the onset of incision and the loss of floodplain comes a commensurate loss in services. The most significant of these are the loss of floodplain water storage capacity, reduced base flow and severely reduced floodplain forage quality and quantity. With incision also comes increased erosion, reduced flood and pollutant mitigation capacity, and the loss of both aquatic and terrestrial habitat. The combined effect of this is to reduce the amount of water available for recreational, municipal, industrial, and agricultural use and to increase the risks of flooding. Figure 2 shows degradation in the form of incision along Magado Creek in the Sacramento Mountains. The incision has resulted in a disconnected floodplain and a loss of flood and pollutant mitigation. There is also a subsequent decrease in water storage, base flow, productivity

Figure 1. Jaramillo Creek provides all the services of a healthy river including flood mitigation, groundwater recharge, pollutant mitigation, aquatic and terrestrial habitat and recreation opportunities.

of the adjacent grasslands and both aquatic and terrestrial habitat.

Threats to rivers often result in geomorphic changes. Confining the river from urban encroachment, installation of levees in the floodplain, and insufficiently designed utility and transportation crossings can result in narrowing the river and destabilization of the bed and banks (Fig. 3). Poor watershed management can result in increased surface runoff and erosion leading to an increase in sediment supply. Dams and other channel modifications can drastically alter stream geomorphology. These impacts are often accompanied by channel adjustment that can then lead to other problems as mentioned above such as bank destabilization and incision.

Figure 2. An incised reach of Magado Creek no longer provides water to the floodplain reducing flood mitigation, shallow groundwater recharge, pollutant mitigation, aquatic and terrestrial habitat, and forage quality and quantity.

To protect our future surface waters from poor management it is necessary to adopt meaningful solutions. These include: protecting healthy rivers from degradation (including the associated floodplain); direct restoration funding toward those areas with the greatest potential for restoration and future protection exists; conduct sound watershed management and upland restoration; promote healthy watersheds; and stop new development on floodplains. These decisions are not complicated, but they are difficult and require viewing our rivers as a resource with multiple services. The path that is chosen will decide the fate of our future surface water supply and the health of our rivers. A quote from Luna Leopold, past Chief Hydrologist of the USGS, sums it up best:

"Water is the most critical resource issue of our lifetime and our children's lifetime. The health of our waters is the principal measure of how we live on the land."

Figure 3. Following multiple attempts at bank stabilization to protect encroaching urban infrastructure, the Rio Ruidoso has been reduced to a concrete canal with loss of all natural function except water transport.

A Rancher's Perspective: Healthy Watersheds—Layered Investments

Stephen Wilmeth
Doña Ana Soil and Water Conservation District

Stephen L. Wilmeth is a rancher from southern New Mexico and is a native son of the state. His family arrived in Grant County commencing in 1880 with arrivals continuing in 1884, 1888, and 1900. He earned a BA from Western New Mexico University and a graduate degree in agricultural economics from New Mexico State University.

From 1981 until 1999 Stephen farmed in California's San Joaquin Valley. The farming company he founded, Met West Agribusiness (MWA), had a portfolio of nearly 14,000 acres of permanent crops when he left California. The major emphasis was grapes that were spread to several major wineries including Canandaigua, Gallo, Beringer, and Korbel. MWA was the largest apple producer in California with nearly 2,300 acres of trees. Granny Smith apples were the major focus, and, if a resident in the states of Arizona, New Mexico, or Texas ate a Granny Smith out of a grocery store in the '90s, chances are it was a MWA grown apple. MWA was also among the 20 largest producers of nuts (almonds) and stonefruit. In 1996, the company was ranked as the fourth largest fruit company in the United States.

Stephen has farmed in 15 different water districts in California, two in New Mexico, and one in Arizona. Water costs varied from $22 per acre-foot in Kern County's districts to $395 per acre-foot in that county's Maricopa-Wheeler Ridge Irrigation District in California. The district ownerships varied from private to state and federal. Water was sourced variously from riparian flow to deep wells and from local sources to California's extensive state and federal infrastructure. Most districts had surface storage although several depended on aquifer banking and sourcing. Water usage varied from in excess of 10 acre-feet of use in flood irrigated rice to 24-acre inches of use in dripped vineyards. His underground drip experience has been in nuts.

Today, Stephen ranches between Las Cruces and Deming, New Mexico. He is a board member of the Doña Ana Soil and Water Conservation District and a founding member of the Council of Border Conservation Districts.

Good afternoon. Thank you, moderator Julie Maitland, conference participants, New Mexico leadership, and invited guests. It is distinct honor for this rancher to be included in the matter of New Mexico water management and the realities of our water resources. I suspect it might have been awhile since a rancher was in the midst of this esteemed group of water experts. I appreciate your invitation and it is my intention to offer a glimpse of our water resources from a very fundamental position. That will come from my shadow across the lands of which I have had the privilege of stewardship.

Ranching colleague Don Thompson once told me that "there is not a land anywhere that expects less and gives more than New Mexico." His words ring truer each and every year. New Mexico, last among all states as a percentage of actual surface water to total area, is a land inhabited by a citizenry that can be as inventive and creative as any other in the entire world.

Much of my professional career was spent in California's San Joaquin Valley. I formed Met West Agribusiness with Metropolitan Life Insurance Company and that management company farmed Met Life investment properties from Sacramento south to Kern County and the foot of the Tehachapis. Of the nearly 13,000 acres of permanent crops we farmed, we dealt with water that ranged in charges from $18.50 per acre-foot for shallow lift costs to just under $300 per acre-foot for emergency aqueduct water. Certainly, we preferred the former over the latter, but we made both extremes work. Free and independent men have an amazing capacity to overcome constraints.

New Mexico has no magic Lake Shasta nor does it have the amazing watershed of the Sierra Nevada, but we do have our versions. We must consider ourselves lucky to have what we have.

The players

Many times I was asked by California colleagues where the best farmers in the world exist. My response was—West Texas cotton farmers. My rationale was that, in order to be successful in West Texas, a farmer had to be better than good. Pumped water, weather risks, and the nature of the commodity they farmed forced them to be darned good or they were—failed managers.

If I were asked that same question today, my answer might be different. My answer would be that best managers are those farmers who are successful growing any federal program crop. My whole view has changed dramatically since I have returned home to New Mexico and now deal with various farm programs. As a beef producer, I don't have direct subsidies, but I do have federal program involvement with drought and cost-share investment programs. I don't like them.

Having dealt with commodities that don't have federal regulatory demands, I think farmers who have to deal with federal programs put themselves at great risk. They become dependent on a system and less nimble to deal with all fluctuations, not the least of which is the market. They lose the ability to maintain what I refer to as stepwise or layered investments.

I'll submit to you that those leaders who conceptualized and carried out the construction of Elephant Butte Reservoir would understand my position. Who, in 1898, could possibly envision the extent of wonders of what impounded and managed distribution of that project would do to the Hatch and Mesilla Valleys? Who could have envisioned the benefit to this state? One reality of the continuing benefit would be the actual footprint of Las Cruces and all other towns south of the Butte. Without Elephant Butte Reservoir, annual flooding would disallow a greater proportion of the current growth patterns of those towns.

Now we gather at this conference and similar forums to discuss future water management. Most of the discussion centers on conservation rather than resource enhancement. Conservation in itself is not bad. In fact, it is a great motivator as long as the steward is free to act upon constraints as they apply to him personally. Examples are widespread. The technology of nut and grape mechanical harvesting are examples of how free and independent men, faced with blistering constraints, figured out revolutionary methods to dispense with overwhelming labor constraints.

Drip irrigation is a better example for today's discussion. When I first visited Howard Wertz and Scott Tollefson in Arizona in 1981 and observed what they were doing in underground dripped cotton, I knew where the future of western farming, in general, was going.

The same impact of benefits from irrigation technologies, such as that of the Israeli Netafim, altered my personal awareness and corporate investment strategies. We first immersed ourselves with more sophistication and higher costs and then with less sophistication and learned practicality. We adapted high levels of sophistication with practical farmer experience to form a more perfect operational and economic union. When our property portfolio was sold at the turn of the century as the consistently fifth largest fruit company in America, we were farming nearly 10,000 acres of drip-irrigated permanent crops. The rest was still dedicated to flood irrigation, but that land also would have been converted in a short time horizon.

But ultimately, without resource enhancement, conservation alone, whether it is tied to crop programs or water sources, is a one-way ticket to past glory. Congress agreed with that over a half century ago. In 1955, a Senate Select Committee on Water Resources predicted that without importations, the West would be out of water by 1980. Agricultural efficiency has improved more than it is given credit for, but more must be done to secure the next generation's water supply. That is where New Mexico, generally, finds itself. It is time to enhance the resource base.

Enhancing the resource base: the tale of two alternatives

Before I return to my beef operation, I'll submit two concepts for resource enhancement of merit that must be pursued in southern New Mexico. The first is water banking. Water banking works and it works exceedingly well where free and independent men are allowed to act.

To those of you who are familiar with California's Kern County's Lost Hills or the Arvin Edison Irrigation District, you might have some knowledge of the significance of water banking.

Where the water comes from and how it is transported is certainly a complicated matter and won't be debated today. But an adequate system must be set in motion and unless the leadership is content to remain at the helm of a declining system. That has no place in a society that is truly intent on maintaining and enhancing generation to generation productivity.

Subterranean water banking is critical. It is environmentally friendly, and it is relatively inexpensive compared to surface banking and permitting. Alternative number one—Water Banking! We must do it and we must pursue it with gusto.

The second alternative in my world and on the minds of my colleagues and fellow board members of the Doña Ana Soil and Water Conservation District is something out of the ordinary. Many of you have heard that Doña Ana County is the future site of the largest inland port in the world. That is no longer a dream. It is a reality under construction. The Port of Santa Teresa is being built!

With that port is a rail right-of-way and future link from the Port of Guaymus on the Sea of Cortez in Mexico. Our concept is to marry the right-of-way across northern Mexico to the Port of Santa Teresa with a pipeline connection, not to a temporal source of future water, but to an ocean of permanent water. One of our board members, John Smith, prepared a white paper for Harry Reid when Commander Smith was the executive director of the Range Commanders Council at White Sands Missile Range. The thrust of the proposal took similar Sea of Cortez water from Mexico, distilled it through a series of parallel nuclear driven desalinization plants at two locations across the international boundary and pumped it north. That water, estimated at 600 million gallons per day would ultimately serve as the primary source of potable water for the Las Vegas metropolitan area.

Our concept proposes to pump ocean water into Doña Ana County within the established port right-of-way and use the 300º F heat source at a depth of 12,000 feet under every square foot of Doña Ana County to provide the safe heat source for the desalinization process. The byproduct, salt, would be stored in the saline water deposits at similar depths. The water, too expensive for agricultural use, would become a primary future water source for potable water demand in the Rio Grande corridor.

Can't do it, you grouse? Such a reminder should only be posed to the conceptual pioneers of Elephant Butte Reservoir in 1895 or visionary leaders who conceptualized the Owens Valley, Central Valley Project, or the Central Arizona Project 35 years before their inception. Free and independent men can do truly amazing and productive things—if they are allowed to act.

Meanwhile, back at the ranch

As a rancher, I am within the ranks of an endangered societal species that, collectively, is a most important ally to water conservation in New Mexico's future. I'll tell you why.

In an arid setting and regardless of where it is, the most important conservation action of stewards is to 'minimize runoff and to maximize retention' of the moisture that falls on the landscape. Nobody is more important to that task than the ranching community in this state. And, yet, nobody is more assailed, minimized, and misunderstood than this segment of our citizenry. I am not seeking sympathy. I don't want sympathy. I simply want the leadership to recognize how vulnerable our lands are if stewards of that land—engaged stewards tied to these lands with the risk of financial failure—are displaced.

Figure 1 is a picture of one of my pastures post monsoonal 2013. That pasture had a monsoonal accumulation of 1.75 inches in 2011 and 1.25 inches in 2012. In 2013, it got about 7.5 inches. The picture paints the case of underlying system health that rebounded when adequate rainfall again fell on this land. Seventy percent of this ranch is now cattle free during the monsoons. I drive a pickup with 350,000 miles on it and I work in pens that are less than efficient, but I ride pretty good horses and I have water in these pastures that allows me to concentrate cattle and when rainfall does fall, I can rest that 70 percent land. We have capitalized water to the detriment of everything except the health of the land, but this picture demonstrates, not past glory, but engaged 2013 management.

"Minimize runoff and maximize retention" is the continuing theme of utmost importance to our landscape. The rest of my story should be reserved for another discussion, but the point must be made. These ranch lands are vital to the

Figure 1. Pasture post monsoonal 2013

system health of our land. Good ranchers are not born—they are made, and they can and are being destroyed. Past glory is no longer an option for our watershed system. Future glory is what we must strive to achieve, and it starts right here, right now, with leaders who don't have biased blinders.

Thank you very much and thank you, God, for the bounty and the resilience of our New Mexico lands!

Author's note: If there isn't a copyright pending on 'minimize runoff and maximize retention', I would propose it be assigned to the ranching community of New Mexico. Those folks understand the concept from their shadow on the ground—to a better vision for our future. – Stephen L. Wilmeth, southern New Mexico rancher

Forgotten Rivers: Riparian Areas

Steve Harris
Rio Grande Restoration

Steve Harris is Executive Director of Rio Grande Restoration non-profit river conservation group dedicated to protection of the ecological and economic values provided by the Rio Grande. In this capacity he writes, speaks and advocates for the resolution of river issues, especially policies to protect flowing water. He participates in public policy forums, such as regional water planning and manages the Rio Chama Flow Project. Steve is also, since 1976, the owner of the river touring company Far-Flung Adventures, which has introduced thousands of persons to the Rio Grande. He resides in a small riverside village in northern New Mexico, at the bottom end of the acequia del ojo.

I'm going to talk a bit about what has happened to the rivers, and I will try to address why I think it matters. Most of us here work in the water resources field, most of us enjoy recreation, most of us go to the river, and so most of us feel some sort of compassion toward the river. I think that is hard-wired into us as human species. I am strongly supportive of wild rivers, and I think that derives from a kind of visceral connection to rivers. There is this feeling you get when you are close to flowing water; it is a connection with the universe. It is a feeling that young people need to be led to deliberately in order to feel a sense of balance. In the coming generations, life is not going to be all about electronic devices; we are part of nature and occasionally we need to be reminded of that. Today I am going to use the Gila River as a case study.

Has everyone seen a Colorado River supply/demand curve? If you have, you know that we are playing it pretty close to the line with water scarcity and we have been doing so for some time. We are confronting a need to either find new sources of water, different ways of relating to water, or ways of doing the same things but using less water. But, I also think that an equally difficult part is keeping these rivers alive. In the face of increasing demands, we are increasing withdrawals. Rivers do have thresholds; there are limits to what we can safely abstract from rivers and we ought to pay attention to those limits.

I have been involved in a Rio Chama Flow Optimization Project, in which we are scientifically trying to determine what the flow benchmarks are, or in other words, points on the hydrograph throughout the year that we have to hit in order to maintain something that functions as a river. We want a river that obeys the laws of physics and not just the water code. Our southwestern predecessors, the Mimbrenos, recognized that we are all tied together–the economics, ecology, fish, terrestrial species, and our human society are all tied together. What happened to our natural rivers in New Mexico is development. Water development is our legacy now, and I believe we are at a point where we must choose between heavy engineering projects, or whether we are going to go a bit softer with the way that we develop water in the future.

When Kearney marched into Santa Fe in 1847, he began a process of Americanizing New Mexico. The result was that our forests, rangelands, minerals, and soils were, according to the policies of the time, to be turned into dollars. Figure 1 shows the Rio Embudo in 1907 where forest clearing was done in order to build the Rio Grande Western and Santa Fe railroads.

Figure 1. The Big Barbecue - Rio Embudo, 1907

We know the logic behind reservoirs and we have gotten a great deal of benefit from them. But there have also been some adverse effects of those engineering developments. Congress in 1948, at our behest, decided that the Rio Grande was going to be 600 feet wide and 300,000 jetty jets were built to try to maintain our legal notion of what the boundaries of the river were (Fig. 2). As part of this development process, we wanted efficiency, maximum utilization, and maximum economic return. If the interest is simply efficiency, what type of channel is more efficient than a perfect trapezoidal channel for conveying water? We have also treated rivers badly both in terms of our land-use practices and by dumping our waste products into the river where due to the physical flow processes, waste moves out of our area and into somebody else's.

Figure 2. 300,000 Jetty Jacks

Figure 3 shows hydrologic effects of the Rio Grande Project. It comes from a book called *Dams and Rivers: A Primer on the Downstream Effects of Dams*. The blue bars represent the annual total discharge into the Rio Grande by year. The dark blue bars indicate when Elephant Butte and Caballo reservoirs were developed. The fact is that these represent a crossing of thresholds where the Rio Grande below El Paso could no longer maintain its integrity as a life support system for nature. When you dam a river, you drop the sediments out of it, and the water released from the dam is sediment starved. As the water first reaches below a dam, the river will scour out the area, and then being sediment starved, it will pick up sediment. This creates a process of narrowing and degrading; the elevation of the river will go down, the river will get faster, and the river will become simpler. Somewhere down the line, where that sediment has been picked up and reworked, it will fall out and be deposited again.

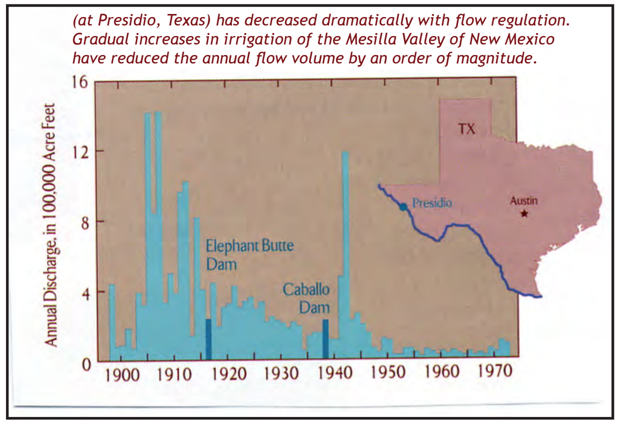


Figure 3. Hydrologic Effects of the "Rio Grande Project"

Figure 4 is a 1905 photo of San Acacia in the Middle Rio Grande. You can see some of the features including a river bend that is fairly natural and sinuous. In the background you can see where water has leaked out of the river and has created wetlands. In fact, this was pretty good duck hunting country at one time. You can see that the nature of the river in response of flood disturbances is that floodplains stay pretty well swept off. The year, 1905, was one of the years after a large flood, and you see from the photo that it was swept clean. On this clean slate, riparian vegetation will emerge. Figure 5 shows the exact same spot, except that the channel has aggradated 25 feet. The vegetation is mostly monotypic Tamarisk and it isn't going anywhere because we are not allowing floods to come disturb the vegetation and create new habitat. I also like this picture because you can see the results of development: the railroad, the levees, the riverside drain, and the low-flow conveyance channel. We have made the river conform to a less natural, more engineered design. It is not a river that is going to go anywhere inconvenient for us.

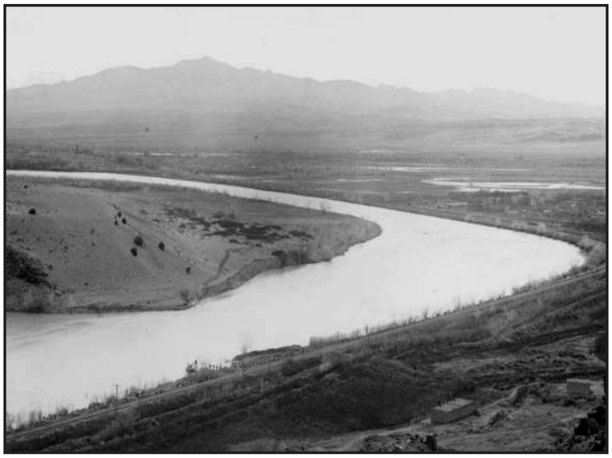


Figure 4. San Acacia, 1905

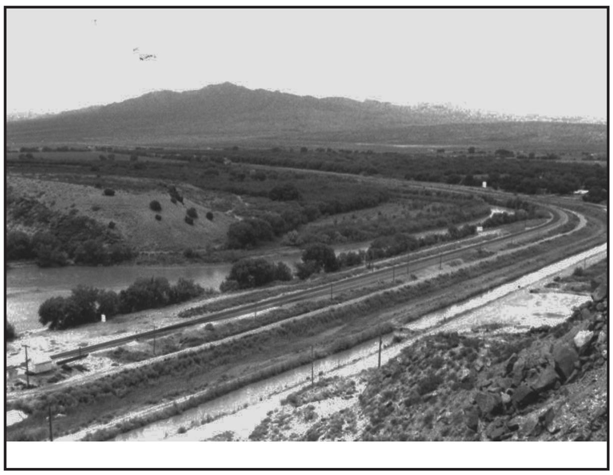


Figure 5. San Acacia, 1989

The graphic in Figure 6 shows the channel aggradation process. It is a cross section of the Rio Grande below El Paso. You can see where the river bed was after the last flood event in 1942. You can also see where it was in successive years up to 1974. On the right side you see a canyon that is contributing sediments and during the monsoon season, it will put a lot of sediment into the river. However, the altered hydrology has not allowed those sediments to be removed and that is the reason why the river is progressively aggrading.

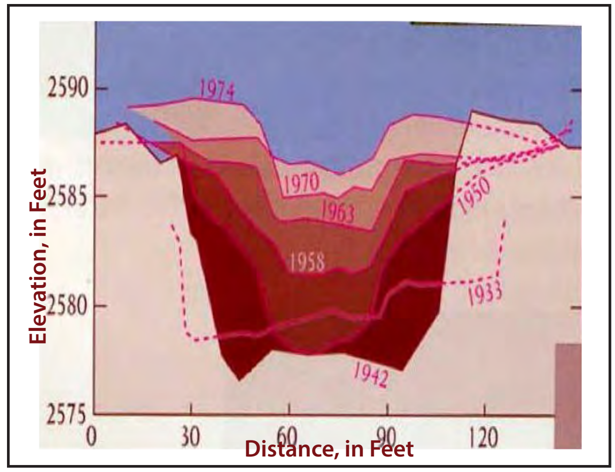


Figure 6. Channel Aggradation

Figure 7 depicts the Forgotten River. We're seeing a process of controlling the river that is alternately causing degradation and then aggradation. This has transformed the ecology and created adverse economic impacts as well. The degradation process will take the water tables down with it, so you don't have healthy habitat developing. In this aggraded type system you have increased flooding. When Caballo was closed in the 1930s, El Paso suddenly experienced floods that the river channel had normally had the capacity to handle. Then, there is also a roughly three-mile-wide patch of Tamarisk bosque that isn't natural. You'll also notice that there is no identifiable channel here.

Figure 7. Forgotten River

Figure 8 depicts a dead river.

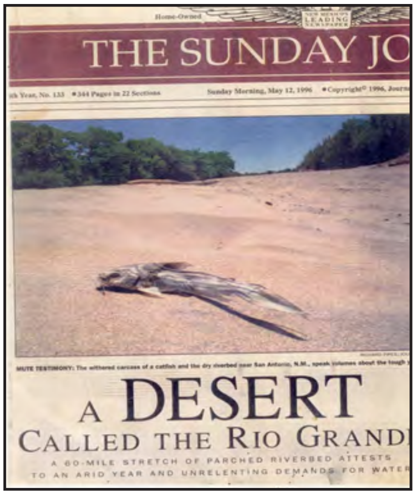


Figure 8. The *Albuquerque Journal* front page photo of a dead river.

With the last five minutes of my talk, I want to talk about a transition from this old development paradigm. In the past we used steam cranes and mule-driven scrapers to engineer straight canals. At this conference, we are talking about innovations to try to secure the real water future that we want to have in New Mexico.

The still free-flowing Gila, as State Engineer Scott Verhines mentioned earlier today, is the subject of a process to decide how the Gila River might best meet the water supply needs of southwestern New Mexico. Fifteen potential projects have been submitted to the Interstate Stream Commission, three of which are diversions. The agency seems to prefer a diversion very similar to the old 1890s water development paradigm. In such a project you divert water from the river, pipe it down the valley into off-channel storage, and pump it once more over the divide and into the neighboring basin. This water then gets distributed to prospective users along the way, perhaps Silver City, Deming, and/or some of the area farms.

Twelve non-diversion alternatives have also been suggested. Scott described how these include: watershed restoration projects, water conservation of both the agricultural and municipal sectors, and water reuse projects. These are the sorts of projects that have been identified in the past 20 to 25 years as concepts for "stretching" existing water supply. These projects are getting some consideration as alternatives to new diversion for additional funding. The amount of $66 million is available for funding the selected project or suite of projects. A diversion, the "New Mexico Unit of the Central Arizona Project," could get us somewhere on the order of an additional $30 to $60 million to help with construction. But, based on experience with the Buckman Direct Diversion and Albuquerque Drinking Water projects of similar magnitude, we are probably looking at $300 to $500 million of today's dollars in construction costs for less than 14,000 acre-feet of water, and we have not yet identified the end users.

It looks to me like this is a classic confrontation between the old way of doing water business and a new way of doing water business. I suggest that the Gila Decision is where we can bring our creative instincts together with the lessons we can glean from modern water management in the other to build something that will both serve the local people and the wild river.

If I were a Cliff Gila Valley irrigator, I would prefer to be served not by a reservoir that would release additional water, but by more reliable infrastructure. This could be a diversion that is more reliable, but more what I'd really want is reliable base flow. And improved late-season flows might be possible if ISC could bring itself to invest in a program of watershed restoration. Watershed restoration—forest thinning primarily—could attenuate the runoff, reduce the instances of wildfires and debris flows that threaten southwestern New Mexico communities. Restoration that promotes water retention on the landscape longer, could restore historic base flow and improving water quality.

In closing, I get a sense that we are in the process of changing our minds about the proper treatment of rivers. Aldo Leopold suggested, "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." Managing the river based upon economic criteria or legal criteria only is not going to get us very far into the future. Make no mistake, we are making decisions today about the future of our rivers. Once a river is degraded by engineering processes, the damage may not be not reversible.

The choice, ultimately, if we are proactive, is between another forgotten river or a healthy river that could support our economic aspirations, the complex water system on which all lives depend and this desert called the Rio Grande.

Legislative Perspectives

John Fleck
Albuquerque Journal

John Fleck writes about science for the "Albuquerque Journal." His emphasis in recent years has been water supply (or lack thereof) in New Mexico and the West. He has been a contributing editor and media fellow at Stanford University's Lane Center for the American West, and is an instructor in the University of New Mexico's Water Resources Program. He graduated from Whitman College with a degree in philosophy, and worked as a journalist in Washington state and Southern California before moving to New Mexico in 1990. In 2009, he published "The Tree Rings' Tale" (UNM Press), a book for young people about climate science, weather and water.

Thank you all for attending today. I was asked to talk a bit about my own perspective on legislative issues on both federal and state and government fronts.

I would like to start with an anecdote about an interaction that Senator Peter Wirth and I had during the legislative session this year that illustrates in a nutshell what is wrong with our legislature. I apologize for beating up on you Peter, but Peter is doing what ended up being the most interesting water legislation I think in the 2013 legislative session. I was trying to interview him, and legislators during the session are incredibly busy. We kept exchanging text messages and phone calls trying to find a time in his schedule. Finally, Peter said, "Why don't you come down tomorrow afternoon? The Senate will be in session, but I don't have to be on the floor all of the time." So I went up to Santa Fe and into the hallway behind the Senate chamber and sent in a note with a messenger to search for Peter saying, this is John come talk to me. What ensued over a period of probably 45 minutes was the strangest interview that I have ever conducted. We start talking about very complicated water policy issues. We talk for about five minutes and then the Sergeant at Arms let out the doors of the Senate chambers into the hallway and shouted "voting!" This is the ritual of the Senate. When the voting is happening, legislators try to run in and vote. So, Peter comes back out and we try to pick up the conversation. We had this conversation in a series of three, four, and five minute chunks. The point here is that the state legislators of New Mexico have to deal with an enormous range of issues.

I spend a lot of time in the legislature watching water policies. Some are quite significant and largely go nowhere, with the exception of Senator Wirth's bill on domestic wells double dipping. The key problem I saw was this issue of legislative capacity. Legislators are in a 30-day or 60-day session, and there are an enormous amount of issues these folks have to deal with like the education of our children plastered with dealing with state pension funding problems–really big complicated issues. Each legislator only has one brain and has so many issues that they have to be knowledgeable about. There are only so many legislators able to focus on so many issues. Water to everyone in this room is an incredibly important thing, but in the legislature it is only one of many very important issues. It is hard for them to have the institutional capacity and to have the time and energy to focus on the hard policy questions. We are hearing a lot of talk about water in the legislative session for 2014 which starts January 21. It is a narrow 30-day session this year in the legislature. The legislature alternates between 30-day sessions dealing with relatively narrow issues and then has 60-day sessions that are open for broader issues.

The governor held a news conference on Tuesday suggesting a broad initiative to use capital outlay money for a substantial amount of capital infrastructure improvements. The legislative reaction was very interesting. The part that I found really interesting is that I was the one calling the democratic leadership to get their comments. They didn't know about it until a reporter called after a press conference. I'll leave you folks to judge whether that is a good way of doing broad policy initiatives, in a press conference versus working collaboratively, which is the main premise of the legislature. But that is the reality. The Governor's initiative has some interesting potential because it uses capital outlay money. For those of you who are unfamiliar with the legislative process, capital outlay is the way that individual legislators get to build senior citizen centers, bridges that cross rivers, and ball fields for little league in their districts. Usually we have a big pile of capital outlay money that is roughly divided up into thirds. The governor gets about a third of it, the House gets about a third, and then there is a third for the Senate. That is the traditional way of dealing with capital outlay money. Governor Martinez has suggested that 60 percent should go to her water initiatives. That sort of action by the Governor has always been met with resistance from legislators, but this is a very clever thing that she is doing because it has the possibility of doing a bunch of water legislation in all of the districts, and that I support. It will be interesting to see how her initiative progresses. So far, we are not seeing evidence of any big policy initiatives being dealt with more broadly in the 30-day session.

Yesterday you heard a couple of comments about some water policy issues that a lot of people think require attention. John Shomaker talked about prior appropriation and said the question wasn't whether prior appropriation was dead, it's just really boring. Em Hall, who I think is the poet laureate of New Mexico water, said there have been a couple of recent Supreme Court decisions that have shifted the angle of repose of prior appropriation. I want to quote from one because I think it is a very interesting observation. This is from the Supreme Court decision in the case of *Bounds vs. New Mexico*. It involved the question of prior appropriation and the impact of domestic well drilling on senior appropriators based on wherever the domestic wells are drilled. The Supreme Court said yes, prior appropriation applies here, but we are not sure exactly how that should be carried out. [transcriber note: speaker reads a couple of sentences but they were inaudible] Seen in the court of appeals is that citizens must look to the legislature and the State Engineer for relief of these problems. Here is the great line: "We urge our legislature to be diligent in the exercise of its constitutional authority and responsibility for the appropriation process. We equally encourage the State Engineer to fulfill its superintending responsibility by applying priority administration for the protection of senior water rights users."

What the Supreme Court is saying essentially is that prior appropriation is the law here in New Mexico and somebody needs to do something about that. It's not a specific piece of water policy, it is finding a way of expanding this sort of institutional capacity of our state legislature, the expansion of staff. There were many people I talked to who would really like to see a full-time legislature. I don't think that is going to happen, but an expansion of staff so that we have some broader ability for the legislature to work with these kinds of problems would be helpful.

I'm going to specifically make a few comments about Congress and the congressional process, which is hopeless right now. That has important implications for water policy, because they are stuck on a whole bunch of issues that involve really big issues and cultural wars in our nation. They are spending a lot of time and energy on those issues. They have much more institutional capacity, but they are spending all of their time on these issues. There are a bunch of things with water policy that aren't being paid attention to. I am going to give you two examples that have plagued us specifically in New Mexico. These are small things; they are below the radar, but they are good examples.

There is an effort underway to figure out a reasonable mechanism, here in the Rio Grande Valley, whereby agricultural water could be leased by someone for purposes of instream flows. There was a lot of opposition to this yesterday. Some really interesting ideas are being done in other places. The institutional mechanisms to make that happen doesn't work here. Senator Tom Udall, who is a member of the Appropriations Committee, included some language in the Senate's Energy and Water Appropriation Bill for 2014 that would kick off this discussion. That bill is dead. So, what you see is Senator Udall being forced by congressional failure—I'm going to use some baseball analogy here—to play "small ball" You don't hit "home runs" you "steal bases." You make small amounts of progress over time. So, this is incredibly "small ball" action. He put back into the Appropriations Bill report language. The bill will never pass, but at least it sends a message, and the Bureau of Reclamation got the message. This is really legislation by inches because bigger things can be done.

There is a second example that is going on right now that also deals with flow into the valley. Cochiti Reservoir, run by the U.S. Army Corps of Engineers, was built for control purposes. There are people who would like to use Cochiti, and they have tried to do this over the past several years, in the spring to change the timing of the flow in the Rio Grande to benefit the flows for the Silvery Minnow. Catch a little bit of water early in the spring, then release it and cause a spike in flow for the minnow later in the spring. It's a pretty straightforward plan in terms of hydrology. We have a dam. It sits there. It doesn't pass. We can do it, but authorization doesn't allow it to happen. Change in the authorization takes an act of Congress so we are stuck with this thing that could be and should be a legitimate policy sketch. There are others who think it is a bad idea and would argue about it, but we can't even get to that point because Congress can't deal with this.

I think we are really hamstrung by Congress's failure and I think it is interesting to watch the clever water managers, the clever congressional staffers, and member of the Senate and House figure out how to work around these problems and play "small ball" because Congress can't do big things. I don't expect on either legislative front big things. I would love to be proven wrong about that by these people here who are smarter than me, but in the meantime, the federal and state governments do have a process of appropriation debt.

Thank you.

Legislative Perspective: The Federal View

Kris Polly
Water Strategies, LLC

Kris Polly is president of Water Strategies, LLC, a firm he began in February 2009 to provide representation and guidance to water, power, and agricultural entities before Congress, the Bureau of Reclamation, and other federal agencies. In addition to representing a variety of irrigation districts, water associations, and irrigation component manufacturers in the 17 western states, Kris is also the editor-in-chief and publisher of Irrigation Leader magazine with a circulation of over 12,000 people. Prior to forming Water Strategies, LLC, he served as deputy assistant secretary for Water and Science of the U.S. Department of Interior from August 2008 until the end of the Bush Administration. During that time he was responsible for advising and assisting the Assistant Secretary for Water and Science in overseeing the Bureau of Reclamation and managing and directing programs that support the development and implementation of Western water policy.

Before his deputy assistant secretary position, Kris served under Commissioner Bob Johnson as the Deputy Commissioner for external & intergovernmental affairs for the Bureau of Reclamation. Kris also served as the Vice President for Government Relations of the National Water Resources Association where he began working as a legislative assistant in 1992. Kris is a graduate of Nebraska Wesleyan University and a native of Wauneta, Nebraska, where his family has farmed for five generations.

Thank you for the opportunity to speak with you today.

There are several issues that I would like to talk to you about this morning. First is small hydropower, which incidentally, is one of the few things that Congress actually got passed. The vote was 433-0 in the House for HR 267 and 416-7 for HB 678. The corresponding bills in the Senate passed. Both bills passed very quickly. They were introduced and passed in their respective chambers a couple months later. As a result, there are now 18 applications for small hydropower project before the Federal Energy Regulatory Commission (FERC), 14 pending.

The Water Resources Development Act (WRDA) was instituted in Congress years ago and the idea was that there would be one WRDA every Congress. This was also done in a time when we had something called "earmarks." An earmark is nothing more than a member of Congress wanting a project and putting it in the WRDA legislation. The WRDA funds the Army Corps of Engineers projects like flood control, wastewater treatment, putting in levees, water pipelines, and things like that. Reclamation is a different apple all together. The last time we had a WRDA passed was 2007, and before that it had been quite a few years. But now, we have a WRDA that has actually passed. This legislation provides $12.2 million for 18 projects that have already been approved by the Army Corps of Engineers. It also sets up a system to identify projects for the authorization. There are two different kinds of legislation in Congress. There is an authorization and there is an appropriation. An authorization is passing legislation to build a project. This is generally pretty easy to do. An appropriation is actually paying for it. Appropriations are difficult because there is a huge backlog list of authorized projects that have no hope of ever being paid for. For this legislation, the Senate reduced the time it takes for feasibility studies to less than three years, improved the environmental review process, and established a 5-year project financing pilot program.

A lot of the states now have funds due to mineral extraction and fracking and from sources of funding that the federal government doesn't have. There is an attempt to have water projects funded by the states as well as federal organizations. In the House, we had a very strong vote of 417-3 to move additional WRRDA (Water Resources Reform and Development Act) legislation (WRRDA with an extra "r" for "reform"). It is essentially the same thing, authorizing $10 billion for priority water resources infrastructure improvements recommended to Congress by the Chief of the Army Corps and de-authorizes $12 billion of old, inactive projects that were authorized prior to WRDA 2007. It sunsets new authorizations to prevent future project backlogs—some of these feasibility studies we have ten years in and there is just no end in sight for time or cost.

Included in WRRDA in the House is levee safety. It provides for federal technical assistance to states to improve or create levee safety programs. It also calls for the establishment of federal guidelines for levee safety that incorporate federal, state, and local activities.

WRDA/WRRDA is actually in conference now, the first meeting took place on November 20. I'm not sure when it is going to be over, not before Christmas or New Year's, probably sometime in the early spring. This is something Congress wants to get done before the elections because they want to be able to point at something that they actually did. Some conferees include: EPW Chairwoman Senator Barbara Boxer (D-Calif) from the Private and Public Works Committee. She is the lead of the conferees for the Senate. You have a lot of westerners: John Barrasso of Wyoming, James Inhofe of Oklahoma, and Max Baucus of Montana, and Barbara Boxer. Others include Thomas Carper from Delaware, Ben Cardin of Maryland, Sheldon Whitehouse of Rhode Island, and Ranking member David Vitter of Louisiana. On the House side you have a mix of westerners and easterners (Fig 1).

I'd like to talk about a different topic, EPA's proposed Clean Water Act Jurisdiction. For years there have been legislative attempts to expand the jurisdiction of the Clean Water Act. The Clean Water Act was the landmark for a lot of environmental laws passed in the early 1970s. One of the things that the Act included was the definition of navigable waters. Congress used that word 81 times in their revision of the Clean Water Act—a lot of people obviously like that term. "Navigable waters" was where the Clean Water Act was supposed to end. State and other folks pick up after that. But there has been a legislative effort in the past three or four congresses, and that legislative effort is over largely because the proponents have been unlikely.

Now we have a draft EPA Rule that has been under-touted for the majority of this administration. What this Rule is reported to do is to say that streams, regardless of size or how frequently they flow, are **connected** to and impact downstream waters. It also says that wetlands and open-waters in floodplains of streams and rivers, and in riparian areas, are **integrated** with streams and rivers, affecting the water flow, introducing nonpoint source pollution, and exchanging biological species. It also acknowledges that there is **insufficient information to generalize** about wetlands and open-waters located outside of riparian areas and floodplains and their connectivity to downstream waters. So basically, our waters are all connected.

House Conferees	
• John Duncan Jr. (R-Tenn.)	• Nick Rahall (D-W.Va.)
• Frank LoBiondo (R-N.J.)	• Peter DeFazio (D-Ore.)
• Shelley Moore Capito (R-W.Va.)	• Corrine Brown (D-Fla.)
• Candice Miller (R-Mich.)	• Eddie Bernice Johnson (D-Texas)
• Duncan Hunter (R-Calif.)	• Tim Bishop (D-N.Y.)
• Larry Buchson (R-Ind.)	• Donna Edwards (D-Md.)
• Bob Gibbs (R-Ohio)	• John Garamendi (D-Calif.)
• Richard Hanna (R-N.Y.)	• Janice Hahn (D-Calif.)
• Daniel Webster (R-Fla.)	• Rick Nolan (D-Minn.)
• Tom Rice (R-S.C.)	• Lois Frankel (D-Fla.)
• Markwayne Mullin (R-Okla.)	• Cheri Bustos (D-Ill.)
• Rodney Davis (R-Ill.)	

Figure 1. 2013 House Conferees

The U.S. Supreme Court said we should look at it on a case-by-case basis and there needs to be a nexus of significant connection between one body of water to another. If you take this theoretically, the jurisdiction of the Clean Water Act could go all the way from the Mississippi to your faucet. The reality is that there is a distinction, and we have states with something called "primacy of state water law." All states in the West are founded upon primacy of water law. This is a situation where federal law is trying to get states' authorities. Another thing the Rule intends to do is create a definition that gets away from a case-by-case basis. Comments are due by November 6. There will be a peer review panel on that report; we will hear more about this Rule as it evolves.

Concerning the Bureau of Reclamation budget, the big point is that it is at best flat-lined. If you adjust for inflation, Reclamation's funding, as with many of the government agencies, continues to go downward. We have sequestered, we had a shutdown, and we have been through so much recently that we are numb to the headlines. But, as a result of all of these things, the Bureau of Reclamations budget has been reduced by $54.7 million. Reclamation's 2014 budget request is $1.0 billion again, with water and related resources at $791.1 million (Fig. 2). Included in the request are items that help irrigation districts. The Water Conservation Field Services program, which is a 50/50 match between Bureau of Reclamation and irrigation districts, is an enormously popular program. It only funds about $3.4 million West-wide.

2014 Reclamation Budget Request

WaterSMART: $35.4 millionGrants: $12 million

- Basin Studies: $4.7 million
- Title XVI Water Reclamation and Reuse: $14 million
- Water Conservation Field Services: $3.4 million
- Shared Investment Water Innovation Program: $1.0 million
- Cooperative Watershed Management: $250,000

Figure 2. 2014 Reclamation Budget Request

I want to talk about FDA Proposed Rulemaking for "agriculture water." In 2011, Congress passed the Food Safety Modernization Act. It is the first major update to food safety standards since 1938. This came across our radar screens the past six months, and we are concerned about irrigation districts. This new regulation came as a surprise. According to the FDA, there have been a number of health scares and problems. This proposed rule is for agricultural water—and, of course, agricultural water is what we think of as irrigation. They are looking at *E. coli* in water.

There are also some exceptions to the proposed Rule, which are curious because this is about food safety. They exempt specified produce commodities that are rarely eaten raw, potatoes are a good example. Also there is an exception for produce grown for personal or on-farm use. Another exemption is commercially processed produce that chemically removes microorganisms. When you process apples, they go through a chlorination path along with other vegetables and produce. Small farms with an average annual value of food sold during the prior three years of $25,000 and farms that have food sales averaging less than $500,000 per year during the last three years and whose sales to qualified end-users that are consumers or a restaurant/retail shop within the state and with 275 miles are also exempt. They want to avoid stepping on local farmers' markets. They kept talking about local farmers' markets and folks who sell to local restaurants and so forth. If you are going to exempt all of those folks but you are concerned about food safety, isn't there a huge hole in your food safety program? When you think about it, the biggest risk you have when you buy apples, for example, is the person before you who picked it up at the market and put it back down.

In April we had a meeting with some FDA folks and Washington State. I want to stress that the FDA has wonderful people. They are educated, very gracious, met with us, spent over an hour talking, and they wanted to learn. They are good people. They are trying their best to work with Congress, but one of the things they told us was that research has shown that Washington doesn't always know what is best. We asked the FDA folks to come out and see us, and they did. They brought about 10 people out and other good folks from Washington, Oregon, and Idaho. We spent a day with them on August 13th. We also read what people would write to our magazine where you have the comment period and would post in an article.

Mike Taylor, the assistant secretary for the FDA attended the tour. On one of the tour stops, we met with a gentleman from Diamond Processing, who is also a farmer. We were standing in an apple processing plant that was inactive at that time, and this happened toward the end of the day. The farmer explained they can work with the FDA in the processing plant—they can have additional spray bars put in; they can increase the time that the produce is in the decontamination wash. Things like that can be done. But how are you going to treat irrigation water? The average irrigation well produces a thousand gallons a minute. How are you going to treat that? It would cost millions and it would be ineffective. The farmer made our case for us. This particular spray bar is being repaired, but Bill pointed out that additional spray bars could be added. The apples will tumble along and get sprayed with decontamination fluid. Bill indicated that they can increase the process time and reduce the potential amount of contamination.

We then went over to visit a canal near Quincy, Washington and saw a typical irrigation district with the Colombia Basin Irrigation Project. Mr. Darvin Fales, the general manager of the Quincy Columbia Basin Irrigation District, explained to the entire entourage including ten FDA folks, some state folks, and a lot of other involved people. At the Quincy Main Canal, our last stop around 5 o'clock, Mr. Fales explained the canal is wider than a city street and moves faster than a man jogs, at about 3,000 cubic feet of water per second (cfs). The canal starts about fifty miles up-canal from that point and goes down-canal about another thirty miles where it gets smaller and more narrow as it makes its deliveries. We showed the tour participants how big this was—and this was only one canal. There are canals up there that move 11,000 cfs. The size of the Columbia Basin is exceptionally large. One thing Mr. Taylor from the FDA said, and it was worth all the airline tickets, the day's efforts, everything—was it is clearly not practical to treat all of this irrigation water. It is not practical. Good decisions are based on good information. It is up to the agricultural community to explain to folks what it is we do and how we do it. By doing tours like this, we can educate folks, like the folks of the FDA, on how to best make their decisions. The comment period was over on November the 15th, and we will be interviewing Mr. Taylor in the magazine, *Irrigation Leader*, so please look for that.

In conclusion, I think you are going to see federal funding continue to drop. You will see states picking up an increasing share of funding. You will see expanded numbers of water quality regulations and an increasing need for the agricultural community to educate folks about what it is we do.

With that, I would like to say thank you and I would be happy to answer any questions.

Legislative Perspective: The State View

Peter Wirth
New Mexico Senator

Senator Peter Wirth is a first-term State Senator elected during the 2008 General Election. He spent four years as a Representative in the State House from 2004 through 2008 replacing Max Coll who retired from the seat. Peter is a lawyer in Santa Fe. He graduated from Stanford University in 1984 with a BA degree in economics and Spanish. He attended law school at the University of New Mexico where he obtained a JD in 1990. Peter was a law clerk for the Honorable Oliver Seth, a Federal Judge with the Tenth Circuit Court of Appeals. His current civil law practice emphasizes mediation and alternative dispute resolution.

During his two terms in the State House, Peter carried a variety of legislation signed by Governor Bill Richardson. Some of Peter's legislation includes laws to expand an open space tax credit, to restrict the use of eminent domain for private economic development, to allow local governments to enact water conservation ordinances, and to better protect homeowners from property damage caused by government action.

Prior to his service in the legislature, Peter served on a number of boards including the St. Vincent Hospital Foundation from 1991 to 2000, the Santa Fe Children's Museum from 2000 to 2004 where he was board chair for two years, and the Historic Santa Fe Foundation from 1991 to 1995 where he returned to serve as board president from 1997 to 2003. Since 2000 Peter has been a member of Rotary International.

He is married to Carol Romero-Wirth, also a lawyer, and they have two children.

Good morning everyone, and thank you, Sam, for the invitation to be here today. Thank you certainly to John Fleck for the introduction. I get worried when someone starts telling war stories about legislature interviews. I thought John might talk about something I said, so I was happy to hear his story was about the process. I think that is an important piece of any discussion about the legislature and I appreciate John going in there with eyes wide open. As he mentioned, I don't spend a lot of time in the legislature and it is an eye opening process for sure. We'll talk about that a bit today.

During the heat of the 2013 legislative session, a longtime person in the building sector with the New Mexico Home Builder's Association said something that I think to me represents a significant shift in direction of our building. It was a simple statement. He said, "Things have changed." It might sound obvious to all of the experts in the room, but I think it is the start of a different direction in the state legislature.

Let me say something about the legislature itself. I'm going to focus on a couple of the key target concern areas that we are looking at, and the successes we had last session. Then I'm going to talk about what I really think of as a potential path forward for our state.

In the past session I served—and this will be my tenth session coming up—I wore a variety of different hats in the Senate. I was on the Finance and Energy Committee, and for the first four years in the House, I focused on the Judicial Committee and the Rules Committee. One constant has been that I have always served on the Water Committee. This year, about two days into the session, the leadership came to me and asked that I chair the Senate Conservation Committee. So, obviously that was another shift in direction and John is absolutely right that we are a true citizen legislature. As he mentioned, I am a lawyer and I basically call the legislature my part-time full-time job. We are supposed to become experts in all types of areas. I am not a water lawyer, but I am a lawyer. Over 20 years ago at UNM, I took a wide range of water law classes including advanced water law. Interestingly, my paper in advance water law dealt with the San Luis Valley and a native gentleman who in the 1980s wanted to drill massive wells in the San Luis Valley because of the nearly unlimited groundwater supply in Colorado. I think he would be very interested to see what is happening in the San Luis Valley today and we will talk about that.

I want to touch on a few of areas of the state that I think really have the legislature's attention. Obviously first and foremost, is the situation in the Lower Rio Grande. Many folks here today are participating in that situation and the litigation in that area obviously has everyone's attention. From my perspective, what really jumped out at me this past session was the scope of the problem. There are 4.5 acre-feet of water rights in a good year with between 3 and 3.5 acre-feet coming from surface water rights from Elephant Butte. This year 3.5 inches was the allotment. The figure that was stunning to me, and continues to blow people away in my Santa Fe district, is that in 2011, 280,000 acre-feet of water was pumped out of the aquifers. During this session, we had a range of testaments on the sustainability of that aquifer, and I can tell you that no one we heard from thinks this could go on for more than ten years—it can even range down to only three to five years.

We have an unsustainable system; mix in multiple levels of litigation, and you get the legislature's attention pretty quickly when we have discussions about the state's water resourses. One of the things we heard a lot in the 2013 legislative session was that we better pray for rain. Fortunately, we have had some rain and I think John Fleck has been terrific in making sure that everyone in the state does not automatically think that their water problem is solved, because clearly it is not. We also heard in the session, which I thought was interesting, a lawyer saying we better pray we win that lawsuit, because the ramifications of losing are extremely significant.

The other kind of real hotspot that has triggered a lot of focus on water is the Pecos situation. I think that Greg Lewis, the Pecos River Basin Manager, is probably the happiest person in the room with all the water that has come down, and the fact that there is water now, for at least a year anyway, and the State has been able to stop pumping its wells. We are creating channels to deal with this, but the irrigation district's problem is a classic situation. What is interesting is that it is in an adjudicated area—and we will talk about adjudication much more—but this is in an adjudicated area with a senior water rights user at the bottom of the river not getting the water to which it is entitled. The Carlsbad Irrigation District brought a bill to the legislature stating that it needed $2 million or it would make a priority call. I think we will continue to see legislation that essentially looks at buying our way out of the problem. We did that to a large extent on the Pecos and set a process for buying out rights. Senator Cervantes will continue to focus on the issue; he carried legislation last year to appropriate $150 million or so to continue the discussion of what direction we need to go.

What I think is interesting about the Pecos situation is the fact that even if we did a priority call on the Pecos, it wouldn't necessarily solve the problem. We have heard a lot about a new doctrine called the "Futile Call" which I think is important to understand. I'll talk a bit about the priority system, but the reality is that even if you do a call and you shut off all the junior water rights users upstream, the water can't simply get to those senior users for a number of years. The economic consequences are significant.

John mentioned two water bills that passed the legislature last session. No one was more surprised by those bills being passed by the legislature and signed by the governor than me. They both dealt with domestic wells. The legislature has been up, down, and around on the domestic well battle, and the Home Builders were a part of that fight. One of the bills, as John mentioned, stopped the practice of double dipping. If you sell all your water rights off of an agricultural piece of land, you shouldn't come back and put in a subdivision using domestic wells unless you bring in water rights or hold back water rights for a new subdivision. The other bill is one that has been around for quite some time. I was the House sponsor of the bill in 2006 or 2007. That bill dealt with new subdivisions and domestic wells; subdivisions of more than ten units with one of the parcels of land with an area of two acres or less. Basically, what this bill said was that you have to bring in new water rights or hook up to a system. You can't simply drill domestic wells.

The Home Builders initially were neutral on these bills, and then actually participated on the pass. There was some opposition. This is an important lesson: when the bills came to the floor in the House, I received a panicked text message from members of the House on what was being debated because there was an effort to kill both of these bills by legislators from Valencia County. The person in the House who stood up and changed the whole direction of the debate was Representative Candy Ezzell from Roswell. She, of course, has lived with the situation on the Pecos and was instrumental in assuring that after the State bought all of the water rights in the Pecos to make Compact compliance, you didn't have the same kind of double dipping. We actually passed some legislation along those lines. To have her stand up and support these bills was a very important signal because this must be a bipartisan discussion and we get into partisanship when we discuss water. We are not where we need to be. I was certainly honored to have her support. The Governor signed both of these bills. I met with the Governor for quite some time to talk about the bills and I think there was opposition from the southeastern part of the state. Obviously there is a huge housing crunch in the Hobbs area and Lea County, but we got those bills signed. They are small steps, I will admit, but at least there is some progress moving forward.

In terms of moving forward, I want to talk about a couple of things. Our acequia system in New Mexico, especially in the part of the state that I represent, is the fabric of many cultures and communities, and certainly a part of the water discussion. Their philosophy of collaborating and working together in terms of water storage is a signal and a model that the state can look to.

I want to talk again about the priority system and share a quote from a Kansas farmer that I thought was interesting and demonstrates the challenges of water adjudication even assuming we are fully adjudicated: "In the past, farmers could call a chief engineer to administer water rights based on the priority system in which older users are protected and junior users cut off. That force of action could enrage neighbors and ripple destructively to the local economy. If surface water was cut off completely, the result would be economic paralysis and unchecked declines in the water table."

What we have in New Mexico is a situation where our water rights are over-appropriated. They have been adjudicated, but we have more rights than we have water, and that water supply is dwindling. The challenge becomes how to adjust for the economic component in the system? We have junior rights, many of which are in municipalities, which obviously play into this. How do you balance for the economics of determining how you shut off systems? The reality is, shutting off water rights is an extraordinarily hard thing to do and something we haven't really done in New Mexico. The State Engineer is being faced with this dilemma pretty much for the first time.

Going back to the San Luis Valley, last week we had a presentation before the Water Committee about what is happening in the San Luis Valley. It had to do with something we are also doing here in New Mexico—Active Water Resource Management. We discussed this a lot in the legislature. In the San Luis Valley, the groundwater irrigators realized the same thing that New Mexico has realized. They were basically pumping, as one of our farmers said, the entire system into a "death spiral." They now realize they are over-appropriated in a fully adjudicated system. They went to their legislators and said they wanted to fix the problem themselves. They created legislation that in some districts gives them the ability in their sub-districts to allocate the water and most importantly, the ability to tax the use of water and charge up to $75 an acre-foot for groundwater pumping in those districts. Interestingly when we had this discussion with one of the farmers that was instrumental in setting this up, and the $75 an acre-foot figure was mentioned in the water committee [transcriber note: speaker does not complete sentence].

Senator Cervantes is a good friend, a former law school classmate, and we were work partners 20-plus years ago. He has a big farming operation in the Lower Rio Grande area in the Las Cruces area near the border. He basically said that $75 an acre-foot ends up being around half a million dollars for them for water they pump on their land for their farm.

What that money does, though, is to allow the district to make economic decisions. If there are areas where land is going to be fallowed, they would be able to write that farmer a check to fallow that land. We certainly have irrigation districts in our state; we have Active Water Resource Management (AWRM)—and I think our State Engineer did a good job during this hearing of standing up and saying that New Mexico's AWRM is the equivalent of what Colorado has done. The question becomes, what is the hammer that makes this happen? What happens when everyone sits down at the table and how do you make this allocation happen amongst close water users? This is something I am looking at as AWRM becomes implemented. In my opinion, it is the direction the state is going in the next five to ten years. We simply cannot get the adjudication done in that period of time. Let me say also that even if we do get the adjudication, we still have the issue of the effectiveness of the priority call. Are we going to litigate our way out of this? I just don't see that happening.

We need to figure out collaboratively how to develop a culture of conservation. It is dealing with a resource that is dwindling, and it is figuring out how the users, those being impacted, are put into positions themselves to be able to make these decisions. During the session, Senator Cervantes brought in a member of one of the very large pecan groves in the Elephant Butte Irrigation District. He sat down with me and said something that really stuck with me. He said, "You know Peter, I realize that things have changed. I just want to be the one making those changes. I don't want it just hammered at me." This is one of the things in the legislative process that is particularly difficult. We need to be able to sit down and create a framework that provides a constructive way to help water users move forward and that involves a collaborative approach. It is interesting that in my line of work I do a lot of mediation. In Senator Cervantes's practice, he does a lot of litigation, so he jokes it is the mediator in me vs. the litigator in him. There will be both; there is no question, but I think one of the things moving forward is creating that culture of collaboration.

The 2014 legislative session is a short 30-day session. You may have seen the press release on the capital outlay proposal. I was sitting with Senator Smith in a meeting and I couldn't help but smile thinking here we go again with the capital outlay fight. Every year, no matter who the Governor is, the administration wants all of the capital outlay. Interestingly, this capital outlay has 60 percent going toward water. That definitely changes the discussion a bit. It is an ongoing issue though because these funds are allocated among legislators. There are many other priorities besides water, but I think it is good that we have the discussion focused on water in the capital outlay, which is a bit different.

We may see some water bills in the upcoming session. I have talked with the State Engineer about a couple of bills I may introduce dealing with the Gila. We have had a number of presentations in the Water Committee about the Gila settlement and obviously the big decision is coming up about a second allocation of money that could come from the federal government if we do a diversion in the Gila. The list of non-diversionary options on the Gila is interesting. I think they are a roadmap for our state moving forward in terms of what we need to do from a conservation standpoint. I am hopeful that we won't spend all of the money to build a diversion structure, which at the end of the day when you factor in the different pieces, is about 7,500 acre-feet of water. Again, I realize it is a separate basin, but when I hear about 280,000 acre-feet of water being pumped from the aquifer below Elephant Butte, and putting in a dam in the Gila for 7,500 acre-feet, you look at the numbers and ask if it is this really the best use of those dollars.

Again, I appreciate the chance to share a few thoughts. Thank you.

The Relationship Between Water and Energy: Run-of-River Hydro and the Electrical Grid

Scott Backhaus
Los Alamos National Laboratory

Scott Backhaus received his PhD in physics in 1997 from the University of California at Berkeley in the area of macroscopic quantum behavior of superfluid 3He and 4He. He came to Los Alamos in 1998 as a Director's Funded Postdoc from 1998 to 2000, a Reines Postdoctoral Fellow from 2001 to 2003, and a Technical Staff Member from 2003 to the present. While at Los Alamos, Backhaus has performed both experimental and theoretical research in the area of thermoacoustic energy conversion including fundamental topics such as several thermoacoustic streaming instabilities, streaming assisted heat transfer, and acoustic power manipulation. He holds seven patents in the area of thermoacoustics, and his work has been recognized with several awards including an R&D 100 award in 1999, a Technology Review's "Top 100 Innovators Under 35" award in 2003, and a "Best Paper of the Year" award in 2011 from the journal Cyrogenics. Recently, his attention has shifted to other energy-related topics including the fundamental science of grid-integration of renewable generation, geologic carbon sequestration, and thermal fluids problems related to energy and climate.

Editor's Note: The following paper represents a transcription of the speaker's remarks made at the conference. Remarks were edited for publication by the editor. The speaker did not review this version of his presentation and the editor is responsible for any errors.

I think that the relationship between energy and water is way too broad a topic for fifteen minutes, or even fifteen months. Given the focus here, I am excited to narrow that down by a lot and talk about our work on the low-head hydro and the electrical grid.

Kris Polly spoke this morning and motivated me to say some things. I am from a scientific organization, Los Alamos National Laboratory, but like Kris, I grew up in Nebraska. My family has been growing corn and soybeans for 80 years there. I am now a New Mexican transplant and I am actually involved with water in many ways both from the electrical grid, but also from the water side. Some of you from northern New Mexico may recognize the name Richard Cook. I heard a couple laughs out there, so some of you may know about the legal wrangling that has been going on. I am one of the land owners that is involved in that wrangling, so I have a stake in water in northern New Mexico. Although I have a white shirt and tie on today, tonight I will go home and take care of the animals and fend for them. I am a stakeholder and I am concerned with the availability and reliability of water that it will be delivered down the Chama River through the Abiquiu dam. That is what I am here to talk about today. How can we use the existing water resources that we have to make the asset owners increase their revenue, and beyond that, also provide some useful services back to the electrical grid?

I picked up a copy of Kris Polly's journal, *Irrigation Leader*, this morning. It is a great journal, and if you haven't seen it yet you should pick up a copy. In the issue I just paged through, there is an article about in-house hydro power in irrigation districts called Common Sense Hydro Power: Small Hydro Power as a Solution, Traditional Hydro Power in the West. Clearly there is a focus here on hydro power, but everything that I have seen so far is from the water direction looking back at the grid. Why can't I have this hydro power and just hook it up to the grid? Well, there are issues with that. You can't just hook anything up to the grid. As you all know, water systems are large engineered networks, and so is the electrical grid. We have to be careful how we do this. Looking at this problem from the grid into the water system, I see the same thing. I see a huge resource in Abiquiu. Why can't I use that the way I want to for the benefit of the grid? Clearly, there are downstream stakeholders. How do we get these two sides to talk to each other for mutual benefit? That is what I would like to focus on today.

Part of this talk was to present a "proposal for meaningful change." My meaningful change would be to change one word in the Flood Control Act of 1960:

Public Law 86-645
86th Congress, H. R. 7623
July 14, 1960

> Cochiti Reservoir, Galisteo Reservoir, and all other reservoirs constructed by the Corps of Engineers as a part of the Middle
>
> Rio Grande project will be operated solely for flood control and sediment control, as described below:…

The one word from Public Law 86-645 that I would like to change is "solely." That is a tough word when it comes to lawyers. Let's modify the rules and regulations governing the sole purpose of the dams of the Rio Grande basin to allow a small degree of flexibility in water flows that will enable hydro-electric owners to provide services to the area that will: increase the economic value of those hydro stations to the owner and operator; provide services to the grid; reduce CO2 emissions and cooling water consumption at other locations; and also ease the integration of some other carbon free resources into the grid, while having minimal impact to stakeholders. If that one word, "solely," were changed, it would provide a lot of flexibility.

What specific installations are we actually talking about? Figure 1 shows the hydro stations owned and operated by Los Alamos County Department of Public Utilities. Abiquiu is run by the Army Corps of Engineers with 17 megawatts of max generation. El Vado Dam, also owned by Los Alamos County Department of Public Utilities provides 8 megawatts of max generation.

Figure 1. Hydro stations owned and operated by Los Alamos County Department of Public Utilities

What are we proposing to do? You all know about water, but let me give you two figures on the important features of the electrical grid that I am going to talk about today. Figure 2 is the U.S. grid and the area of concern is the Four Corners region with its big coal stations. You all now understand what I am talking about when I say the electrical transmission grid. It is the bunch of big wires that you see running down the side of I-25 and it is meshed so there are many ways that you can get from BPA down to PNM. It is primarily supplied by large synchronous generators: big chunks of spinning steel hooked to steam turbines that are connected to generators on the other side. The rate of rotation is what determines grid frequency, which is sixty hertz coming out of the wall. Generation and load are rebalanced every two seconds, while balancing water is done every 24 hours. It is a much harder job rebalancing every two seconds and to a fine degree of accuracy. You can think of it this way: if you flip the light on in the back of the room, it increases the load on the system. If you don't have the power to meet that requirement, the power has to come from somewhere–it starts sucking it out of those big spinning chunks of steel, and that is why it has to be rebalanced every two seconds or the frequency starts to fall. Large deviations can cause imbalances that are disruptive to the grid. By large, I mean large enough that a big generator trips off line. It would be like the big generator in the Four Corners area tripping off line. Throughout the entire West, this happens about twice a week. Sometimes these disruptions lead to large cascading blackouts. If you think that delivery of water is important, recall the 2003 Northeast blackout. It cost the country billions of dollars in just over a couple of days. Reliability of the grid is important, and I think that hydro power can play a role by providing lower cost reliability.

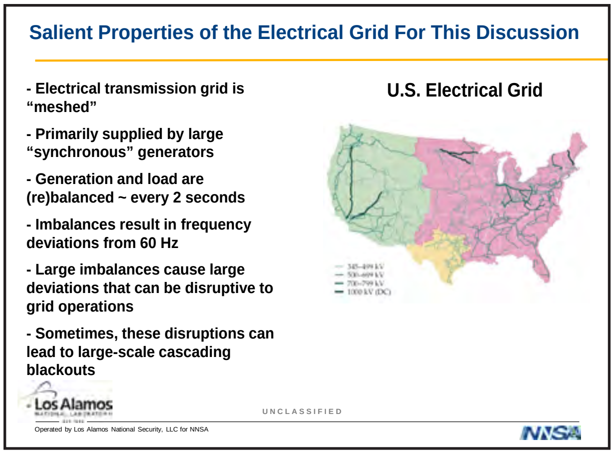


Figure 2. U.S. grid with the Four Corners region electrical transmission grid

How do we take care of the reliability? We procure spinning reserves (Fig. 3). What are spinning reserves? Imbalances are created by failures of the largest generators. It isn't the generator's fault, something disturbed it, and it tripped off line. Grid operators plan for such contingencies by buying large sections of spinning reserves, basically a fossil plant such as a big coal plant sitting on standby ready to generate power on a moment's notice to replace a generator that has been tripped off line. It must be available within five minutes, and typically used for one hour. Generally in the West, we have two such events every week, and we would need such reserves for that one hour twice a week.

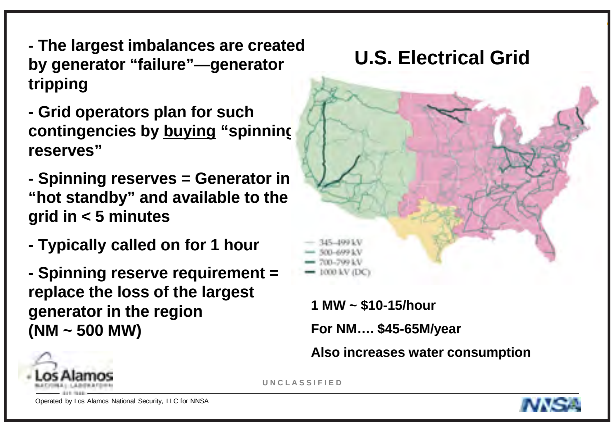


Figure 3. Spinning Reserves—Properties and Costs

To give you a sense of the economics here, the FERC requires that you be able to replace the largest generator in your area. In New Mexico, that is about a 500 megawatt generator. One megawatt costs about $10-15 an hour to have as a spinning reserve. In New Mexico, that means about $50 million a year in costs to provide this reliability service. Providing that service doesn't just produce CO2 emissions, it also increases water consumption, because those coal plants that are sitting in hot standby need cooling, while they are not providing any energy to the grid.

Kris Polly also mentioned today about other people's perception compared to reality. What really goes on compared to what people think goes on? We have done our homework from both sides to try to show that the services provided by the water won't impact stakeholders and beyond that, they can even earn extra revenue while providing services to the grid. We worked with the Department of Public Utilities to identify the available resources, focusing on Abiquiu, and how much flexibility in megawatts that dam can provide without impacting their revenue profile. We have looked at the impact of modifying U.S. Army Corps of Engineers steady-state operations on water flows. We have compared them with existing operations and talked to the Corps about the feasibility of these windows. We have looked at the impact of a spinning reserve event on downstream stakeholders, and we have performed simulations of real-time operations on those dams to get a better idea of impacts to the grid.

The next part of this talk is that part I love because I am a science guy. We have identified the available resource (Fig. 4). Abiquiu consists of three turbines including two 7-megawatt units and one 3-megawatt unit. These units have different flow regimes and different efficiencies, which can be characterized by efficiency curves. You want to maximize revenue for energy from any flow given to you by the Corps. You don't want to disturb that because it is your main resource. You can see in Figure 4 that for a typical flow rate, which is 300 cfs through that dam, you are generating $200-250 an hour. Remember, I want to provide a service that is will generate an extra $15-30 an hour. That means we would be increasing the value of that dam by 10% by effectively doing nothing, just sitting by and being prepared to provide that energy to the grid. That entails only providing service for two hours a week.

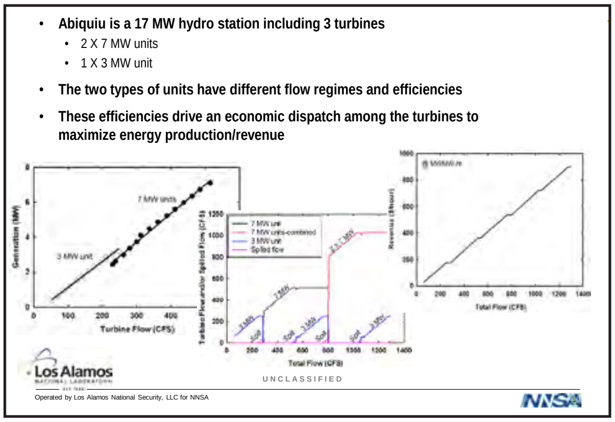


Figure 4. Abiquiu's Available Resource—Base Revenue

There is math behind this right? Yes, of course, but I won't go through all the math on Figure 5. We have done the optimizations to show that you can maximize revenue, maybe constrain water operations by a little bit, but provide extra value. Having spinning reserves requires that units be online and synchronized, which means that for a given amount of water that the Corps provides us, we would figure out how to dispatch all of our units. If we dispatch our units, what we find is that to keep our revenue at a maximum, and to provide this extra revenue to ourselves while providing this service to the grid, we have to constrain the water operations to be within certain windows. Depending on the size of the resource that we want to tap into, those windows get more and more narrow.

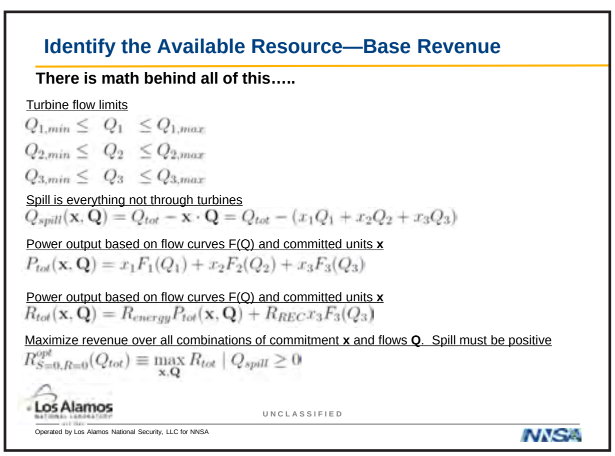


Figure 5. Identifying the available resource

Figure 6 shows the outcome of increasing the revenue of that dam by 5-10% a year. This shows normal operations for that dam in February with flow rate through the dam as a probability density. Usually in February we are normally well below 100 cfs, while in May you have spring runoff and peaks around 1500 cfs, although I think those operations have changed a bit and pushed that peak down. In August we are in irrigation season, and by November we shut down again. You can take these historical operations and force them into these little black bands as shown in Figure 6. If we constrain the steady-state operations to fall within those bands, we can do two things: continue to maximize revenue in terms of energy from those dams; and still provide 10% more revenue with the services we provide. It is pretty simple and straightforward. However, we do have to constrain the water operations. Remember, I'm a grid guy mostly looking at this from the grid size. I'm saying, that's no problem, can't you just keep the water flow within these bands? No, not exactly. What is the impact to the downstream stakeholders? If we could keep operations within those bands, with those flexibilities as I like to call them, depending on how much service we ask for, operations for one megawatt are already within that band a bit more than 50% of the time. We wouldn't actually be moving operations around that much. The revenue obtained sent back to the land asset owner is $87,000 a year. That is about a 5% increase in value of the asset over and above what it already is today. If we constrain operations a bit more and go up to a two megawatt capability from that dam, we are almost up to $200,000 a year increase in value.

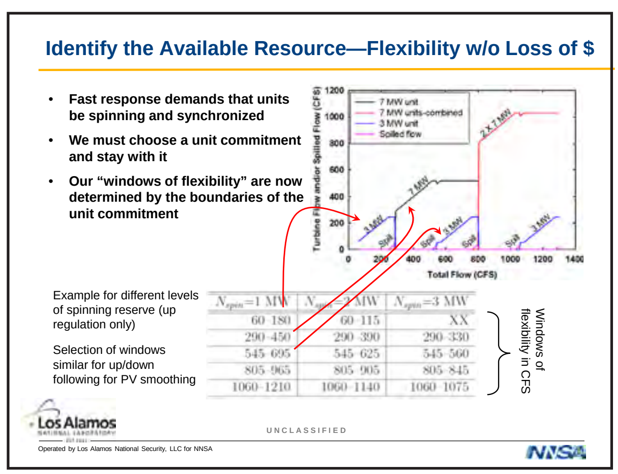


Figure 6. Outcome of increasing the revenue at Abiquiu

Kris Polly mentioned this morning that there are 18 small hydro projects that are going to cost around $12 million to implement. The cost of doing this monetarily is zero. There is no cost. The only cost is the sweat to get that one word in the legislation changed. We need the wording changed from the “sole” purpose to the “primary” purpose for flood and sediment control as well as other beneficial uses. Again though, I am an electrical grid guy looking at this from my side. I am trying to cross over enough that I understand what is going on. You might think that if I start tweaking with the water operations in the Chama River that the irrigators might be very upset, and that I might be somehow affecting the flows coming into their ditches or affecting the availability and reliability of the resource. That is the perception; the first thing they hear is that we are going to play with the water and they say, no you aren’t.

We are scientists, so let’s do some experiments. Look at Figure 7 for the effects. We used the commissioning of a three megawatt low-flow turbine a couple years ago to conduct a spinning reserve experiment. Part of the acceptance testing was to take the turbine from zero and ramp it up to a couple megawatts, hold it there for a couple hours, and then bring it back down again. We replicated what that would look like.

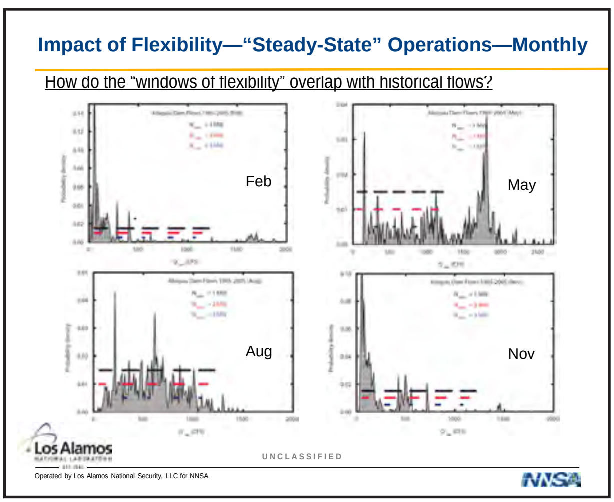


Figure 7. “Windows of flexibility” and overlap with historical flows

I want to point out a couple of things on Figure 8. The figure shows hours since midnight in May 2011, so this test is a bit old, but you can see the flow rate. These are typical operations from the U.S. Army Corps of Engineers. At 10 a.m. every day they appear to change the flow through the dam. This is a typical change you might see. Sometimes you might see nothing, but this is fairly typical. So that is already a pretty big change. You can see the commissioning test with the spinning reserve pulse that we sent down to the gauging station right below the dam. This pulse has an effect if you go maybe 40 or 50 miles downstream to the gauging station at Chamita. The effect on the water isn’t that significant. This isn’t perception, this is the data. This is the effect, and this would happen twice a week perhaps on average at Chamita far downstream. What if there is a stakeholder right down below the dam? What is the effect to them? They will be the ones who complains the most. We had people from the Corps go out and put gauges at the first two diversions to get an actual measure of impact to those stakeholders. The river stage during that spinning reserve pulse changed by a few inches. The anecdotal evidence from those studies was that it didn’t actually affect the flow into those ditches much at all.

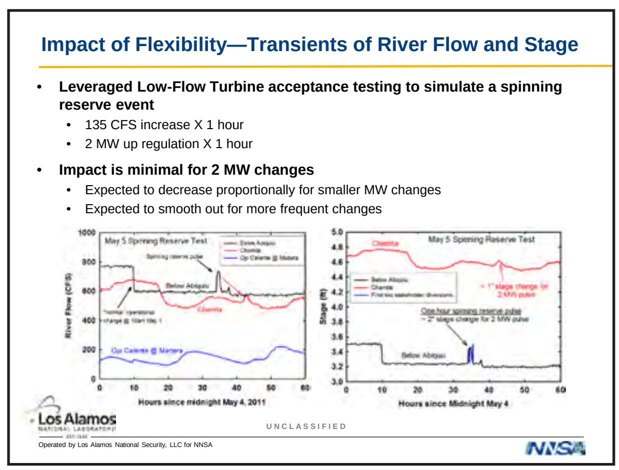


Figure 8. Transients of River Flow and Stage

What I would claim is that this simple service would increase the value of that asset by 10% with revenue on the order of a $200,000 a year. It may not seem like that much, but you start pushing that out into other resources in New Mexico and in the U.S. and it starts to add up to some reasonable dollars–dollars that could be reinvested in other hydro-power projects.

Also, we looked at the spinning reserve calls in this area for a year, and on average it is called on about twice a week (Fig. 9). So it would, in fact, be calling on the system about twice a week.

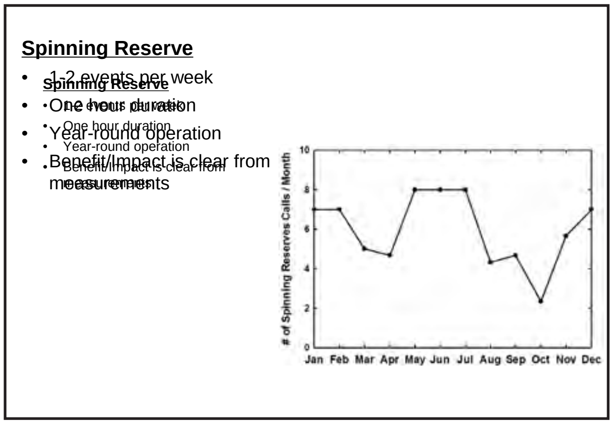


Figure 9. Frequency of transients

To wrap up here, run-of-river hydro is an underutilized electrical grid asset that can provide services while meeting other water stakeholder needs. We have done our homework both through simulations and experiments/observations to look at impacts on daily flow scheduling following services delivered and transient impacts on stakeholders.

Again, my meaningful change is to change that word “solely” in the law to “primary” and to allow a small bit of flexibility with the appropriate studies to provide additional services for run-of-river hydro.

Thank you.

The Economic Importance of Western Irrigated Agriculture Impacts, Water Values, and Strategic Policy Questions

Darryll Olsen
Pacific NW Project

Darryll Olsen is principal-in-charge for The Pacific Northwest Project (PNP), a regional planning-resource economics consulting firm. The firm specializes in water, energy, and natural resource management and development issues, economic analyses, and economic impact assessments. The firm conducts and manages technical project evaluations, administrative review and legislative projects, and complex litigation actions affecting water resources management. Darryll has about twenty-nine years of experience working on resource development and management projects for federal, state, and local agencies and private sector clients. He earned a doctoral degree in applied energy studies from Washington State University (WSU) (1983). The degree is an inter-disciplinary degree sponsored by the Office of Applied Energy Studies, the Program in Environmental Science and Regional Planning, and The Departments of Agricultural Economics-Rural Sociology at WSU. He also received a master's degree in quantitative analysis-history) and bachelor's degree from Central Washington University in history and philosophy (double major) with an environmental studies minor.

Editor's Note: The following paper represents a transcription of the speaker's remarks made at the conference. Remarks were edited for publication by the editor. The speaker did not review this version of his presentation and the editor is responsible for any errors.

Good morning, and thank you very much for the invitation here today. I like coming down to New Mexico because it is like being immersed in water policy reality. You folks have real issues and problems, and they usually revolve around water supply. I come from the Pacific Northwest and eastern Washington–our idea of a bad year is when we are down to 140 million acre-feet. We have fights and we have management problems, but they are all kind of metaphysical in comparison.

One of the problems throughout the Southwest is the difficulty in getting across to policy decision makers the magnitude and the implications of irrigation agriculture to the economy. The Environmental Protection Agency invited the Family Farm Alliance and others to visit Washington D.C. to explain to their upper management the impact and value of water to the nation. EPA asked three very specific questions and we answered those questions very specifically. They asked us about values. What is water's dollar value impact? Because we are economists, we think about economic value. And they asked how well we knew what we were doing–how certain were we? They asked us to express key issues and questions and what changes we would make.

We described to EPA staff the economic engine that is agriculture, and it is literally an economic engine in the West. We stressed the concept of opportunity costs, and opportunity costs is the most violated principle in research economics. It is violated at the federal level as well as at the state and local levels. It is even violated in my household. It is very hard to get across the principle that the trade-offs you make are not about the value you get, but the value of what you give up. We tried to express to the EPA that these agriculture's opportunity costs are "silent opportunity costs" and explained how those costs can affect the food security issue. We turned the food security issue away from things like terrorist activities, imperfections, pesticides, and so on that you normally hear about, to economic impact. It is a recent shift–only since 2012–that we and others have made.

When referring to the irrigated agriculture industry, I am talking about three sectors: direct agricultural production, agricultural services (the red tractors, green tractors, etc.), and food processing (dry goods, frozen good, etc.). When we talk about economic impact, the statistic we focus on is household income. In discussing our key measure of household income impacts, we work with values that you are used to seeing. Figure 1 shows estimated irrigated acres from 2008 to 2012 in the western United States, totaling over 42 million acres. You get a very strong appreciation for states like California and Texas and the contributions from other states. Another statistic that you are used to seeing is production value (Fig. 2). State agriculture agencies, agricultural services, or the agricultural census provide the estimated agricultural production value in dollars. What you do not see are the algorithms and equations that are used to derive the irrigated agriculture numbers, which includes vegetables and fruits, grains, and cattle and dairy. Taking into account affected industry like cattle and pasture, how do we make this estimation? Basically, over the past 25 years of experience, state economists have been able to produce these estimates in a way that they are happy with. The punch line is that about 70% of total agriculture in the western U.S. is directly tied to irrigated agriculture, and that is about $117 billion worth of farming product.

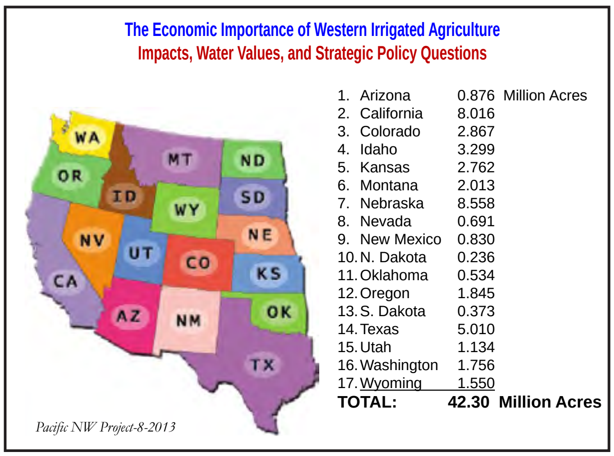


Figure 1. Western U.S. estimated irrigated acres 2008-2012

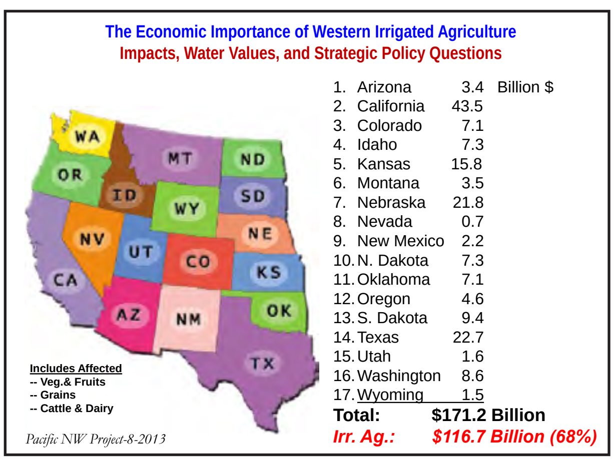


Figure 2. Western U.S. estimated agriculture production value in 2011 dollars

Figure 3 shows trends over the past decade on product and farming value. It is basically the same trend that has been repeated over the past decades, and typically you see a plateau period and then a spike, like the 2006-2007 period. A decline was tied to recession, followed by an uptick, and then another plateau period. If you were to take 2011 and flatten it to a horizontal line, that is what we expect for the next seven or eight years in terms of agricultural production prices. Something can always go wrong as the cattle guys often worry about and the apple guys who are always convinced that what goes up always comes down. But when we look at the numbers, we see a stable period for agricultural commodities and prices over the next seven or eight years.

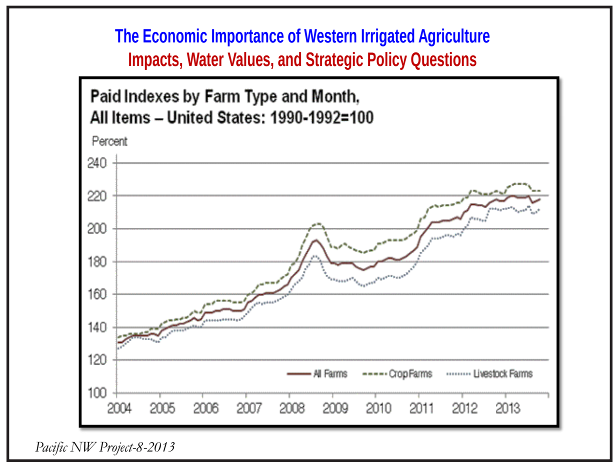


Figure 3. Paid indexes by farm type and month, all items

Taking those numbers that you are used to seeing and turning them into numbers that you are not used to seeing is reflected in Figure 4. No one else tries to measure household income for irrigated agriculture on a state by state basis or west-wide in the United States. We are the only ones that do it and we have done it only a couple of times for the Family Farm Alliance and others. These are fairly unique numbers because you have to work through the algorithms for each state, look at commodity to commodity considering what is allocated in irrigated agriculture, and then add the multiplier effects for the agriculture industry. The industry includes agricultural production, services, and processing as well as other impacts like those from butchers, bakers, economists and statisticians, fertilizer people, and basically everybody else who is providing services. At the end of the day, our industry is about $156 billion a year for household income generated in the western United States. This is a big number. It is competitive with any other industry groups in the West like Boeing, aerospace, or the electronics industry. The only other group that rivals agriculture is the health care industry. People don't realize agriculture's huge impact. As we went through this with the D.C. folks, you could see they were waking up to the importance of the agriculture industry.

The Economic Importance of Western Irrigated Agriculture
Impacts, Water Values, and Strategic Policy Questions

Irrigated Ag. Annual Income Impact:

	Direct $	Multiplier	Total $ Impact
1. Arizona	$1.8	2.5	$4.5
2. California	31.2	2.5	77.9
3. Colorado	1.7	2.2	3.9
4. Idaho	2.7	2.5	6.7
5. Kansas	2.0	2.2	4.4
6. Montana	0.4	2.1	0.9
7. Nebraska	4.2	2.5	10.7
8. Nevada	0.4	2.1	0.8
9. New Mexico	1.5	2.2	3.3
10. N. Dakota	0.9	2.1	2.1
11. Oklahoma	1.0	2.2	2.2
12. Oregon	1.7	2.2	4.0
13. S. Dakota	1.6	2.1	3.4
14. Texas	6.9	2.5	17.1
15. Utah	0.8	2.1	1.7
16. Washington	4.7	2.5	11.7
17. Wyoming	0.2	2.0	0.3

TOTAL INCOME IMPACT: $156.0 Billion

Pacific NW Project-8-2013

Figure 4. Irrigated agriculture annual income impact

New Mexico has about 830,000 acres of irrigated agriculture with major productions areas of cattle; milk and dairy; hay and hay products; nursery and greenhouse products; and fruits and vegetables. With the drought conditions, I think New Mexico may have less than 800,000 acres currently. Total farm production expenditures are $2.0 billion each year. We can say with technical confidence that the impact of the irrigated agriculture industry to New Mexico is over $3 million dollars in annual household income. It is a substantial number for the state.

My presentation is not complete without discussing water values. What is the value of water, particularly irrigated agriculture water, in the West? Looking at water markets in the West, particularly as they relate to irrigated agriculture, we are somewhere between $1,500 and $3,000/acre-foot capital values (Fig. 5). It is important to remember that municipalities' marginal cost of water and marginal value is essentially at the top end of the marginal value. They can always go out and make purchases or transactions. Figure 6 shows market and non-market values of water and is essentially the direct net opportunity costs of irrigated agriculture. Economists are good at quantifying just about anything that moves. We have experience quantifying market things like water and power, and other things that we consider non-market, such as recreational use like boating. We are also getting pretty good about dealing with climate change. We can put values on climate change assuming that the base numbers are correct. These statistics become the direct net value or opportunity costs.

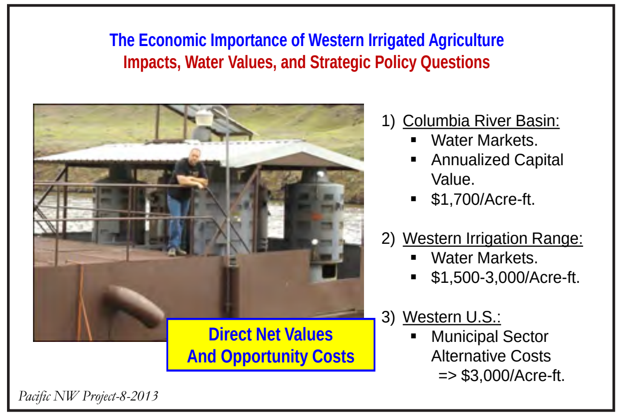


Figure 5. Direct net value estimates for irrigated agriculture

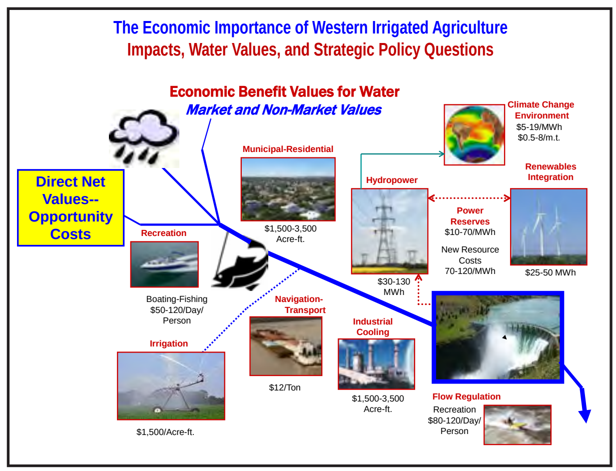


Figure 6. Market and non-market values for water

When talking with the Washington D.C. folks, we briefly informed them that there is another set of opportunity costs that we are not accounting for here with irrigated agriculture. If you start taking water away from irrigated agriculture, there are other tertiary benefits in place, and there are opportunity costs associated with what happens with the impacts to the economy. Those kinds of impacts are where we should be addressing the food security issues. Interestingly, we are not the only ones saying this.

Concerning the food security issue, we can look at organizations like the World Bank, the Institute of World Economists, and all of the NGOs involved in international work. They are indicating that food security is directly and squarely targeted on the water available for irrigated agriculture worldwide. You know, they made this pivot. They are literally alarmists about this. We have picked up a change in their attitude as these international organizations, international monetary funds, and so on, are now suddenly bringing up the United States. These organizations are concerned with food security issues in the United States as they relate to irrigated agriculture and impacts to our economy. They are concerned about the impacts of our consumer economy. About 70% of our economy is the consumer economy, and we have that economy because of the amount of disposable income we are able to spend on things other than food. There is no better representation of this than what is on this Figure 7. The graph shows the amount of food costs relative to disposable household income since World War II to the present. We have gone from having nearly 25% of our household income directed toward food to where now we are down to around 6%. This is almost entirely unique to the United States. Anyone who travels around the world will tell you, particularly in Europe or Asia, that they have much higher household income expenditures directed toward food. It is very low in the United States, and irrigated agriculture has significantly contribution to that.

So, our punch line both to the D.C. people and to our local folks is what I would like to illustrate in an example. Three weeks ago I had lunch with our director in the Department of Ecology, and the Washington State Department of Ecology is a major industry regulator. We sat down, and in Washington State we are kind of enthralled by CO_2. There is a battery of folks working on that issue, because among other things, it is a very sexy issue you know, with national and international implications. So we sat down and said to her, you might get tired of working on this. When you do, do you really want to work on an issue that has a reality and a material impact on the U.S. and world economy? Because, that is what we do with irrigated agriculture in the West, and we have an opportunity to do something with irrigated agriculture in the West in each state. So when you ask what can we do to change things, you can go in and start bringing state level policy makers up to speed on these issues of irrigated agriculture, food security, and the impact that is has on our economy as well as the world economy. Part of the things that we are saying to them as well is that there is a lot of emphasize on efficiency in irrigated agriculture. We are big proponents of that, but we are saying that we need to drill those efficiencies back into irrigated agriculture. We need to both protect the industry, and where we can in certain places in the West, expand the industry because it does have very concrete impacts to our economy and the health and well-being of what we are doing in the U.S. as well as other countries. So that is my pitch for change. Thank you.

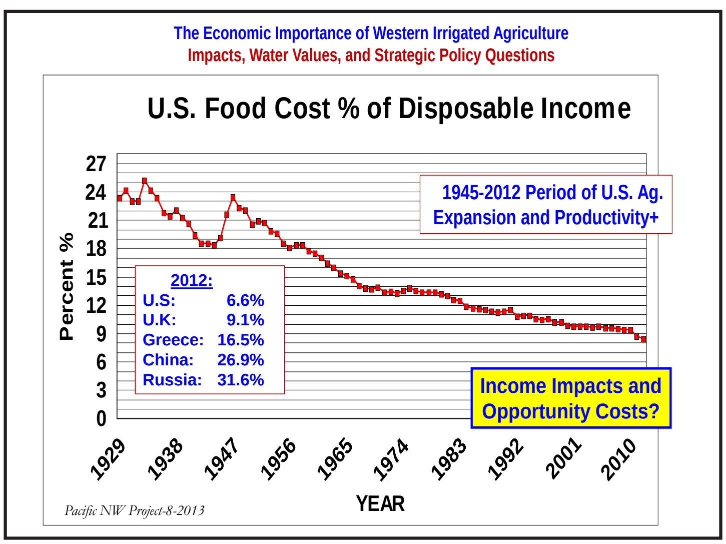


Figure 7. U.S. food cost as a percentage of disposable income

Solutions: El Paso as an Urban Example

John Balliew
El Paso Water Utilities

John E. Balliew is a native of El Paso and started working as a laboratory technician for El Paso Water Utilities in 1983. Since then, he has held several leadership positions before being named Vice President in 2007. During his career at EPWU, John has been directly involved in many of the innovative projects that have helped secure El Paso's water future. Those projects include the 50-year water resource plan, construction of the nation's largest arsenic-removal plant, the Kay Bailey Hutchison Desalination Plant and implementation of a leak detection system that reduced unbilled water by 43 percent. Additionally, he has been involved with the expansion of groundwater resources and on-going projects designed to mitigate the impacts of the region's on-going drought. In January 2013, John accepted the role as President & CEO of EPWU where he is now responsible for all aspects of water, wastewater, stormwater and reclaimed water management for the greater El Paso metropolitan area. He reports to and implements strategic policies set by the Public Service Board. He received a BS in chemical engineering from Texas A&M University in 1982 and is a licensed professional engineer.

Thank you for inviting me here to this lovely seminar. I want to talk about water solutions using El Paso as an urban example. Here in the Lower Rio Grande, as we refer to it in New Mexico, in a full release year, irrigation districts use the bulk of the water (Fig. 1). You can see that El Paso gets a little sliver, and Mexico gets a sliver. That is the allocation that we would expect from a normal release year from the Rio Grande Project. Historically, there has been some variability in terms of the reservoir level at Elephant Butte (Fig. 2). Levels have gone up and down, and right now we are in one of those down portions.

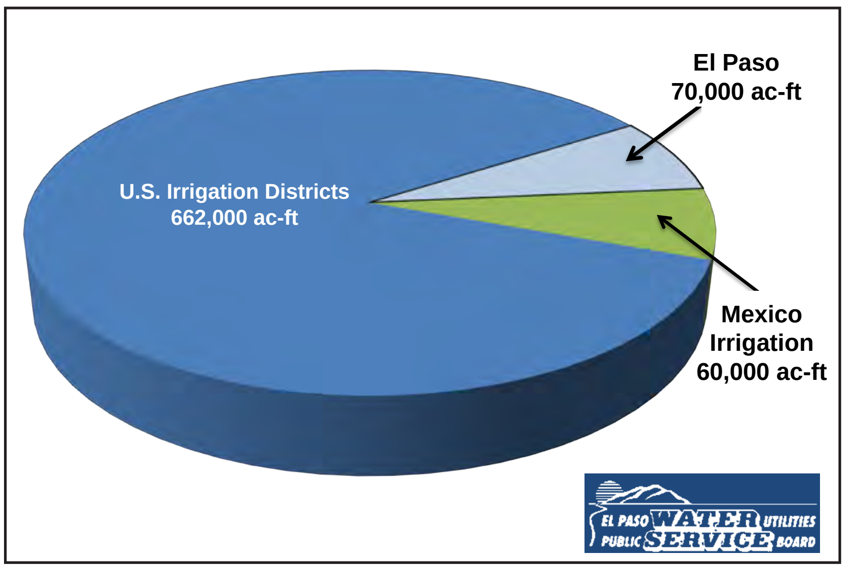


Figure 1. Allocation of Rio Grande water, full release total = 792,000 acre-feet

What does that mean for El Paso? When you look at the amount of water that we have been able to utilize from the Rio Grande Project, out of the last 17 years, only 3 years have been above average (Fig. 3). Most years have been below average, especially during recent years. Normally in a full release year, we have 70,000 acre-feet of water rights. In 2012, we received only 32,500 acre-feet and we thought that was pretty low. Then 2013 came along and we budgeted for only 25,000 acre-feet knowing that we were going to be reduced from the 32,500 that we received in 2012. We received only 7,000 acre-feet. That is the lowest amount that we have received since the inception of the Rio Grande Project in 1906.

This drop in available water has forced us into doing things quickly to take care of the problem. It only took three successive seasons for the release to go down to 32,500 and then 7,000 acre-feet. Figure 4 shows the municipal perspective. This graph covers from May 1 to July 31, the time frame in an arid city when a lot of the water is used for irrigation. The graph shows demand that

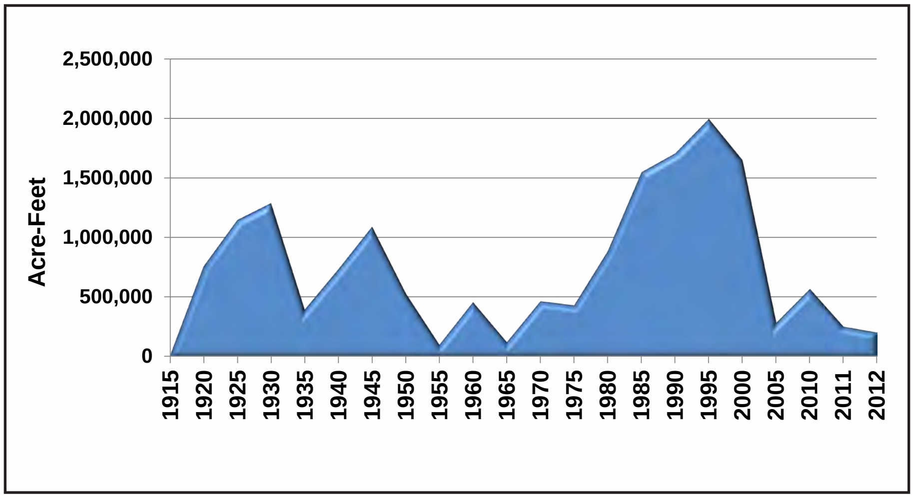


Figure 2. Elephant Butte Reservoir historic levels. Bureau of Reclamation: Upper Colorado Region historic data

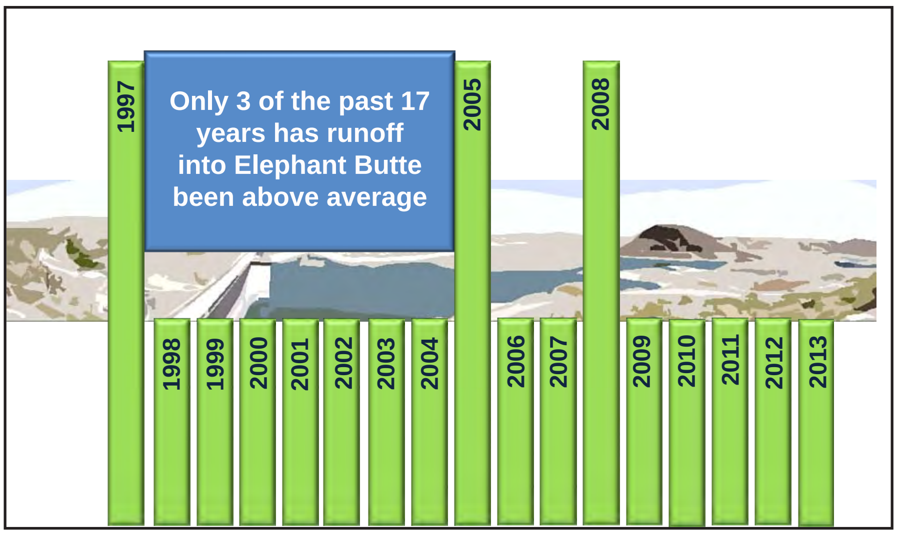


Figure 3. Drought history for Elephant Butte, 1997-2013

must be met and where we run into difficulties. Why? Normally you would have a big blue box representing available water. The red line represents forecasted actual use or demand. To plot this graph, we look at long-term forecasts, population growth, and the other various inputs. This shows you the impact of the drought. All the purple that you see above the blue box represents water that we are not getting from the Rio Grande. You can see the impact in that normally on a May 1 date we would have sixty to seventy million gallons a day of reserve capacity. You need that because things can change relatively rapidly. You may have one week when it rains followed the next week with 110 degrees–water demand can change extremely quickly. You can see at three points that we are forecasting demand to be greater than our available supply. That is a very troubling situation for a city utility because it is our job to provide water to our customers. Practically every city in the country has something that goes under the name of "water emergency" or "drought response plan" with stages that go along with it. Each one of those stages presents real economic impacts on the community.

El Paso has been practicing water conservation for a long time. Our normal course of action is very similar to what many cities have as their Stage One in their drought plan. By the time we start implementing actions, we go immediately into the economic viability of the community. We look at closing car washes and similar, and how those actions will impact customers. It is not comfortable to be in this type of a situation. In 2013, as it turned out, we had a better year than what was forecasted. The yellow line in Figure 4 represents the actual demand in the system. We had some very unusual weather patterns with precipitation that kept coming and going.

In 2013, we had a lot of variability, but the demand overall was less than what we had forecasted. This particular year we "squeaked by," and I believe that is a very accurate term to use. How did we do that? One of the things that Ed Archuleta, former EPWU President and CEO, setup was a diversified water resources portfolio including surface water, reclaimed water, conservation, groundwater, desalination, and importation. To put this into perspective, when I was hanging out in the lobby I picked up a copy of Catherine Ortega Klett's book on New Mexico's water wars. I flipped through some of the chapters to remind me of what took place in the 1980s, because back then, El Paso only had surface water and groundwater. That was it. We thought the surface water was limited because at the time, we had a poor relationship with the El Paso County Water Improvement District #1. We primarily looked at groundwater and ways to expand it, which didn't work out well for anyone.

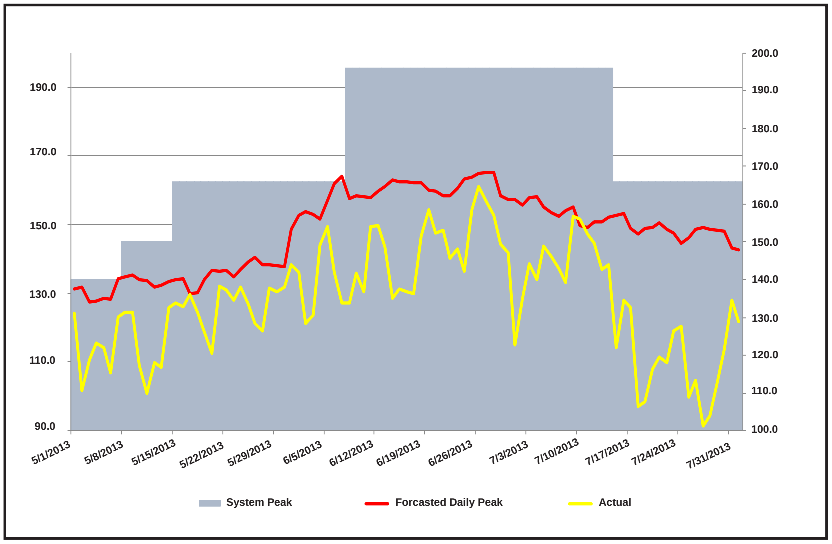


Figure 4. 2013 Summer daily peak, May 12013 to July 31, 2013

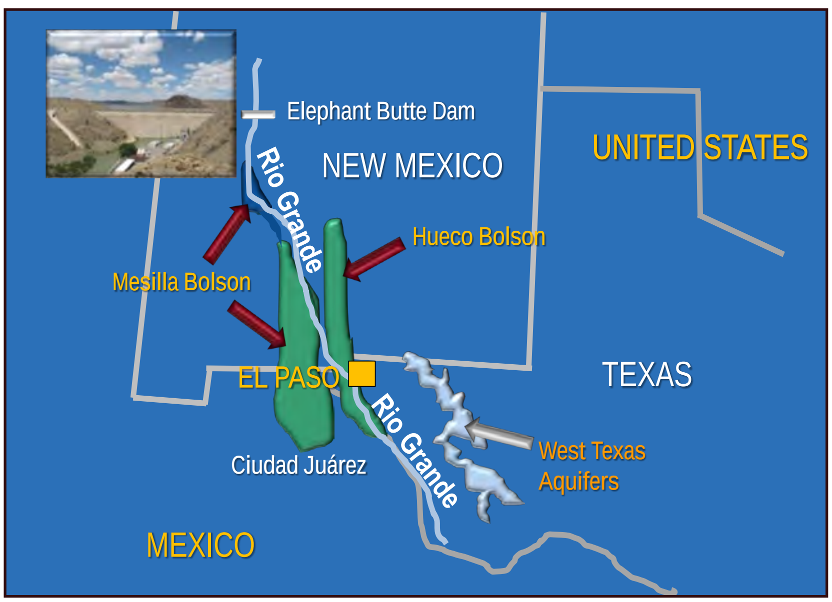


Figure 5. Regional water resources

By expanding into these other areas, we have taken care of our own situation fairly locally (Fig. 5). In our area we have brackish water resources, and I think this applies throughout the West. In Texas, there are billions of acre-feet of brackish groundwater and New Mexico has a similar situation. Concerning reclaimed water, we make use of municipal wastewater, which I will talk more about later. Conservation is very important: every gallon that is saved is a gallon that can be supplied to customers at a later time. When I talk about importation, I am talking about importation from other basins within Texas. As the Rio Grande flows south from Albuquerque to Elephant Butte, we have two aquifers on either side of the mountain range that runs through El Paso: the Mesilla Bolson and the Hueco Bolson aquifers. These aquifers extend way up into New Mexico, with part in Texas and part in Mexico as well. About ninety miles east of El Paso are a few smaller aquifers that we refer to collectively as the West Texas Aquifers. These smaller aquifers are isolated from the Rio Grande and from the Pecos. They have internal drainage and when water evaporates, it essentially creates a salt flat. These resources are what we have to work with.

El Paso has two surface water treatment plants and two groundwater plants. The two surface water treatment plants take water out of the Rio Grande when it is seasonally available. Other places in Texas, such as Dallas or Houston, run their treatment plants year-round. Even in a good year, El Paso runs about 210 days out of the year. When the Rio Grande is turned off, we clean the plants, do maintenance, and simply let the plants idle. In the Upper Valley, we have a large arsenic removal plant because the Mesilla Bolson is impacted by arsenic. Just to the east of the airport is an area that contains huge reserves of brackish groundwater and El Paso's Kay Bailey Hutchison Desalination Plant. Pumping inside the city has caused brackish water to move in so the plant has a two-fold purpose: to intercept that water, and then to also provide it as a potable water source.

In 1985 we built the Fred Hervey Water Reclamation Plant to take wastewater, reclaim it to drinking water quality standards, and then inject it back into the basin. We also have three wastewater plants: the Northwest Wastewater Treatment Plant, the Haskell Street Wastewater Treatment Plant, and the Robert R. Bustamante Wastewater Treatment Plant in the south. We have been investing in what we call the Purple Pipe System: we treat water until it is suitable for use in irrigation, then we supply a separate system of pipes, pumps, stations, and reservoirs to supply customers with reclaimed water for irrigation. The system has worked very successfully. The next phase of this effort is to take the water directly to potable, drinking water quality standards, and put it directly into the system. The reason we are doing this is simple economics: we want to incentivize the customer to use this water as there is a real cost to the customer. Salt is a big deal–when water is used by customers, the wastewater produced has more salt than the water the customers started with. Customers will have to deal with salt impacts so we need to incentivize its use; because if it is potable, we can charge full potable price.

What are El Paso's water challenges? First we have the specter of drought. We also have normal customer growth. El Paso grows at an extremely steady growth rate of about 2.0 percent every year. It has never been less than 1.8 percent or above 3.5 percent. We also have $800 million of capital improvement needs over the next ten years, which creates a large financial obligation. We must produce revenue to put these types of facilities in the ground. Energy is the biggest cost that we incur–it takes energy to pump water from one place to the other and to treat that water. And we have personnel issues. We have about 1,000 employees in El Paso utilities, and about 300 of them could retire in the next year. I think many companies around the country are facing similar situations.

Now let's move to drought management. The impact of the Kay Bailey Hutchison Desalination Plant has been significant (Fig. 6). The plant has operated under a fairly steady state since 2007. We try to have a balanced approach; we get as much water from the Rio Grande as possible, but when we can't do that, we operate the Kay Bailey Hutchison Plant at full blast.

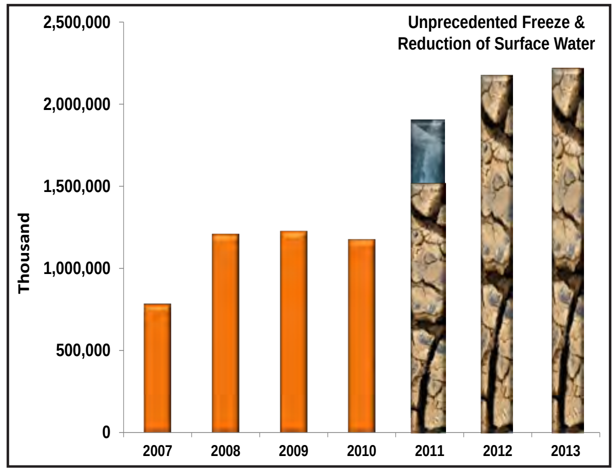


Figure 6. Kay Bailey Hutchison Desalination Plant product, 2007 – 2013

In terms of El Paso's overall supply, Figure 7 shows the two groundwater basins, the Hueco (in blue) and the Mesilla (in red) that constitute the bulk of our supply. We have been using more Rio Grande water when it is available, but you can see from the figure when we had drought years. In 2007 for example, we had to increase supply with additional groundwater pumping and our desalination plant kicked in.

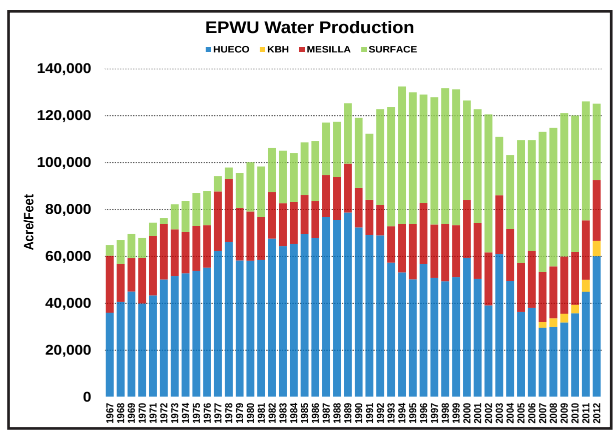


Figure 7. El Paso Water Utilities water production, 1967 – 2012

What does El Paso do to supply water in the face of drought? One problem is that we have been dependent upon the Rio Grande. We have large pipelines that go from the Rio Grande north into the city. Now we have well fields in the north and have to get that water down to the central and downtown parts of the city. This required two pipeline projects to essentially reverse the flow of the water to take the groundwater into the central area.

We became complacent with our wells as we used more and more of our surface water supply. We let many of our wells sit idle and when we wanted to turn them on, they didn't work. Those wells required a good bit of maintenance and rehabilitation. El Paso is also working with the potable reuse as I mentioned earlier. I'll be in Austin next week to meet with regulators to decide on what type of pilot plant we will need.

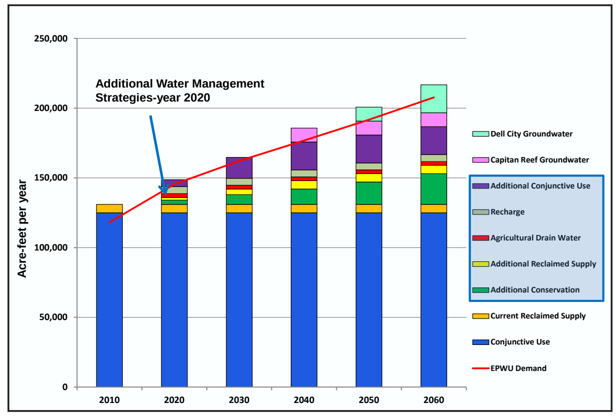


Figure 8. Water management strategies for EPWU and projected demands (2011 Plan)

The state of Texas is divided into individual regions for water supply and planning purposes. Figure 8 describes the crux of our regional plan and you can see, for example, that by 2060, the Dell City Capitan Reef Groundwater will be used for West Texas water importation. The blue part of the bars represents our conjunctive use, which is our surface water and groundwater use combined. Conjunctive use will remain relatively constant, so we will need to enhance our supply in the future.

El Paso's current planning involves potable reuse/indirect potable reuse and expansion of the Jonathan W. Rogers Water Treatment Plant. One thing that we have seen with this drought is that we may have water, but only for a short period of time. At times, we may have more water than we have treatment capacity. If we have additional treatment capacity, we can treat the full capacity of what we have and inject what we can't put into the system. In our system, we also have a plan to treat agricultural drainage water. We produced a technical report with the Water Research Foundation on a study of agricultural impacts, and we need to work out the details with the districts and the downstream users. We also are updating our costs for water importation from our West Texas basins. We will also revise our hydrogeologic models on the Mesilla and the Hueco Bolson solute model.

Figure 9 gives you a bit of perspective on the importation aspect. El Paso County is located in blue on the left-hand corner with Hudspeth County next to it in green, a distance of about 90 miles. It is a very expensive project to tap these very minor aquifers–it is a $750 million importation project. This isn't something that we entertain lightly. We also take leak detection very seriously.

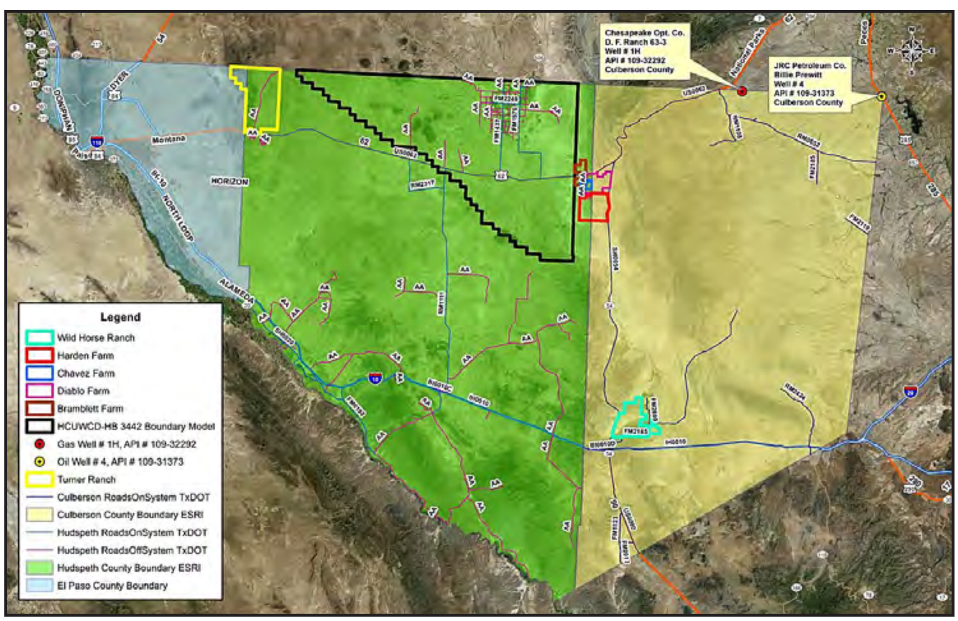


Figure 9. A map of the three westernmost counties in Texas showing Underground Water Conservation District Boundaries and the proximity of oil and gas production.

In 2013, peak demand in El Paso was 154 million gallons per day (Fig. 10). That number should actually be substantially higher. If you take into account the reclaimed water that we put in–another 6 million gallons–you come to 160 million gallons per day. The leaks we fixed in the last ten years also adds up to an additional 4 million gallons. That puts our total at 164 million gallons per day. If we actually had a 164 million gallon peak, we would have run out of water this year, so you can understand the importance of conservation and reclamation.

Thank you.

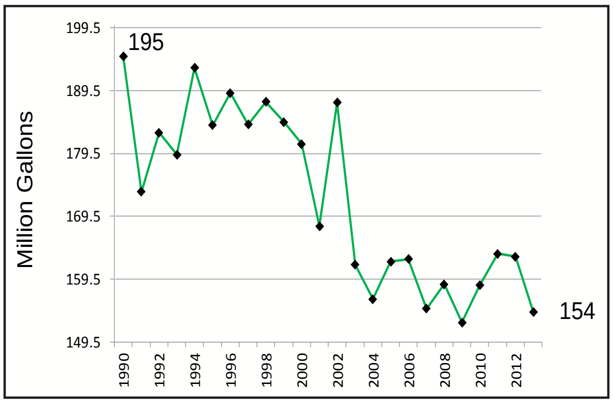


Figure 10. Peak water demand by calendar year

The Pecos Settlement—Manage Conjunctively, Or Else!

Greg Lewis
NM Interstate Stream Commission

Greg Lewis is the Pecos Basin Manager at the New Mexico Interstate Stream Commission. He oversees implementation of the 2003 Pecos Settlement, tracking of New Mexico's compliance with the 1948 Pecos Compact, and ISC's assistance with meeting the terms of the 2006 Biological Opinion for the Pecos bluntnose shiner. Greg has been working on New Mexico water issues for over 25 years. Prior to joining ISC, he worked at the New Mexico Environment Department and in private consulting. Greg holds an MS degree in hydrology from New Mexico Tech.

Editor's Note: The following paper represents a transcription of the speaker's remarks made at the conference. Remarks were edited for publication by the editor. The speaker did not review this version of his presentation and the editor is responsible for any errors.

Thank you for the introduction, and as Hilary Brinegar mentioned, I manage the Pecos River for the Interstate Stream Commission. The Pecos is a little river that demands a lot of attention given its size. It shares many problems of western rivers many times its size including: Interstate Compact disputes; listed aquatic species under the Endangered Species Act; senior surface rights that are being intercepted by upstream junior groundwater pumping; and the Pecos is extremely susceptible to changes in climate and drought. With these problems has come a lot of knowledge. The Pecos Basin played a major role in developing the tools for hydrologic analysis and, in fact, could be considered the birth place of a significant portion of modern hydrology with a great many hydrologists contributing substantial knowledge to the hydrogeology of the Pecos River.

Today I want to talk about issues affecting the Pecos and how the Pecos Settlement was designed to deal with those issues. If we look at historical compact noncompliance, this is where we started getting into trouble. The Pecos Compact was signed by the states in 1948 and was approved by President Harry Truman in 1949. You can see from the graph in Figure 1 that we got into trouble almost immediately. We had some good years in the late 1950s, but by the early 1960s, we headed below the blue line, which is our net zero deficit with deliveries to Texas. Down we went with roughly 10,000 acre-feet a year under-delivered to Texas. Part of that was because the Compact was based upon climatic conditions that did not hold true into the future. Another factor was increased groundwater pumping that was depleting the river resulting in reductions in the base-flow return between the Roswell and Artesia areas. The bright side is that we now have much better management of groundwater resources, mostly due to the administrative efforts of the Pecos Valley Artesian Conservancy District (PVACD). However, we did mess with Texas, and as you know, Texas does not like that. Texas sued us in 1974 and New Mexico lost. New Mexico was given a $14 million fine, and we must abide by the Court's 1988 Amended

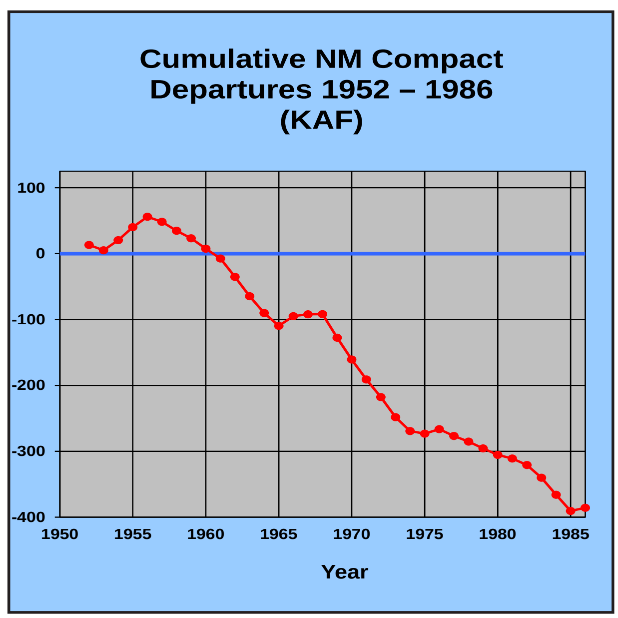


Figure 1. Historical Compact Noncompliance

Decree, which defines how the accounting will be done with the Federal River Master overseeing all deliveries to Texas.

It turns out that $14 million was a pretty good deal for all the water we got to use. Steve Reynolds, State Engineer at the time, was an advocate of saying that it was a good deal–and it probably was, but the $14 million payment was not what was most significant. This Supreme Court litigation forever changed the playing field of water accounting and management on the Pecos River. Fort Sumner Dam is located between Fort Sumner and Santa Rosa, and in general terms, about half of the flow that comes out of the Fort Sumner Dam is gaged just below Fort Sumner on the Pecos (Fig. 2). About half of that must go to Texas, and about half of the tributary flood inflows come in over that whole reach from Fort Sumner to the state line. It is more nuanced than that, of course, but in round numbers, that is what we must deliver to Texas. According to the amended decree, New Mexico cannot under-deliver to Texas again. We must make that delivery. If we miss our goal in a year, we must make that up by March of the next year in water to Texas. That is a pretty hard thing to do when we don't have water in the reservoirs as has been the case for the past couple years. New Mexico quickly figured out how we were going to do this in order to stay in compliance.

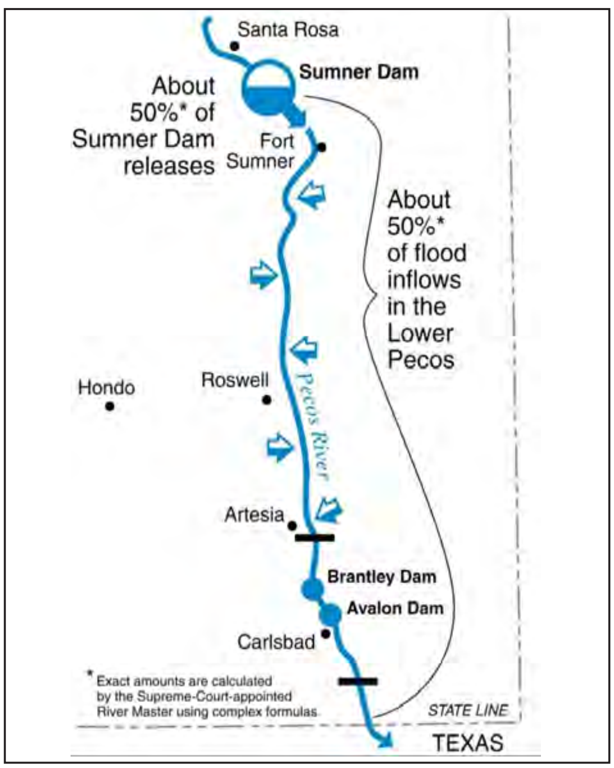


Figure 2. Pecos River Compact Compliance

During the 1990s, the New Mexico Legislature graciously appropriated in the neighborhood of $30 million to the Interstate Stream Commission (ISC) and State Engineer to acquire water rights. We delivered to Texas from that and stayed in compliance, but just barely. Figure 3 shows that we kept bumping along, but when we got to what we used to think of as a severe drought in the early 2000s, we were on the verge of going into a net deficit with Texas again. We brought the water interests together and worked very hard on what we could do to protect New Mexico's position and to protect water for New Mexico water users.

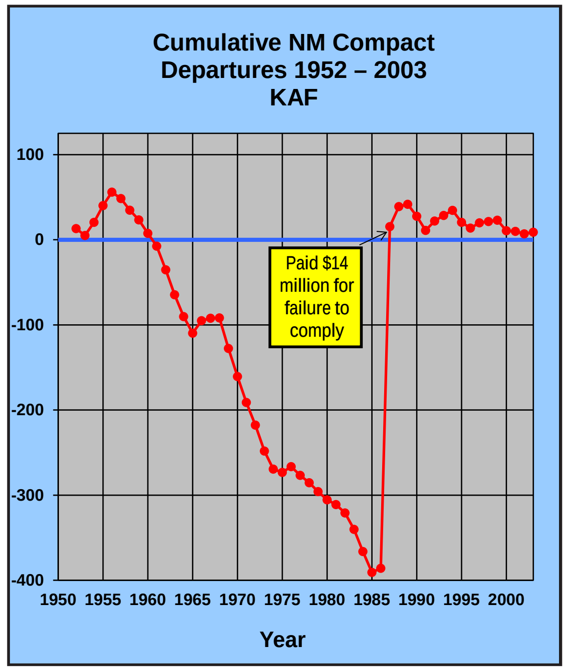


Figure 3. Compact Compliance Post-Decree

The ISC pulled the water interests and partners together and contracted with the best people that we could find to do hydrologic analyses and modeling of the system. The result was the 2003 Pecos Settlement. It was fortuitous that it happened when it did because of the state's financial position at the time. There was enough money to actually implement a plan and I don't know if that would have been the case if this had happened in the past few years. The money would not have been available to implement a plan like we did in the Pecos Settlement. The Settlement was signed by the parties of the Settlement in March of 2003: the State Engineer, the ISC, the U.S. Bureau of Reclamation, Carlsbad Irrigation District, and the

Pecos Valley Artesian Conservancy District. The parties of the ad hoc committee that was assembled to work on this was much broader and included water interests throughout the basin including industry, oil and gas, the Farm and Livestock Bureau, counties, municipalities, and so on. It was a very broad spectrum group, but only those who signed the Settlement have obligations tied to the Settlement.

The Settlement was finally implemented in 2009. It took six years for the ISC to gather water rights, drill wells, and connect wells with pipelines. The State Engineer worked on the Carlsbad Irrigation District adjudication and other things on which they were committed to in this Settlement. This was done with much hard work, and it wasn't cheap. To date, the State has contributed $100 million. There was also no guarantee that this would work. We did the best planning we could do and gave it our best shot.

The objectives of this Settlement include: permanent compliance with the Pecos River Compact and Decree; increased and stable water supply for the Carlsbad Irrigation District (CID wanted a bit more water as it felt that its senior water rights had been compromised from upstream groundwater pumping); reduced likelihood of a priority call affecting groundwater users in the Roswell Basin (thus giving upstream users more security and confidence in the use of their water); and to bring the basin back into hydrologic balance (we knew we were over-depleting the basin in order to meet the requirements of both getting enough water to CID and still delivering water to Texas).

As we move forward to achieve the Settlement objectives, we look at the key hydrologic elements. We retired irrigated land up to 6,000 acres within the CID, and 11,000 acres in the Roswell Basin. There was a Settlement minimum pumping capacity of 15,750 acre-feet/year to implement and we did so in 2009: 4,500 acres in CID and 7,500 acres within the Roswell Basin.

What are we going to do with those water rights? We will not use them when there is water in the river, but the wells in the Roswell Basin will be used to pump water into the river and the water will be delivered to CID and Texas when needed. We own 4,500 acres of water rights that we purchased in the CID, and we reallocate those rights to farmers or for state-line deliveries depending on climatic conditions, and the amount of credit that we have with the State of Texas. The Settlement also tells us when we are going to pump, what our minimum supply is, and what time of year we should turn our pumps on our well fields. As I mentioned, we have spent over $100 million at this point and it requires about $2 million a year to run the program.

How does this work? How can we take water out of the ground and pump it into the river? It would seem like doing this would dry up the river because the surface and groundwater are connected. The nice thing about Pecos River hydrology is its unique hydrologic conditions that let us get away with this. It allows for this effectively conjunctive management of groundwater and surface water resources. We have a productive artesian aquifer that comes out of the Sacramento and Guadalupe mountains, moves down, and discharges into the Pecos River. The pumping accelerates the rate at which that water arrives at the river when we use it on a temporal basis and dependent on demands. This is unlike the Rio Grande where if you pump from the alluvial and Bolson aquifers, you have an almost immediate effect on the river. On the Pecos River, you don't have the same type of impact.

As for our well fields, we have two. One is located near Lake Arthur with five wells and a design capacity of about 10,000 gallons per minute. Our major well field is near Seven Rivers and discharges directly into Lake Brantley. It has a design capacity of about 20,000 gallons per minute. The Lake Arthur well field was designed as a complementary well field because we cannot use it year round. We cannot pull water down from Lake Arthur to the Brantley Reservoir during summer irrigation season because the losses are too high–it isn't efficient during the summer, however, it works great during the winter.

How has this worked out since 2009? The year of 2009 was great: no pumping was required, but we still signed an agreement mid-year and agreed not to pump. The following year, 2010, was also a good year with no pumping required as there was flow in the river and it was about an average water year. Keep in mind that the flow on Pecos River is about 100,000 acre-feet a year on average, about an order of magnitude less than the Rio Grande, which is again about an order of magnitude less than the Colorado River. The first year that augmentation pumping was needed was in 2011. We had a new system, we had not used it for system compliance yet, and then we were hit with one of the driest years on record. By the time we got everything working, we were able to produce about 13,000 acre-feet that first year. We also pumped all year in 2012–about 19,000 acre-feet between the two well fields. In 2013 we pumped a bit over 12,000 acre-feet, but were able to stop pumping on September 13 due to the remarkable storms we received.

How much are we pumping relative to what is in the basin? Figure 4 shows total Roswell Basin pumping for water year 2011, which is November 1 through October 31, and the numbers for water year 2012. Of the total water pumped, about 3 percent in 2011 and about 5 percent in 2012 was Settlement pumping. We only do a small portion of the pumping in the area, but since we pump in localized areas, there are local impacts to the water table, and we hear about that.

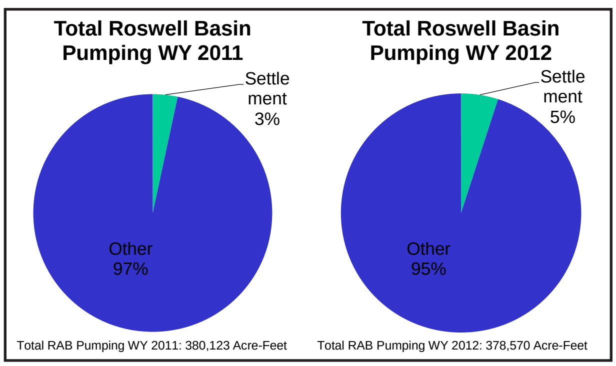


Figure 4. Settlement Pumping Proportion in Roswell Basin

We have heard a lot about the current drought, but it was remarkable to me how quickly things turned around. The years 2011-2012 were the hottest and driest 24-month period in 117 years of record. Looking at Santa Rosa Lake Gage, we saw 174 days in 2011 and 286 days in 2012 with record low daily flows. There were over 160 days of low flow in the first six months of 2013. There was zero flow at Near Artesia Gage for 24 days and the first zero daily flow since 1964.

The graph in Figure 5 shows Pecos River flow above the Santa Rosa Reservoir gage in percentiles. Yellow represents the fifth percentile and you can see that in 2011, we got below that percentile, and after some periods of rain, we have a lot of flows below that percentile. You can see when the rain came in during September, but look how quickly it goes back down again into record low territory. The system has been really stressed.

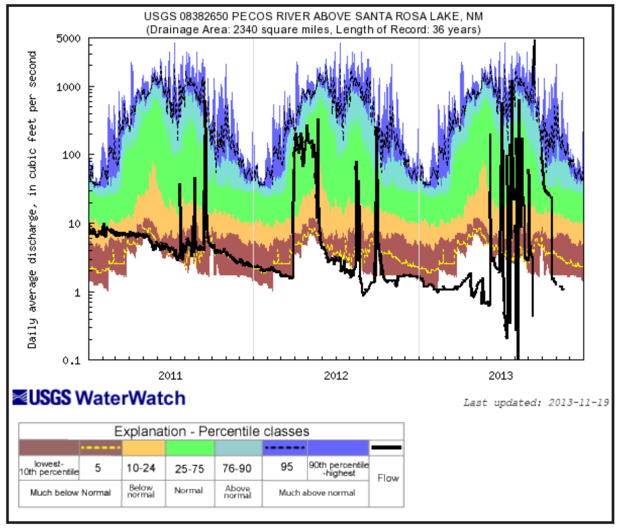


Figure 5. Pecos River Above Santa Rosa Reservoir

Figure 6 shows what has happened to base inflows. This is from above Artesia. We were in the 70,000 to 80,000 a year range until around 1945. You can see the drop that coincided to our under-deliveries to Texas. The line flattens out and then basically follows the climatic conditions. You can see a tailing off in this most recent drought and when we got to about 12,000 acre-feet of base inflow. It is painful and it is making it very difficult for CID to figure out how much water to put out. The take away message from that is that augmentation cannot make up for lack of surface flows. When we have years with basically no water in the river, we just can't make our required deliveries. The drought is beyond what was evaluated in the Settlement design. The Settlement targets water supplies not achievable from March 2011 to September 2013. Of course, CID is not happy about this either. It still had to do a priority call based on what was in the Settlement, and we are trying to do the best with what we have available. This might suggest that we need to make some changes to the Settlement to account for extreme climatic conditions.

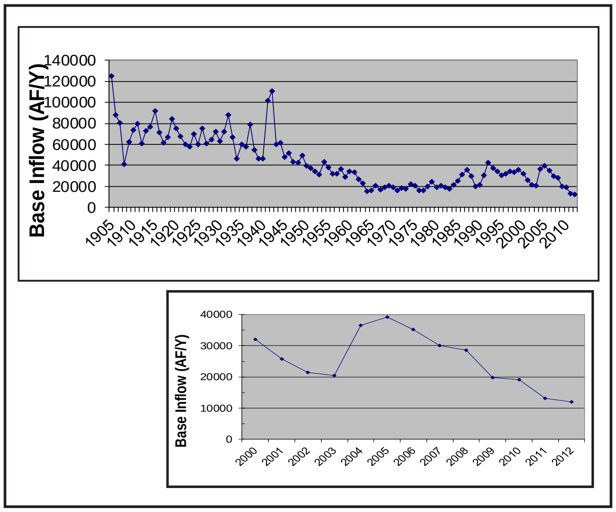


Figure 6. Base Inflows — Acme to Artesia

Anyway, this brings us to the bright side of the discussion. How are we doing on our Compact compliance? New Mexico has accrued significant cumulative credit since the Settlement signing. Remember that we started in 2003, acquired water rights soon after, and we almost immediately had credits (Fig. 7). Some of that was due to favorable climatic conditions, but some was also due to acquiring rights within CID, and which went to Texas. In 2012, we ended with a total credit of 102,000 acre-feet.

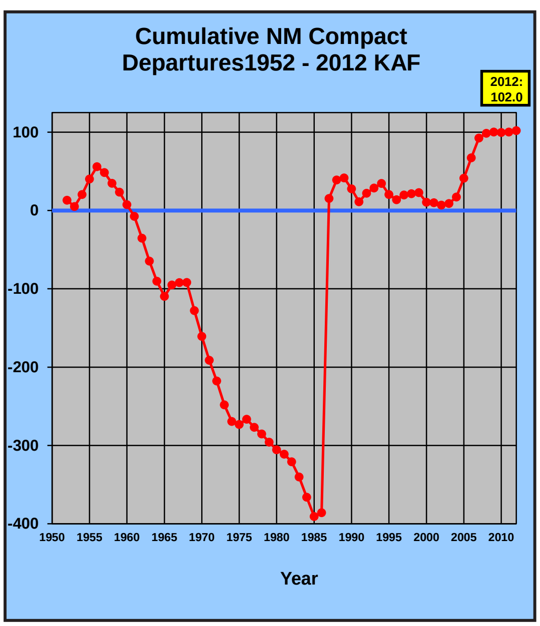


Figure 7. Compact Compliance Post-Settlement

That brings us to the use and deficits for this year. It looks like we will only have between 5,000 to 10,000 acre-feet of deficit this year, so we will still have a healthy credit with Texas. I don't have an exact number because the USGS is still rebuilding hydrographs after having to replace many of the gages from that extraordinary storm event the week of September 8th. The storms brought much needed moisture to the Pecos Basin in particular. Pecos reservoirs went from essentially empty to conservation storage limits in less than a week. ISC stopped augmentation pumping on September 13, 2013. This credit allows New Mexico a lot of flexibility. It is very important to have that credit so that we can use the water that we have in New Mexico, especially in dry years.

Figure 8 shows what a blessing the September storms were to the Pecos. This is Rocky Arroyo on September 12, peaking at 25,000 cfs. In a small drainage like that, it was truly remarkable. Reservoirs went from empty to conservation storage levels in less than a week. Santa Rosa gained 90,000 acre-feet in two weeks, which raised it 44 feet. Fort Sumner had 34,000 acre-feet in two weeks, which raised it about 26 feet. Lake Brantley also got 34,000 acre-feet, which raised it up 22 feet. This allows CID to start with full reservoirs in 2014, and that is the first time that has happened since 2010.

Figure 8. Rocky Arroyo on September 12, 2013

Figure 9 shows our well fields at South Seven Rivers; those of you who know the area and the streams know it isn't very impressive. Before June 2013, we were thrilled with the rains and even had enough rain to leave a little puddle. We were elated about that. The photo on the top is the same location, but after the September storms. You can see the same road and features from the picture on the bottom. The gravel bank came down the river from the South Seven Rivers arroyo. It doesn't look that impressive from this view, but it is 20 feet high. The amount of sediment that moved is simply astounding.

Figure 9. Storm Effects on the South Seven Rivers; before June 2013 (top) and after October 2013 (bottom)

Is the Settlement working as a conjunctive management tool? I think the overall opinion is yes. We have a large Pecos Compact credit, which gives us a lot of operational flexibility. We have been able to supply a significant additional amount of supply to CID. It isn't as much as they would like, and not as much as we would like to provide them, but this extraordinary drought was beyond what anyone had contemplated when designing the Settlement and some of the estimates weren't near realistic in years as dry as 2010 to 2013. Perhaps we need to make changes in the Settlement for adapting to extreme conditions. This goes back to some of my earlier thoughts. How do we accommodate senior water users in years when the water just isn't there? However, the September rains were amazing, and we turned our well fields off on September 13, which allowed us to take care of some maintenance and do some other work.

Thank you for your attention.

River Restoration Activities in the Rio Grande Canalization Flood Control Project in the Lower Rio Grande, NM

Elizabeth Verdecchia
International Boundary and Water Commission, U.S. Section

Elizabeth Verdecchia is currently a natural resources specialist in the Environmental Management Division at the International Boundary and Water Commission, U.S. Section (USIBWC), in El Paso, Texas. During her tenure at USIBWC, she has also managed water quality reports and data for the international boundary before serving as the Program Manager of the USIBWC Texas Clean Rivers Program for the Rio Grande Basin for four years. She received a bachelor's degree in geology and environmental science and engineering from Rice University in 2000, and obtained a master's in applied geography from New Mexico State University in 2008. Elizabeth worked in several National Parks in resource management and cartography, including George Washington Memorial Parkway, the Everglades (through the U.S. Geological Survey's Biological Resources Division), and Mammoth Cave National Park (through the Student Conservation Association and the Geological Society of America). She also served four years in Paraguay, South America, as a Peace Corps Volunteer in the fields of environmental education and information technology.

Thank you Hillary. This is baby Maya, and she is going to prevent me from getting to the podium so I will just stand to the side. I am going to talk about a really exciting project that the International Boundary and Water Commission (IBWC) agency is undertaking. This project, like the Minute 319 project that Tanya Trujillo talked about yesterday, is one of the most exciting projects that the agency has done in a long time.

The Rio Grande Canalization Flood Control Project was authorized in 1935 by Congress and was constructed in the 1940s. It runs 105 miles from Percha Dam just below Elephant Butte and Caballo all the way down to American Dam in El Paso. It consists of a rectified river channel with a levied floodway. The purpose of the Project was to facilitate deliveries in the U.S. and Mexico under the 1906 Convention as well as to maintain flood capacity (Fig. 1).

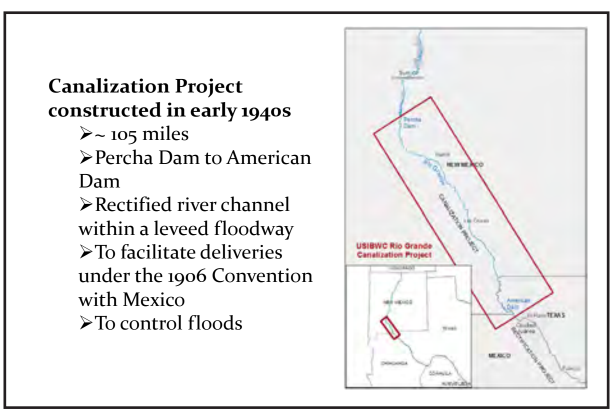


Figure 1. Rio Grande Canalization Flood Control Project

In Figure 2, the top left picture was taken in 1938 at the Las Cruces/Picacho area looking upstream, before the levees were constructed and before the channel was stabilized. The top right was taken in October of 1942 at the same location after the levees were constructed along the side, but bank stabilization had still not occurred. The bottom picture is basically what it looks like today even though the photo was taken in 1956. There are levees on both sides and the channel is stabilized throughout. The agency has basically maintained it this way since the 1950s. We mow the floodway and dredge the channel to maintain its full flood capacity and to make sure that the project is meeting its intended purposes.

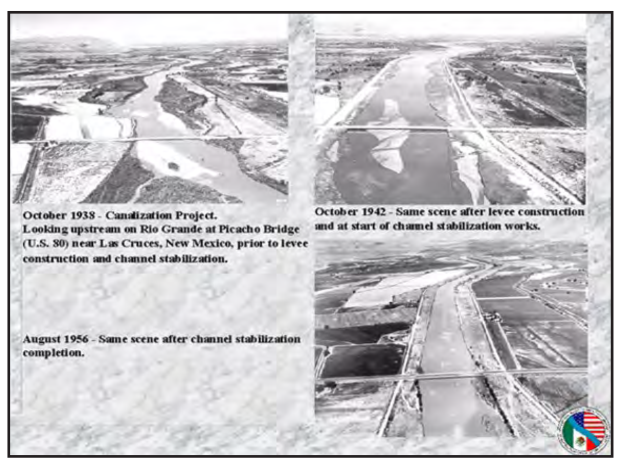


Figure 2. Las Cruces/Picacho area before and after levees were constructed and the channel was stabilized

In the 1990s, environmentalists' voices became a little louder with concerns that this was not the most ecological way of managing the river. So the agency embarked on an environmental impact statement process, and it took about ten years for that project to be negotiated. The IBWC signed a Record of Decision, and my job is to implement this decision. In 2009, Commissioner Ruth decided that we would go with the Integrated Land Management Alternative. An important part of this plan is that it maintains much of our operations and maintenance procedures that we need to ensure that the project goals are met, such as water delivery, flood control, and channel maintenance. It allows us to increase the capacity of the levees. It also called for the implementation of several environmental restoration measures (Fig. 3).

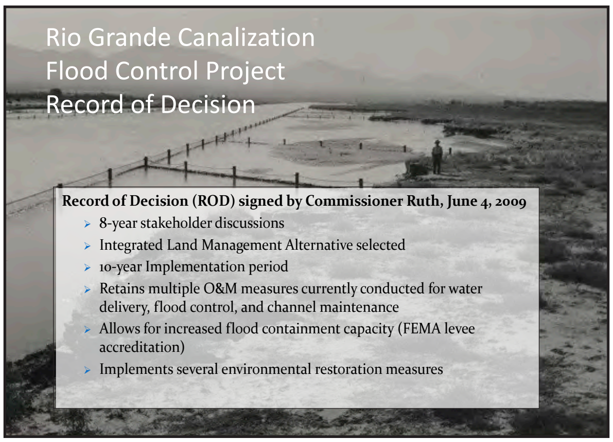


Figure 3. Rio Grande Canalization Flood Control Project: Record of Decision

For example, we are eliminating grazing leases. One method of maintaining the floodway is mowing and another is to issue grazing leases to private land owners for cattle grazing. As leases come up for renewal, they are being discontinued. We also have thirty restoration sites totally 550 acres that we are implementing, targeting a dozen different types of riparian habitat including riparian woodland, savannah, grassland, and more. We also want to make sure that we are meeting our requirements for the Endangered Species Act. The little guy pictured on Figure 4 is the endangered southwestern willow flycatcher. We are also changing floodway management. Now there are about 2,000 acres designated as no-mow zones; they are going to be managed grasslands where we will treat exotic species in that area. We are also establishing an Environmental Water Rights Program. If we are restoring sites along the river where we previously mowed and see that no vegetation is growing, we now plant vegetation, and that means we are using water that belongs to somebody. We are dealing with a fully allocated system, and we manage every drop in the river. That was our argument before the Record of Decision was signed. Where was the water going to come from for these trees? Because of this, we will be purchasing some water rights. We are also evaluating channel maintenance and looking at alternatives to dredging and for maintenance.

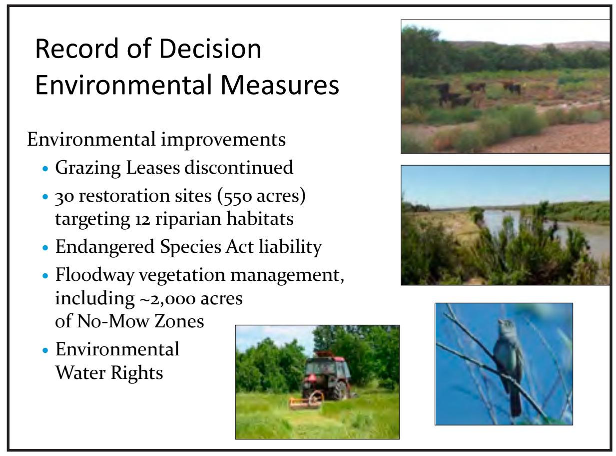


Figure 4. Record of Decision Environmental Measures

A lot of planning was involved before we could break ground at any of these restoration sites. We have soil surveys, a conceptual restoration plan, surveys for endangered species such as the southwestern willow flycatcher and the yellow-billed cuckoo, cultural resources and Section 106 compliance, site implementation plans, and hydrological monitoring. All of these studies had to be completed before we could break ground on the restoration sites (Fig. 5).

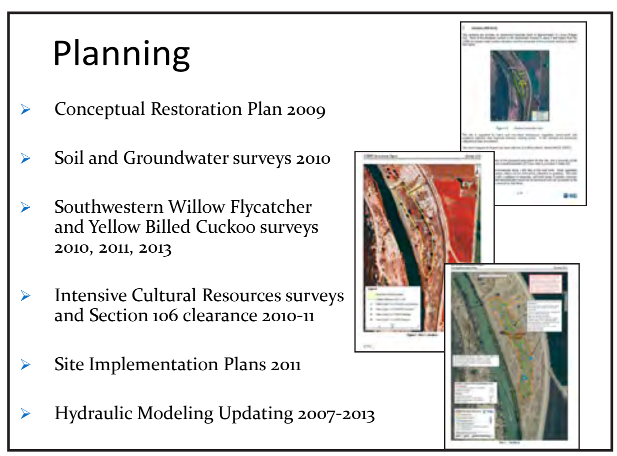


Figure 5. Rio Grande Canalization Flood Control Project Planning

In addition, we have substantial contact with the stakeholders who were involved in the original negotiation process for this Record of Decision. We have regular meetings to make sure that stakeholder input is heard. Some of the key stakeholders are the irrigation districts, which is mainly the Elephant Butte Irrigation District, and local elected officials such as Senator Udall, Senator Heinrich, and former Senator Bingaman. We also meet with environmental groups such as the Audubon Society of New Mexico, the Southwest Environmental Center, and the Paso Del Norte Environmental Council. The Bureau of Reclamation and various divisions within our agency also participate on a regular basis.

In order to meet requirements under the Endangered Species Act, from 2011 to 2012 we conducted Section 7 Consultation for the southwestern willow flycatchers. That process normally does not take long, but we involved the stakeholders to make sure that their concerns were met. We have a water rights system to use water for these restoration sites. What happens in drought years when there is a shortage, will the flycatcher trump the farmers' rights to use the water? We wanted to make sure that we are sharing shortages in times of drought so that the farmers' water isn't confiscated for endangered species. That was something that had to be negotiated. We also requested that critical habitat be excluded. We now have a Biological Opinion that requires us to maintain a minimum acreage of flycatcher habitat. We are required to conduct annual flycatcher surveys. The Bureau of Reclamation did surveys last year, and we are collaborating with them. It is great to note that territories are increasing and we have met the Recovery Goal for two years.

Another part of this Record of Decision was to update our river management plan. We are outlining all the procedures for managing vegetation along the flood banks, what type of channel maintenance we are doing, how we are protecting the flycatcher, how we are implementing these restoration sites, what areas we aren't mowing, and so on.

We have also installed shallow water monitoring wells. We had 53 wells constructed at 20 sites in 2013, all of them along the floodway. These are providing valuable data, particularly before and after irrigation season and for looking at the effects of the drought. The data are already revealing that we need to plant our trees at greater depths to make sure they have water during drought years.

We also have many properties along the river we are trying to acquire for potential restoration sites. Figure 6 shows one that we acquired in 2011, and we are looking at others. A couple of these already have flycatcher habitat established on the sites.

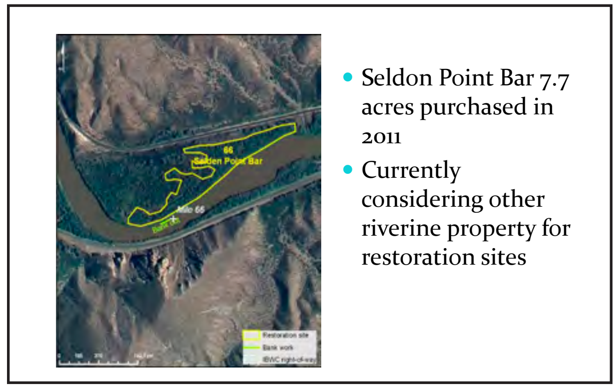


Figure 6. Property Acquisition along the Rio Grande

Here is the fun part: implementing restoration sites (Fig. 7). The picture in the background is one of our sites in the Las Cruces area, with native trees that we planted. We have an Interagency Agreement with the U.S. Fish and Wildlife Service (USFWS) because the IBWC does not have the staff or expertise to implement this program on its own. The USFWS has helped implement the first five sites. Over the last two-and-a-half years, we have treated over 300 acres of salt cedar and we have planted nearly 3,300 trees. Although that is a significant number of trees, it isn't nearly enough to meet our restoration goals. We have four additional sites that we are implementing with the USFWS and the goal is to plant over 20,000 trees in the next three years across four new sites as well as those first five. All sites have signs indicating that these are designated habitats under construction.

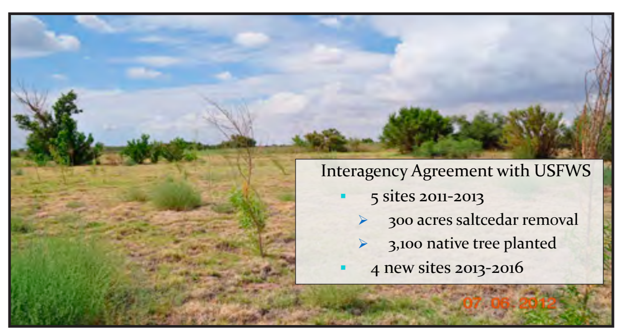


Figure 7. Implementation of restoration sites

Figure 8 shows the Crow Canyon site in the Hatch area. The top photo shows some native willows lining the bank and in the background are a lot of large mature salt cedar blooming. This was an area that was mowed. One of the first things we did was to stop mowing on the restoration sites, which is allowing some native vegetation to come back. The bottom picture shows salt cedar that was treated along the bank as well as large patches throughout the flood plain. Around 200 acres of salt cedar was treated. At this site in Hatch, we planted 187 black willows and about 40 cottonwoods.

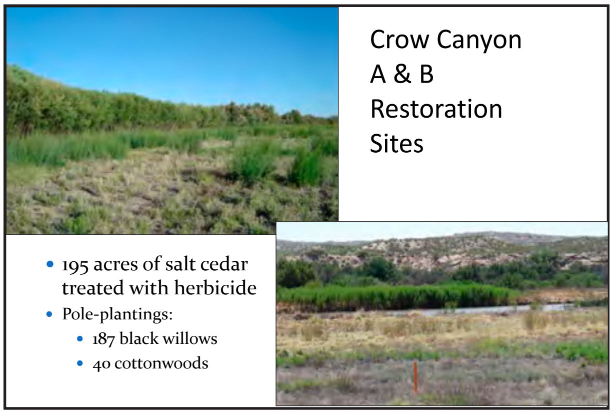


Figure 8. Crow Canyon site in the Hatch area

What is interesting about stopping the mowing was that at the Crow Canyon site it allowed native vegetation to come up on its own, like the willows in. Figure 9. We did not plant them; they just came up after we stopped mowing. On the right is a picture of a cottonwood we planted in 2012. It is blooming here, but now you can't even see it through all of the native willows surrounding it from the bank. It is a very nice restoration site. The bottom photo is a picture of the salt cedar that was treated. It is cut with a type of machinery and then sprayed. Overall, the saltcedar is not coming back.

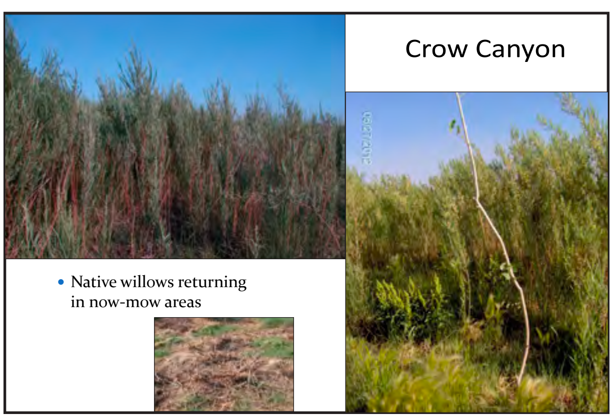


Figure 9. Crow Canyon site when mowing has stopped

Figure 10 is one of my favorite pictures, which provides an overview. You can see the river bank and the floodway. You can see many of the native grasses coming in and we have several layers of willows from different years. We do have some patches of exotic weeds, but it appears that they are being out-competed by the native grasses–a really nice grassland mosaic of the different habitats here.

Figure 10. Crow Canyon B August 2013

Figure 11 shows the same site but a bit closer to the river. We do have low spots with wetland areas. You can see some native brush and three layers of willows along the bank with the treated salt cedar.

Figure 11. Crow Canyon B, August 2013

Figure 12 is a picture of our Broad Canyon Arroyo site. The top left photo shows the area near Broad Canyon Arroyo around 1940; there wasn't much of anything around the area. Site conditions have changed since: a sediment dam has been constructed on Broad Canyon Arroyo. In 2011 you can see a dense monotypic salt cedar stand. Twenty acres of salt cedar were removed by an excavator in 2012 (Fig. 13). A patch was left where the yellow-billed cuckoo had been observed.

Figure 12. Broad Canyon Arroyo site

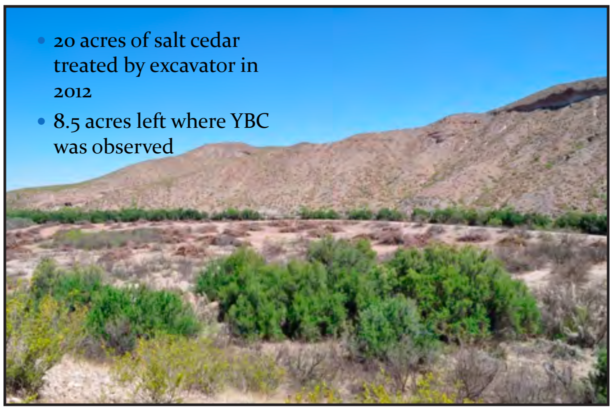


Figure 13. Broad Canyon Arroyo Site with twenty acres salt cedar removed

Figure 14 shows piles of salt cedar debris that were allowed to dry, and then the USFWS conducted controlled burns. When the piles burned down they look something like the photo on the right. Piles were allowed to cool, and then we planted willow poles.

Figure 14. USFWS controlled burns at Broad Canyon Arroyo Site

Figure 15 shows the lower terraces that are targeted for flycatcher habitat, which consists of dense shrubs planted very close together using a deep auger. This one is actually eight feet long. Willow poles are harvested from mature willow stands and put into water for a couple of weeks. Then they are planted in eight-foot auger holes where, technically, their toes are in water year-round, grow roots, and then hopefully they take off and sprout. Figure 16 shows trees that are coming up along with native vegetation. Wolfberry and native grasses are in the foreground. At this site, we planted nearly 1,400 willow trees and 105 cottonwoods.

Figure 15. Lower terraces at the Broad Canyon Arroyo site ready for habitat restoration

Leasburg Extension Lateral site near Las Cruces is show in Figure 16. You can see cottonwoods and some of the native poles that we planted. Native vegetation is coming up because we aren't mowing. At this 30-acre site, salt cedar was treated on twenty-six acres. We planted 400 black willows, 99 cottonwoods, and 420 coyote willows.

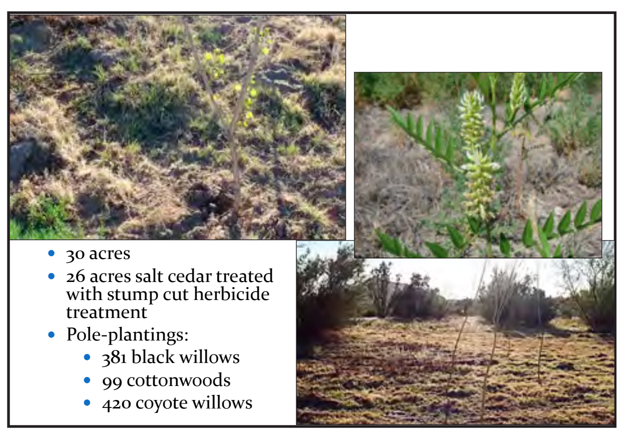


Figure 16. Leasburg Extension Lateral

The Mesilla East site is very close to Leasburg site (Fig 17). The top left photo can be considered a "before" picture and you can see the treated salt cedar piles. On the top right is a recent picture. Look at all of the willows that are coming up on their own from the riparian zones.

Figure 17. The Mesilla East site

Lastly, I wanted to talk about what is probably the most interesting to you, our Environmental Water Rights Transaction Program. The program was established to obtain water rights for three different purposes: to offset depletions caused by increased vegetation; for supplemental irrigation as some sites will not have growth under current conditions if left unirrigated; and for conceptual environmental peak flow, which doesn't look likely in the drought, so we might purchase water rights to simulate over-bank flow conditions.

The Environmental Water Rights Transaction Program is a public-private partnership that is a very unique and interesting program. We have an interagency agreement with the USFWS, and they have in turn contracted with the National Fish and Wildlife Foundation, which does a lot of work with water rights in the western states. They are contracted with the New Mexico Audubon Society, which has been instrumental in getting this program off the ground especially considering all of the rules and procedures that go along with water rights acquisition. I would also like to thank the Elephant Butte Irrigation District, which has been working with us collaboratively. We have a very good working relationship with EBID as well as with the Bureau of Reclamation.

Our plan is to acquire a minimum of 457 acres of water rights that will cover all of our depletions. Then we might buy or lease more rights if we want to supplement irrigation. We want to buy these rights from willing sellers and we are currently pursuing this. We also intend to pay a fair market value, so we are trying to establish a value for these water rights, focusing primarily on surface water.

Our future plans include finalizing our river management plan; incorporating all of the stakeholders' concerns; and quickly moving on purchasing water rights because we have five years left of our ten-year restoration process. Then lastly, we want to prioritize our next restoration sites.

Please look at our website at http://www.ibwc.gov/EMD/canalization_eis.html for documents and more information and feel free to contact me at 915-832-4701 or elizabeth.verdecchia@ibwc.gov.

Thank you.

Water Data on the Web

David Maidment
University of Texas at Austin

David R. Maidment is the Hussein M. Alharthy Centennial Chair in civil engineering at the University of Texas at Austin where he has been on the faculty since 1981. He received a BS in agricultural engineering with First Class Honors from the University of Canterbury, Christchurch, New Zealand, and MS and PhD degrees in civil engineering from the University of Illinois at Urbana-Champaign.

David is a specialist in surface water hydrology, and in particular in the application of geographic information systems to hydrology. In 2012, he received the Ray K. Linsley Award from the American Institute of Hydrology in recognition of his contributions in the field of surface water hydrology. In 2011 he received the Ven Te Chow Award from the American Society of Civil Engineers for notable contributions in water resources engineering, hydrology and hydraulic engineering, outstanding service to the profession through application of GIS in surface water and groundwater hydrology, authoring books and research papers in water resources engineering, and mentoring of young engineers. In 2011 he received the Distinguished Alumnus Award, Civil and Environmental Engineering Alumni Association, University of Illinois at Urbana-Champaign, "for significant and lasting impact on teaching, research and practice in the fields of hydrology and water resource engineering, including the pioneering of geographical information systems applications in hydrology and technologies that have been adopted by national and international institutions." In 2010 he received the AWRA Award for Water Resources Data and Information Systems, in recognition of his outstanding contributions to the application of Geographic Information Systems to water resources engineering and sciences. This award was also permanently renamed the David R. Maidment Award for Water Resources Data and Information Systems, in honor of his many contributions to the field and his furtherance of the mission of the American Water Resources Association.

I am very happy to be here and to learn more about what is happening in New Mexico. I have been in Texas for nearly thirty years, so I have looked upon you from a distance. Today I would like to begin by talking about the "cloud." I hear a lot about cloud computing and I obtained some slides from a colleague, Kristen Tolle, who is from Microsoft Research. She told me that she is permitted to say that Microsoft has more than ten but less than a hundred of the facilities that I am going to discuss.

When Microsoft started on this, which was about eight years ago, they began with moving computers to buildings and putting the computers in racks and then moving racks into buildings. After a while they asked, who needs buildings? We'll just put weather proofing around the racks and we'll move those instead. Figure 1 shows a rack that is actually on the back of a truck in Austin at the Dell facility, and it is being trucked across the country to Longmont, Colorado. When it gets to Longmont, a crane lifts it off the back of the truck and that is the cloud (Fig. 2). It looks like an RV park in Longmont, Colorado (Fig. 3). If you want to know where your iCloud is, it is in places like this. The interesting thing that has happened is that now the cost of moving information has gotten so low that the aggregation of information in facilities like this has become cost effective. Thus if you have a computer that works less than 40 percent of the time, it is cheaper to use one of these than to have your own computer.

Figure 1. Shipping a Rack

Figure 2. Modular Cloud Construction

Figure 3. Completed Cloud Computing Facility in Longmont, Colorado

So what does that mean for water? We collect lots of data on water such as measurements on rivers, rainfall, soil water, water quality, meteorology, and so on. Those are time series measurements at point locations. For a number of years, I was the leader of the Hydrologic Information System project of CUAHSI, which stands for the Consortium of Universities for the Advancement of Hydrologic Science, Inc. It is supported by the National Science Foundation for the advancement of hydrologic science in the U.S. We invented the WaterML language for transmitting hydrologic data through the internet. The U.S. Geological Survey (USGS) adopted it a few years ago and now they put out all of the information for their time series using WaterML. You can get information in this rather odd looking language that you see in Figure 4 from the USGS webpage (usgs.gov) or by going to waterservices.usgs.gov, which now means machines talking to machines. The USGS did this because they found out that 60 percent of the requests for information were coming from computers. Computers were being programmed to just get past the webpage. Now web **pages** deliver text and images and web **services** deliver data encoded in XML (Fig. 5).

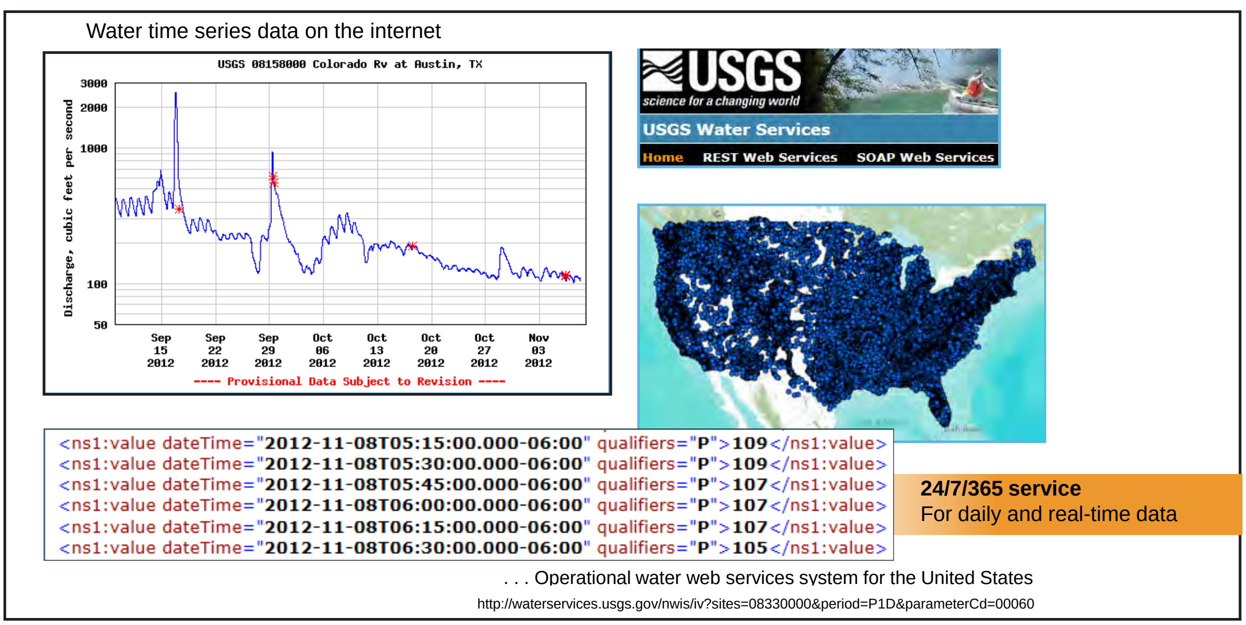


Figure 4. WaterML - the U.S. Geological Survey

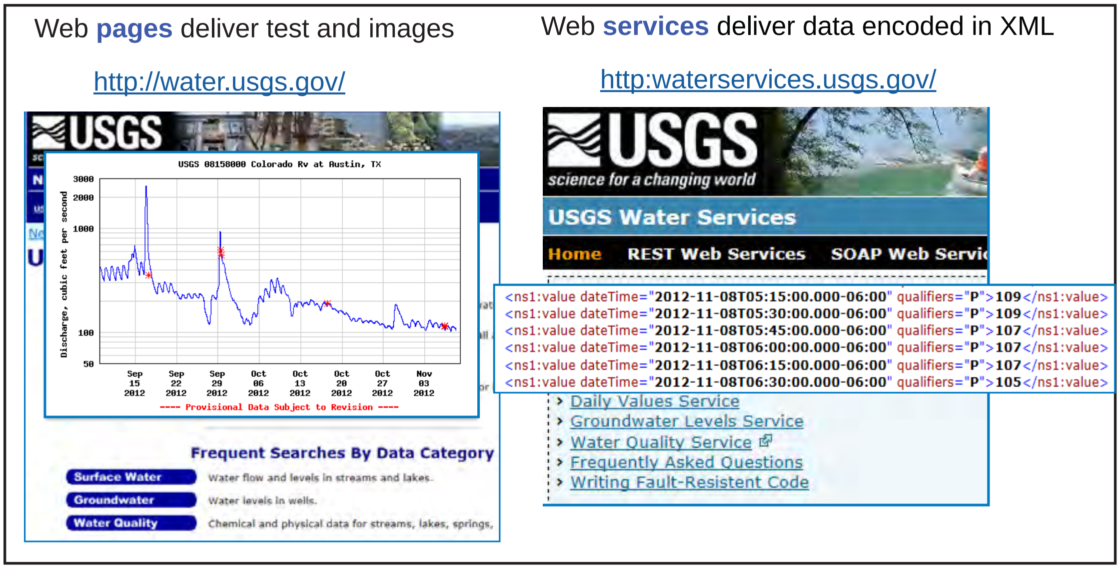


Figure 5. Web Pages and Web Services

By going to an archive and having direct machine access to that archive, you can have information downloaded in XML. I then asked myself, how do we institutionalize this so it can be applied across the world and not simply in the United States? An organization, the Open Geospatial Consortium, with over 400 companies and agencies, provides internet data standards for maps and observational data. In 2008, I proposed that there be an agreement between the Open Geospatial Consortium and the World Meteorological Organization to build an international system that would do this (Fig 6). This was legally concluded in 2009 and plenty of work has gone on since that time, like international experiments and so on. In 2012, a new international language was adopted as an OGC standard, WaterML2, which is now the first public standard for the exchange of water information across the Earth.

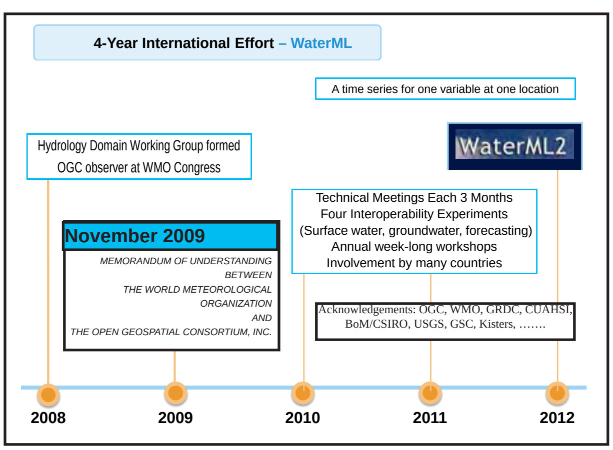


Figure 6. OGC/WMO Hydrology Domain Working Group

We have started setting up global observation systems and Figure 7 shows our network of streamflow observations. The yellow dots are locations where streamflow was recorded and housed at a global center, the blue dots are USGS data, and the green dots are from CNR in Mexico. Some others are located in other countries as well–quite a few in Italy. Just for fun, I got today's data at 8:00 a.m. for the Rio Grande at Albuquerque from the worldwide web services put out by the USGS (Fig. 8). I also checked on the Manawatu River at Teachers College, New Zealand (Fig. 9). Manawatu River at Teachers College has the longest flow record in New Zealand. I am originally from New Zealand. What you see at the bottom is the new international standard. So water data is being obtained simultaneously from far away New Zealand.

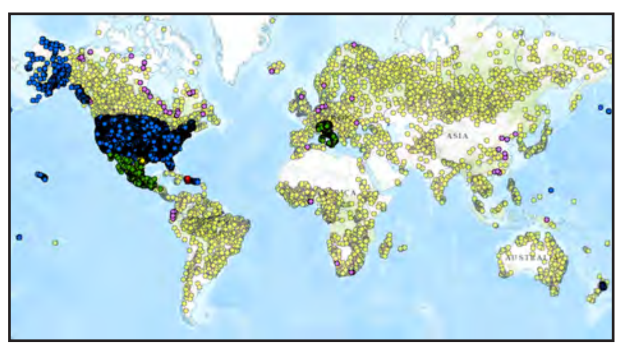


Figure 7. Global Streamflow Observations

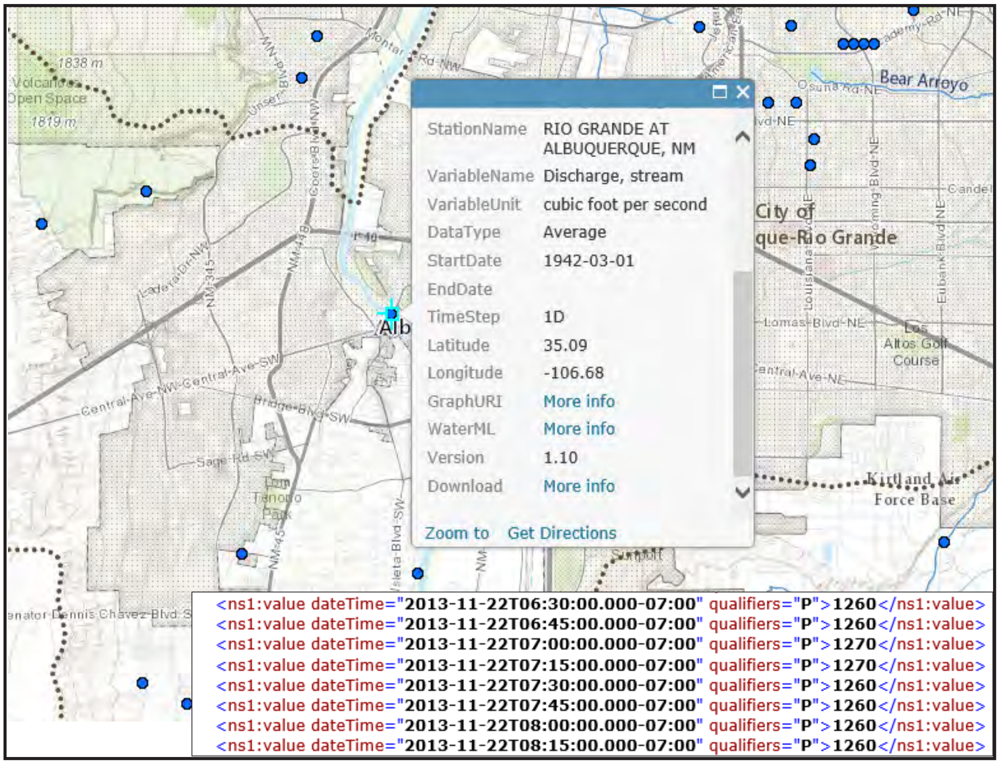


Figure 8. Rio Grande River at Albuquerque, NM

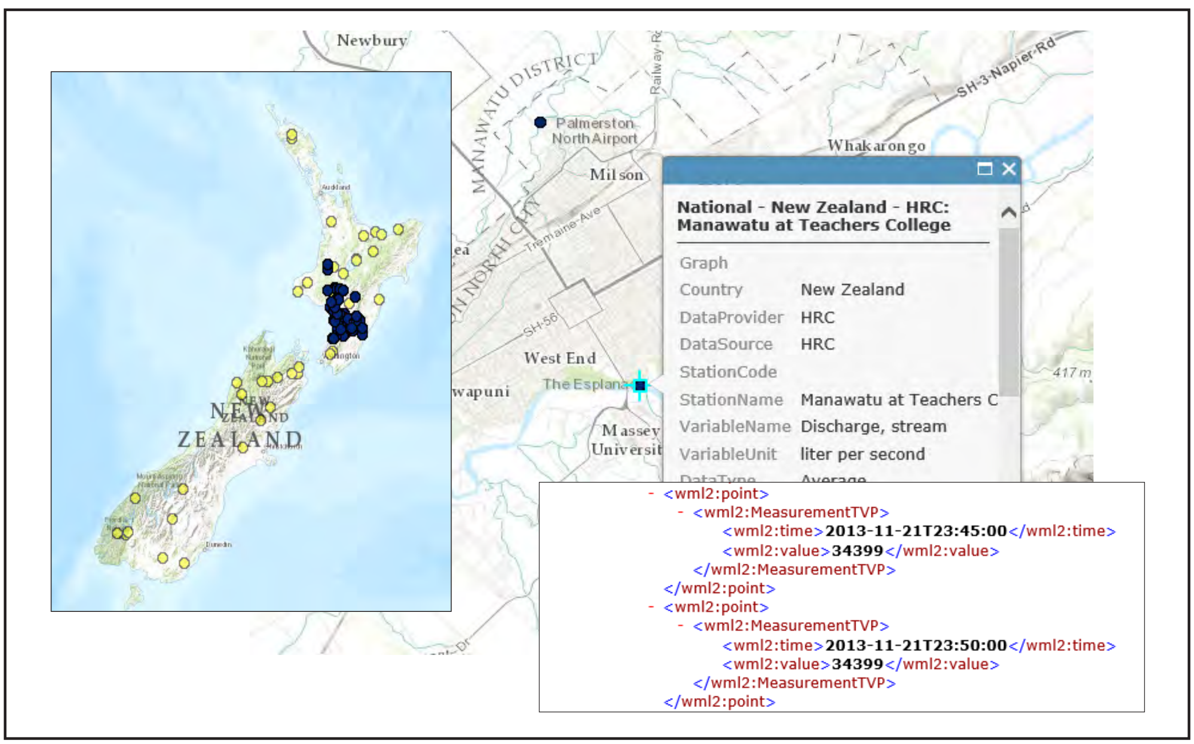


Figure 9. Manawatu River at Teachers College (New Zealand)

We now have a common language for water observations. What about water modeling? Figure 10 shows something that we are doing in the San Antonio and Guadalupe basins and with a little animation we can view the flow in the basin with calculations for every stream reach on a three-hour time scale. We are doing this in many other areas in city basins and other projects. The idea is that we have USGS coverage of the streams, and we can also have modeling of flow on every reach of the streams, not simply where the flow is being observed. If we can do that, we can start to optimize the operations of the water diversions on those streams.

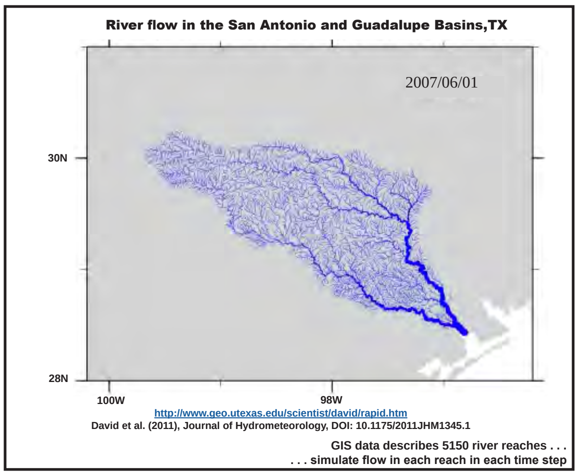


Figure 10. Flow in the San Antonio and Guadalupe Basins (RAPID model, June-September 2007, 3 hour time steps)

Figure 11 shows a project that we are cooperating on the Texas Commission of Environmental Quality Watermaster Program. The green dots are services that we are getting and are derived from USGS flow data; the triangles are water diversions in these basins, around 400 of them, some of which don't actually make diversions; and the purple dots are forecasts of flow that are being put out by the National Weather Service. The USGS does things in the present and the past while the National Weather Service does things in the future. We need to get information from the past, present, and future and aggregate all of this information into one place, which we have done in Austin. In Austin, we have a big data hub that is used as the base for this operation, and we can pinpoint the flow at any one of the 550 reaches within this basin. Thus the model becomes a service, the observations become a service, the diversions become a service, and we have an operating system that allows us to manage carefully the water in this basin.

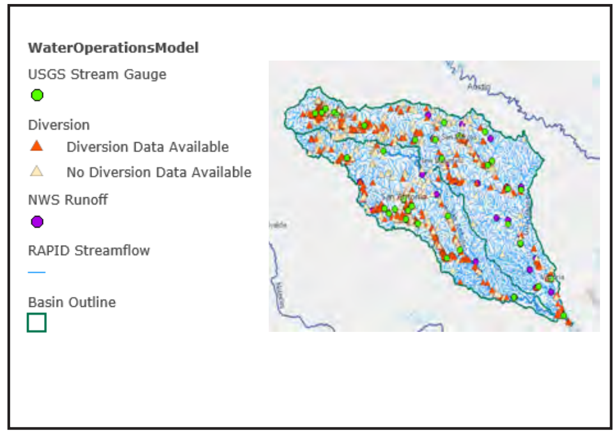


Figure 11. San Antonio — Guadalupe Water Operations Model

Another thing that is important when you start thinking about global water is that water is just kind of sloshing around the world. Figure 12 shows measurement of the water content of the Earth as measured by GRACE (Gravity Recovery and Climate Experiment). Two satellites fly about 500 km above the Earth and the distance between them is around 220 km. The color that you see in the figure represent the depth of water measured in centimeters. It turns out that water is heavy enough that its movement can be measured by satellites. This is sort of an eye in the sky measuring how much water there is. We can measure the water storage within our state of Texas. Figure 13 provides our current water situation, and you can see on the graph the average depth for the last ten years. From the 2011 drought through earlier this year, our water storage is about a hundred cubic kilometers down. That is equivalent to about 70 Lake Travises for those of you who are familiar with Lake Travis near Austin. What this says is that our state is very low on water, and since our state is next to New Mexico, I would imagine that New Mexico is low as well. This is one of the reasons that the flow in the Pecos River is so low—the whole water system is very low right now, and we can measure that from space. One of the things I am often asked is if this correlates to drought measure, and yes, it absolutely does. The top graph in Figure 13 is the U.S. drought monitor intensity measure, and you can see that the water usually drops as the drought increases.

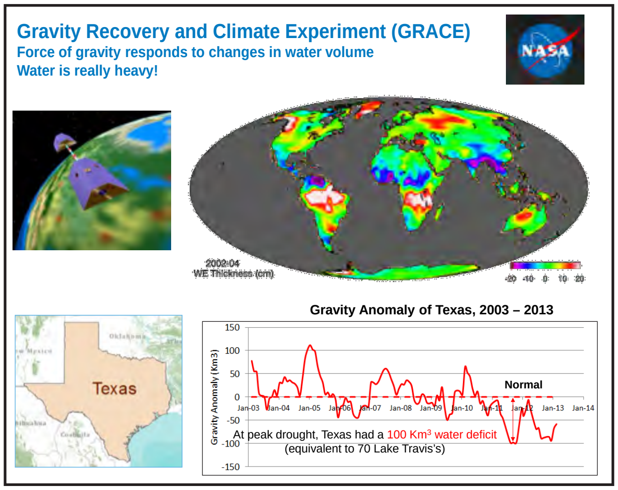


Figure 12. Gravity Recovery and Climate Experiment (GRACE)

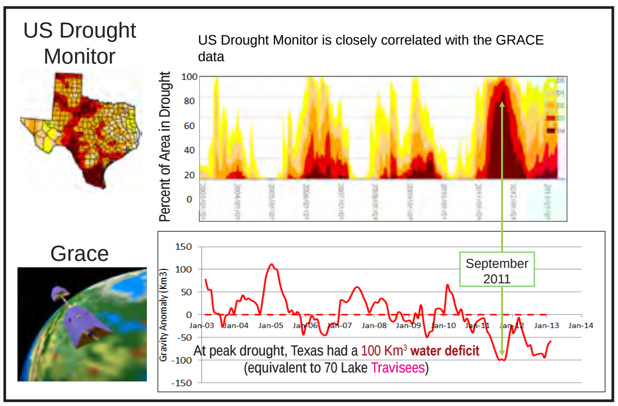


Figure 13. Drought and GRACE

The Texas Water Development Board compiles the records of the surface water reservoir system. We have 119 reservoirs accumulated and presented in Figure 14. You can see that the reservoir volume and GRACE anomaly are almost parallel lines. What that says is that our service water reservoir system is reacting as one huge system, and you can measure that with the GRACE satellite that is spinning around the Earth. It is quite remarkable when you really think about it.

It turns out that 90 percent of the water that we lost in the 2011 drought didn't come from the service water reservoir system–less than ten cubic kilometers came from that system. That means that the soil and groundwater systems are very critical. NASA is assessing this using the Land Data Assimilation System (LDAS) where they model the circulation of water around the U.S. in the atmosphere and the exchange between the land and the atmosphere. NASA does this atmospheric modelling on a 1/8 degree mesh (Fig. 15). Figure 16 is an example of what that information looks like for Travis County where I live. You can click on a point and, for example, get the soil moisture level in this county at that point.

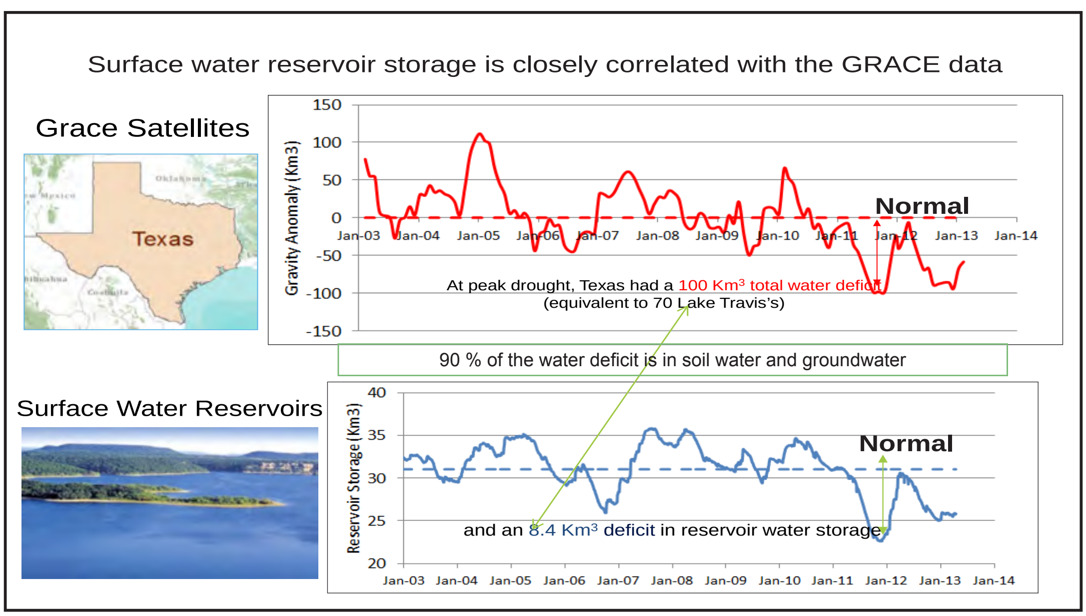


Figure 14. GRACE and Texas Reservoir Water Storage

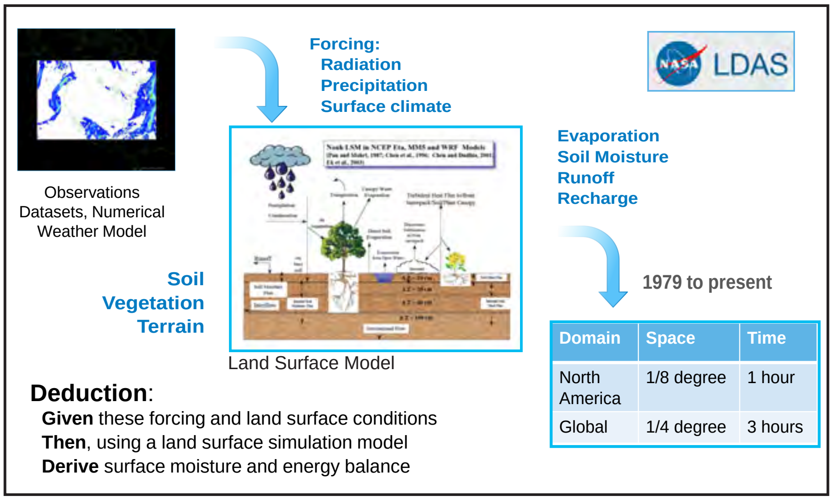


Figure 15. LDAS—Land Data Assimilation System

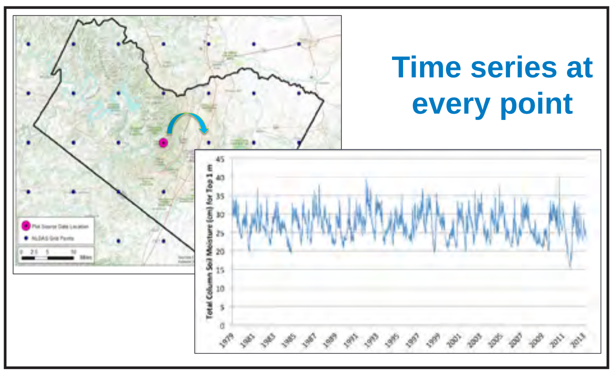


Figure 16. LDAS "Data Rods" project

We are also working with NASA on a project using time series data of soil moisture, evaporation, precipitation, and any data that can be used in this model. This information is useful when we compare a measurement today with the same time last year, or the same time the year before, and how they vary as compared to the average. In Figure 17, the red line is 2011, the purple line is 2013, and the green line is 2012. This is interesting because you can start to get a quantitative measure as to what exactly is happening. How dry is dry? How dry is it exactly relative to how dry it was last year or previous years?

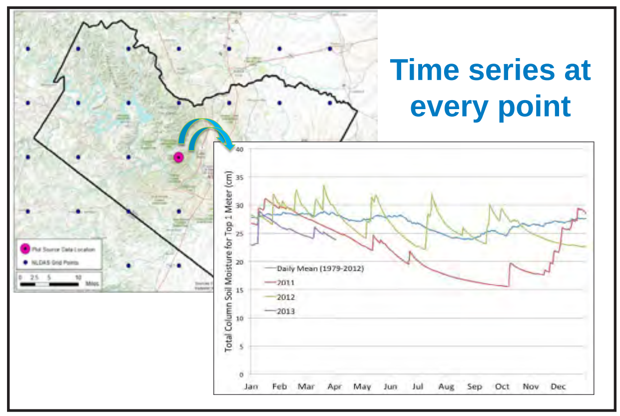


Figure 17. Current Soil Moisture Conditions

NASA has built these "data rods" for the whole country and Figure 18 shows the data rods for Texas. You now know how much water is being stored in the basin. I can ask myself, how much water do we have in soil moisture in Texas? It turns out that in the top one meter of soil, we have about 45 cubic kilometers of water that we lost during the 2011 drought. Nearly half of all the water that we lost was in the top one meter of soil, which is why there is a lot of discussion at this conference about soil moisture (Fig. 19). The soil is a crucial component of understanding what is going on in this situation.

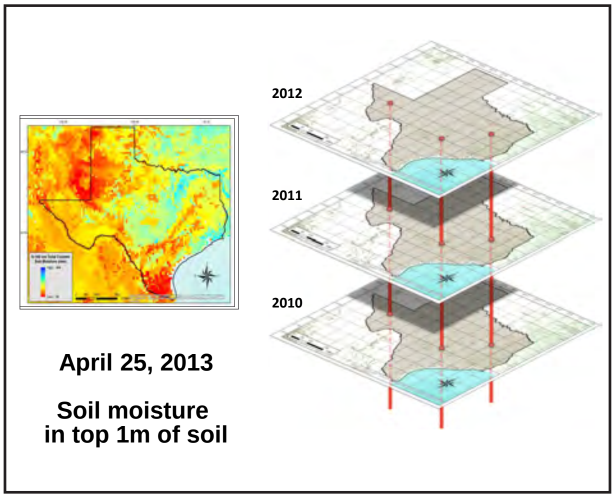


Figure 18. "Data Rods" for Texas

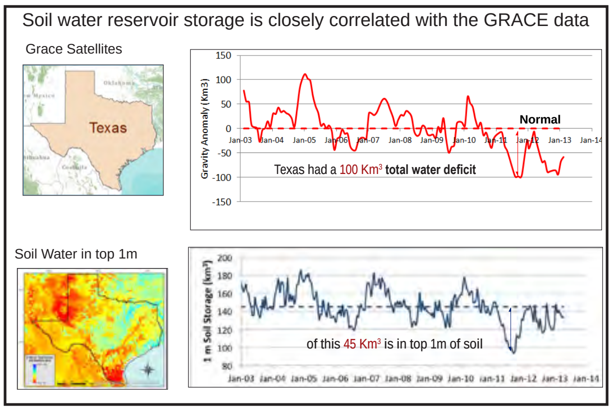


Figure 19. GRACE and Texas Soil Water Storage

What I envision in the future is something that I am going to call World Water Online that brings together water data across the whole Earth at all spatial scales linking data, modeling, maps, observations, and everything else on the web. I am going to dream here a bit (Fig. 20). I imagine that at the world scale, we would think about how we assess water and climate issues similar to what I was showing with GRACE. How are we going to understand drought and how it moves? At the national scale, we will think about the landscape and how much water we have. At the regional scale, we will solve aquifer and watershed management problems. At the local level, we will look at households and how households, individual wells, and so on, are affected.

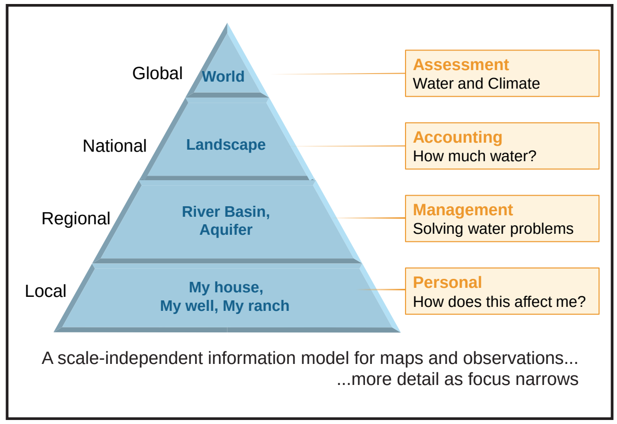


Figure 20. Scales of Application

Let's imagine that we could do this. To give one example of what is being done, Figure 21 shows Google Map images of rivers. It starts with a global map of all the rivers in the world–the Amazon is seven times larger than the next biggest river, so that is why the amazon looks big there. Then you have the rivers of the United States, and you can see the Mississippi. Then you have the rivers of Texas, and here are the rivers that surround my house where you can see a little stream that we call Panther Creek. You can do this similarly with any stream anywhere (Fig. 22). You can see any active watershed on Earth. It turns out that there is an active watershed right next to my house, and I didn't even know exactly where it was located.

Figure 21. World Hydro Overlay Map

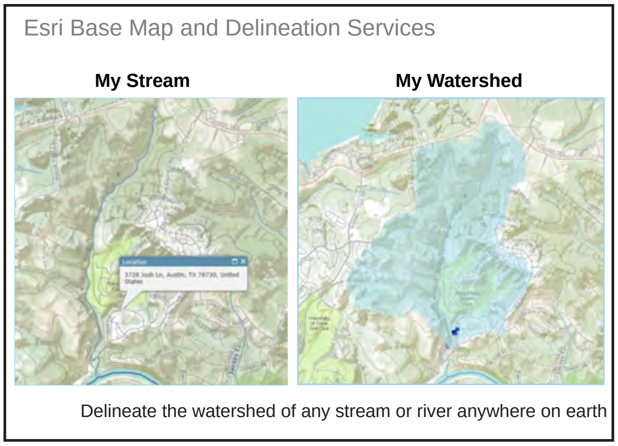


Figure 22. Watershed of My Stream

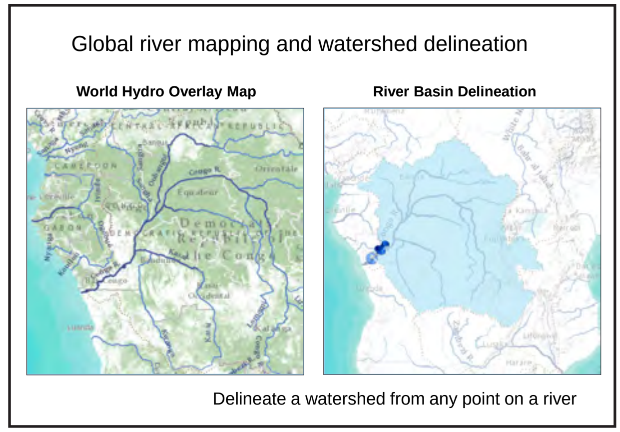


Figure 23. Congo River Basin

Figure 23 shows how we can delineate a watershed from any point on a river anywhere on the planet. This capability is already working in most places of the U.S. It is now being expanded to Africa and the figure shows a view of the Congo Basin. You can use this for the small stream by my house and at the same time use it for the rivers of the Congo without having to go get any data at all. This is all happening because something in Longmont, Colorado or somewhere else, is doing all the work. This is not happening on my computer at all. What is happening is that all of these computations and data are being housed at these huge facilities and processing happens on top of them. Figure 24 shows the precipitation across the Congo Basin. The idea is to link hydrologic processes with drainage areas. I would like to believe that we can build a World Water Online as a system to link people everywhere with water data, maps, and models.

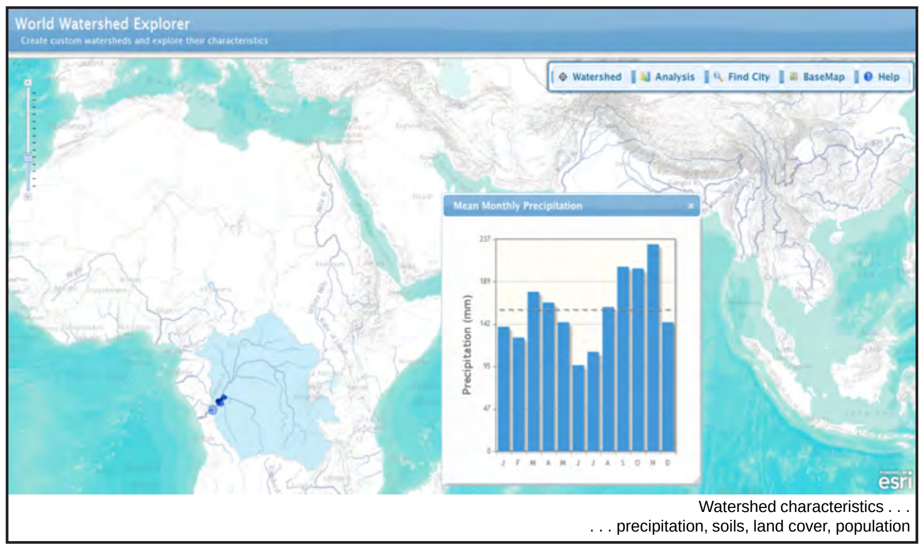


Figure 24. World Watershed Explorer—Congo Basin

Thank you.

Changes & Challenges: Reflections on Water Issues & Management in New Mexico

Bruce Thomson
Univeristy of New Mexico

Bruce Thomson *will be retiring from the University of New Mexico where he is a Regent's Professor in the Department of Civil Engineering at the University of New Mexico and is Director of the UNM Water Resources Program. He has a BS degree in civil engineering from the University of California at Davis, and MS and PhD degrees in environmental science and engineering from Rice University, Houston, TX. Bruce teaches in the areas of water chemistry and treatment, groundwater hydrology and remediation, and water resources management. Recent research has included projects on water resources of New Mexico, the impact of energy and mineral development on water resources, and water reuse and treatment. He has served on many federal, state and local committees involved with management and protection of water resources. Bruce was recently elected to the Board of Directors of the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA). He is a licensed Professional Engineer in the State of New Mexico and received the 2013 New Mexico Public Sector Engineer of the Year award.*

A Short Preamble

Being invited to present a retrospective paper on water issues in New Mexico is both an honor and a challenge, but also an indirect public acknowledgment that one is approaching geezerhood. But with approaching geezerhood comes some freedom from traditional constraints in that you don't have to be quite as diplomatic with your opinions because if you offend somebody what are they going to do, fire you? Of course, there's also the risk that you will descend into past memories and pointless reminiscence resulting in total disregard of your thoughts and opinions. I will attempt to find a middle ground; not offend anybody but also not dwell on the past. Nevertheless, it is a pleasure to be offered the chance to reflect on some of the challenges associated with water in New Mexico.

Introduction

During the course of my career there have been remarkable changes in the technologies we have used in water research and management. Calculations were done with slide rules and adding machines. (Aside: Hewlett-Packard introduced a basic scientific calculator the year I graduated from college. Its 1971 cost of $395 would be over $2,200 today.) Water quality measurements were performed by hand using burets, color indicators, and instruments with dials. Computers filled entire rooms, used as much power as a residential neighborhood, and were programmed with punch cards. Cars didn't have seat belts. And students and faculty were allowed to smoke in class. Those weren't necessarily the good old days, but they were different.

One of the most apparent differences between then and now is the lexicon (Table 1). Our terminology has become more convoluted, more oblique, and now avoids words with common negative perceptions (i.e., sludge, garbage, and dump). The words and phrases are also longer (an average of 6.6 syllables vs. 3.8 syllables) as if we can improve our public image of the profession by using more complicated words and phrases.

The evolution of the environmental engineering profession has been driven by the proliferation of environmental legislation. This is stunningly illustrated by a plot I did several years ago of the number of laws that are relevant to the profession (Figure 1). The first Earth Day, considered by many to be the beginning of the environmental movement, was in 1970. In the next 20 years over 30 major pieces of federal legislation were passed, actions that dramatically altered the profession. One of the more provocative commentaries on this change was a talk presented around 1990 by Bob Hogrefe, a water engineer with the City of Albuquerque titled "Whatever Happened to BOD?" that reflected how much the profession had changed as a result of these laws and their subsequent regulations.

Table 1. Changes in terminology in the environmental engineering profession

Old Terminology	No. Syllables	Current Terminology	No. Syllables
Sanitary engineering	8	Environmental engineering	9
Sewage	2	Wastewater	3
Sewage treatment plant (STP for short)	5	Water reclamation plant	7
Water treatment plant	5	Water purification plant	8
Sludge	1	Residuals Biosolids	4 4
Garbage	2	Solid waste	3
Dump	1	Solid waste management unit	8
Septic tank & leach field	6	On-site wastewater treatment and disposal system	13
Drinking water standards	6	Maximum contaminant levels	9

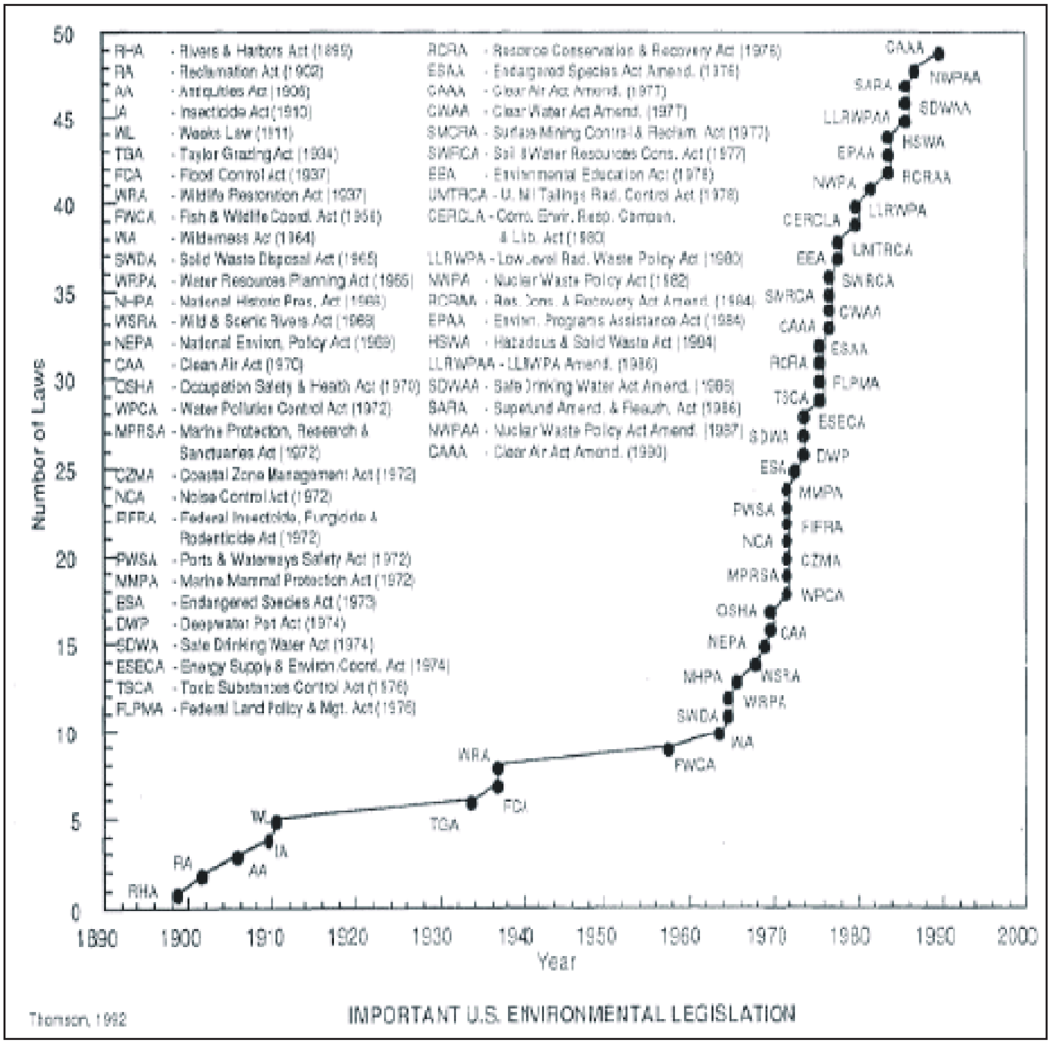


Figure 1. The evolution of major federal environmental legislation with time up through 1990.

Environmental Engineering Technology

As with nearly all technologies, in the last 30 years the advances in the performance of environmental systems have been breath taking, to the point that the effluent from most well operated sewage treatment plants, oops, wastewater reclamation plants meets drinking water criteria. But don't ask me to drink it!

However, sometimes the inflexibility of environmental regulations lead to solutions for problems that don't exist. For example, the Clean Water Act (CWA) requires that all communities use the activated sludge process for wastewater treatment, a proven and reliable but complicated and expensive technology. But many communities in the arid southwest discharge to dry streams and arroyos. Though these are technically "waters of the U.S." as defined by CWA regulations, in reality there is seldom any water in them and certainly no aquatic environment needing protection. So why can't we utilize much simpler and far less expensive technologies such as wastewater treatment lagoons? Pushing the envelope even further are recent requirements for advanced treatment, including removal of nitrogen and phosphorous, from discharges to intermittent effluent dominated streams. We're requiring some of our poorest communities to incur very large treatment costs to protect an aquatic environment that wouldn't exist if the discharge was discontinued.

Another consequence of this myopic regulatory environment is the tendency to require action on new contaminants with little regard to their actual threat to human health and the environment, and with virtually no consideration given to the secondary consequence of the regulatory implications. The classic example of this is the new drinking water standard (maximum contaminant level or MCL) for arsenic.

The 1996 amendments to the Safe Drinking Water Act required that EPA promulgate a new standard for arsenic. This was finally accomplished 10 years later when the MCL was lowered from 50μg/L to 10 μg/L, even though no study of populations in the U.S. or Europe found a correlation between illness and elevated arsenic concentrations. Instead, justification for the standard was principally based on extrapolating down from epidemiologic evidence from rural communities in Taiwan exposed at very high concentrations. The data and several different statistical models are shown in Figure 2. Though it's possible to calculate a reduced risk from this model, the inherent uncertainty is stunning. Nevertheless, based largely on this data and accompanying analysis, EPA passed the new standard that was projected to costs estimated at $5 to $15 M per life saved (Gurian, 2001). Water utilities have stepped up to the plate and most are in compliance with this new regulation, but credible epidemiologists note that we will never be able to actually measure the consequences of this action in terms of reduced mortality or morbidity. At the same time, one can't help but wonder if those very large amounts of money couldn't have had greater benefit by applying them elsewhere.

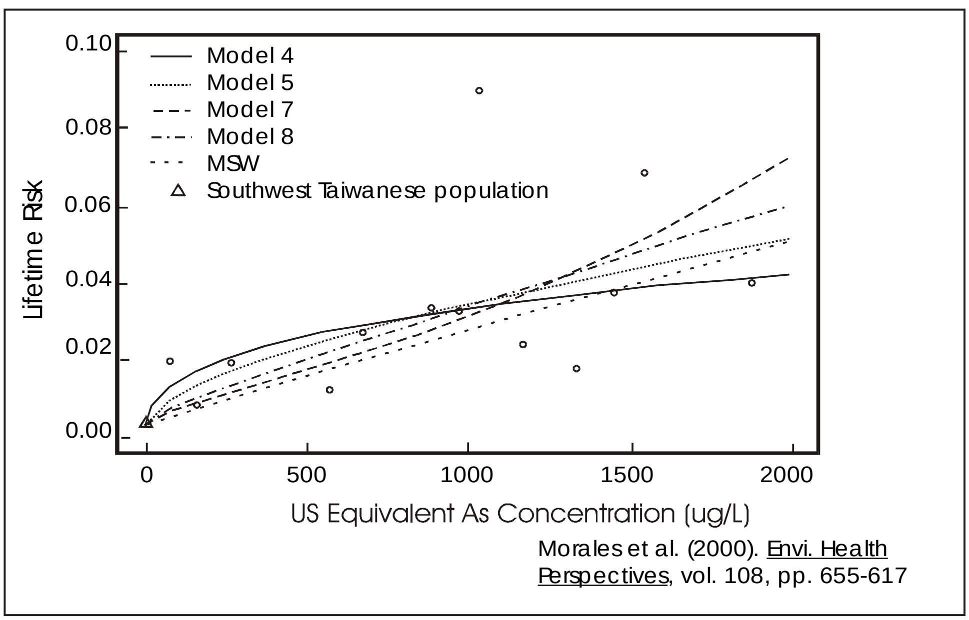


Figure 2. Correlation between arsenic in drinking water and risk (Morales et al. 2000).

Arsenic is an example of a class of compounds that can be referred to as "political pollutants," a description coined by Lamar Miller, an environmental engineering professor at Florida State. Political pollutants are those which the public believes to be a far greater threat to human health than is supported by actual data. I maintain that if Joseph Kesselring had instead titled his 1939 play “Dysprosium and Old Lace” the drinking water MCL for arsenic would not be 10 μg/L today. This is an important lesson that we should remember as analytical chemists develop new methods for detecting ever lower concentrations of aqueous constituents. Although we can measure a constituent in water, proving that it poses a risk to the public is a very difficult, costly, and contentious task.

Water Resources Management in New Mexico

Most of the water resource challenges we face in New Mexico are the result of laws, decisions, and policies that were instituted 100 years ago. It is especially important to remember that NM water law, first codified in 1907 as the Territorial Water Code, was passed and implemented largely as a mechanism of encouraging economic development in the territory. At the turn of the last century, the state’s population was less than 200,000 people and its economy was dominated by agriculture, timber, and mining; there was little municipal demand for water and virtually no manufacturing or industrial use. Hence, the water code was intended to support this type of development and protect it into the future (Buynak, 2008).

A plot of the historic volume of Elephant Butte Reservoir (Figure 3) illustrates the history of water supply of the Rio Grande as it provides a way of integrating supplies over the entire basin and also has the effect of providing a running average of data over several years. Through the end of the 20th century, water managers in the state were able to meet nearly all demands for water. This was assisted in part by two decades of unusually high precipitation and in part by groundwater mining of large aquifers in the middle Rio Grande and the eastern plains. Extended drought conditions since 2000 have resulted in recognition of the vulnerability of our water supply to drought and climate change. And falling water tables have increased awareness of the limitations of groundwater as a sustainable source of supply without careful management.

As the state searches for strategies to deal with future water demands, it is worth examining some of the most important institutional laws and policies that constrain rational water management. The original goal of territorial water managers in the territory was to promote economic development. During the first 70 or 80 years of the 20th century, the state developed compacts, laws, regulations, and policies largely to encourage and protect this type of development. In the context of the 21st century social and economic structure of New Mexico, many of these don’t make sense. Some examples:

- Why is the right to appropriate water (i.e., a water right) granted forever? Other public resources such as grazing rights are for a limited term. A perpetual water right is a tremendous benefit to the person who holds it but effectively removes it from its owners, the public. Furthermore, ownership in perpetuity introduces all sorts of complexity into managing the resource.

- Does priority administration of water rights make sense? If the principle were rigorously applied, it removes all incentives for conservation by owners of senior rights, often referred to as “use it or lose it.” In the absence of adjudication, there is a large uncertainty (chaos might be a better term) associated with managing water because information on the amount and priority date has not be determined (Benson (2012). Furthermore, in hopes of creating order out of chaos, the state and water rights holders are spending a fortune on 14 current adjudication proceedings that take many decades to complete. The state hasn’t even begun to think about the 500 pound gorilla in the room; adjudicating the Middle Rio Grande basin.

- The Rio Grande Compact requires storage of water in Elephant Butte Reservoir, one of the hottest and driest locations in the state with a pan evaporation rate of nearly 10 ft/yr. Evaporative losses depend on the lake’s surface area, and though the lake averaged about 20% of its capacity from 2008 to 2012 (see Figure 3), during this same time it lost 84,000 AF/yr to evaporation (MRGWA, 2014). This is roughly double the consumptive use by the City of Albuquerque. Agreeing to store water in Elephant Butte wasn’t a concern in the 1930s when the Compact was being negotiated because the first three decades of the 20^{th} century were unusually wet and the reservoir had plenty of water. However it certainly doesn’t make sense based on 21st century hydrology, hydraulics, and water use. Is it possible to modify the Compact to allow storage in upstream reservoirs that have half the evaporation rate of Elephant Butte and recover some of that water lost to the atmosphere?

- The NM constitution states that water "...is hereby declared to belong to the public and to be subject to appropriation for beneficial use…" In other words, a water right does not constitute ownership, only the right to use it. In keeping with the public lands analogy presented above which notes that the state charges for grazing rights, why isn't there a similar charge for use of the public's water? A modest charge for water use would both provide an incentive to conserve the resource and generate revenue that could be dedicated to water projects.

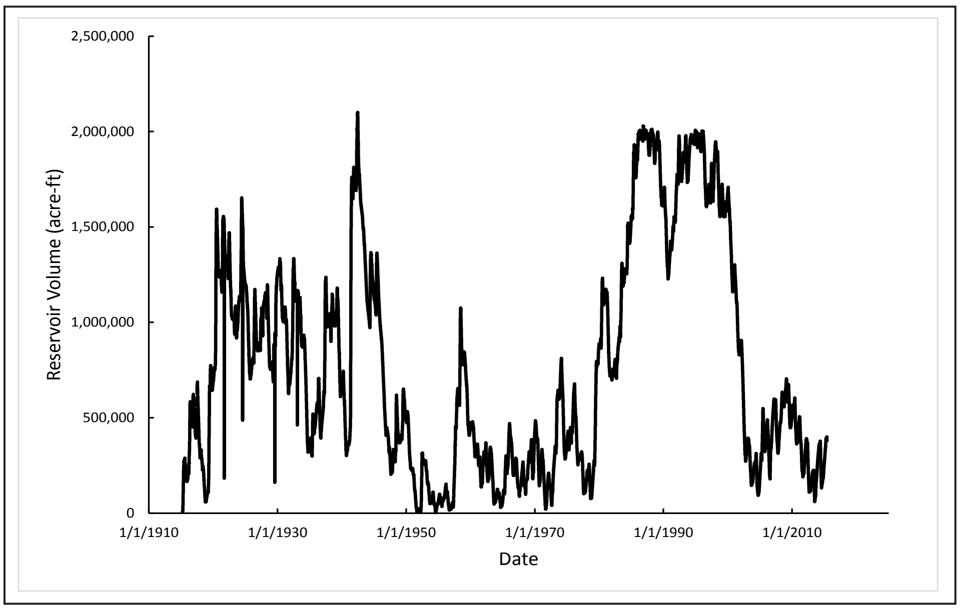


Figure 3. Historic volume of Elephant Butte reservoir

I fully recognize that political realities make each of these constraints impossible to change. The social, cultural, and economic investments that have occurred over the last century as a result of these laws and policies are too solidly integrated into the institutional organization of the state to expect changes. The combination of institutional complexity introduced by the four points noted above, increasing demand for water to meet the needs associated with population and economic growth, and the enormous uncertainties and highly variable nature of the southwestern climate create a classic example of a "wicked problem." This is defined as a problem that is impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize (Rittel and Webber, 1973). Using the terminology of mathematics, our water problems are over constrained.

Though there is no single solution to water problems in NM, there is value in explicitly identifying and considering the root causes. Most meetings and conferences focus on the hydrologic cycle and its uncertainties, especially those regarding possible climate change. Since 2008 it is not possible to attend a meeting of hydrologists and engineers without a discussion of stationarity (Milly et al., 2008). And while variation in the water supply creates challenges, it is the institutional constraints that create the biggest obstacles to innovative management strategies, and these are seldom discussed. As water professionals we should recognize that water management is a wicked problem, identify the issues that make it such, and include them in future dialog on how to address the problem.

Concluding Remarks

Humans have been storing, diverting, treating, and distributing water for thousands of years; consequently the hydrology and water engineering professions are pretty mature. Though we can't control it, we have a high degree of understanding of occurrence and movement of water (i.e., hydrology). Likewise, we can design and construct very effective systems for storing, treating, and distributing water (i.e., engineering). Arguably the biggest challenges facing water professionals are in developing institutional mechanisms for rationally managing the resource. The present institutional system creates near gridlock in which decisions are often made by individuals with limited understanding of the engineering and natural science complexities associated with the hydrologic cycle.

Circling back to the introductory remarks reflecting on my career, I note that one of the first papers I ever published discussed the role of the engineer in the public participation process (Thomson, et al., 1983). This paper made the observation that engineers and scientists seldom take an active role in developing public policy, and yet many of the most challenging issues facing the community have fundamental technical underpinnings. The paper concluded by urging engineers and scientists to play a more active role in the decision-making process, and especially to seek opportunities to lead the public dialog on policies based on technical issues. The water problems we face today have far more technical complexity than were present 100 years ago when the first sanitation laws and water rights laws were being passed. I think it is more important than ever that the plea in that 1983 paper for participation by engineers and scientists in development of environmental and water policies be extended.

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Poster Abstracts

Optimization Techniques in the Membrane-Based Desalination Technologies

Leili Abkar, New Mexico State University
WERC/IEE, PO Box 30001, MSC WERC, Las Cruces, NM 88003-8001
abkar@nmsu.edu, 575-640-5236

Abbas Ghassemi, New Mexico State University
WERC/IEE, PO Box 30001, MSC WERC, Las Cruces, NM 88003-8001
aghasem@nmsu.edu, 575-646-2357

James Loya, Program Manager at WERC/IEE
WERC/IEE, PO Box 30001, MSC WERC, Las Cruces, NM 88003-8001
jloya@nmsu.edu, 575-646-6305

Poster Abstract 1

Optimization is the matter of investigation on other options or methods regarding the system expenditure or utmost performance based on the specific circumstances. This objective can be achieved by maximizing desired elements and minimizing undesired ones. To optimize the membrane-based desalination technologies such as reverse osmosis and electro dialysis reversal the desired factors and undesired ones should be determined. The desired factors that should be maximized are permeate flow rate and water recovery. Concentrate flow rate, energy consumption, operating pressure, final cost of water production are taken into consideration as a undesired factors, which should be minimize in order to optimize desalination system. In this paper, factors that contribute to the optimization is investigated and the techniques which have been applied are summarized.

Contact: Leili Abkar, New Mexico State University, WERC/IEE, PO Box 30001, MSC WERC, Las Cruces, NM 88003-8001, abkar@nmsu.edu, 575-640-5236

WITHDRAWN

Assessing Change and Resilience in a Northern New Mexico Acequia Irrigation Community

Amy Miller
University of New Mexico, 3337 Betts Drive NE, Albuquerque, NM 87111
amyrmiller11@gmail.com, 510-299-0689

Poster Abstract 2

Acequias in New Mexico are the oldest water management institutions of European origin in the United States. Remarkably, the acequias studied in this project have been continuously maintained for over 200 years. These communal water management systems have survived through major droughts and persisted through time, but are now vulnerable to new disturbances that threaten their livelihood. Research on these disturbances helps us protect acequias, not only for their inherent cultural and historic values, but also for the example they provide as an effective way to manage water in times of scarcity. This should be particularly important in an era and region of current and projected water shortages. Three major disturbances affecting the Rio Hondo acequias were studied in this project: land use change, climate change, and demographic change. Land use change was quantified over time by examining historic and contemporary aerial photos of the region in a Geographic Information Systems program and by utilizing a historic crop report. Climate data were collected from a number of sources and evaluated using a statistical trend test. Demographic data were collected mainly from the U.S. Census and the American Community Survey and analyzed through time. The findings suggest a loss of 25 percent of the agricultural lands in the Rio Hondo between 1969 and 2010, a shift towards less crop diversification, and displacement of agricultural land by development. The climate change research findings indicate that the region has experienced increased temperatures and drier conditions over time. Substantial shifts in demographics took place, including a decline in Hispanics and increase in Anglos, an aging of the population, and large overall population growth rates. Even with these major changes, the acequias in the Rio Hondo are found to be resilient, although there is some evidence of weakening of the acequia institution. Recommendations for future resilience are provided based on the report findings.

Contact: Amy Miller, University of New Mexico, 3337 Betts Drive NE, Albuquerque, NM 87111
amyrmiller11@gmail.com, 510-299-0689

Potential Climate Change Impacts on the San Juan - Chama Project

Jesse Roach
Sandia National Laboratories, P.O. Box 5800 MS 1137, Albuquerque, NM 87185-1137
jdroach@sandia.gov, 505-284-9367

Dagmar Llewellyn
U.S. Bureau of Reclamation, 555 Broadway Avenue NE, Albuquerque, NM 87102
dllewellyn@usbr.gov, 505-462-3594

Poster Abstract 3

The San Juan - Chama (SJC) inter-basin diversion moves water from the Colorado River basin into the Rio Grande basin. The SJC project, since it began operations in 1971, has never experienced a shortage, and as recently as 1999 was estimated to have a firm yield of 96,200 acre-feet per year (AF/yr). In the past 10 years, cities in the Rio Grande Valley have begun to augment local supplies with direct diversion of SJC water, making the reliability of those supplies ever more important. This poster presents results from the Upper Rio Grande Impact Assessment (URGIA) on the reliability of the SJC project under a changing climate. URGIA is an activity within the United States Bureau of Reclamation's West Wide Climate Risk Assessment. URGIA analysis suggests that a 96,200 AF/yr yield will not be firm if the future is at all similar to that characterized by the suite of general circulation models (GCM) simulations utilized in Phase 3 of the Coupled Model Intercomparison Project (CMIP3). According to URGIA simulations, the SJC project will experience supply shortages in more than 10% of simulation years in the 2020s, more than 25% of simulation years in the 2050s, and more than 35% of simulation years by the 2090s.

Contact: Jesse Roach, Sandia National Laboratories, P.O. Box 5800 MS 1137, Albuquerque, NM 87185-1137, jdroach@sandia.gov, 505-284-9367

Riparian Habitat Restoration of the Lower Rio Grande

Elizabeth Verdecchia
International Boundary and Water Commission, U.S. Section, 4171 N Mesa C100, El Paso, TX 79902
elizabeth.verdecchia@ibwc.gov, 915-832-4701

Poster Abstract 4

In 2009, the International Boundary and Water Commission, U.S. Section (IBWC) signed the Record of Decision (ROD) for long-term river management of the Rio Grande Canalization Project in New Mexico and Texas. The ROD incorporated 10 years of stakeholder discussions of river management alternatives and committed the IBWC to implement 30 habitat restoration sites and new management practices within the river channel and floodplain, such as phasing out grazing leases, evaluating channel maintenance activities, ceasing mowing in certain areas to develop managed grasslands, and invasive saltcedar control.

The U.S. Fish and Wildlife Department, through an interagency agreement, is assisting the IBWC to implement restoration sites. Since 2011, the two agencies have planted over 3,000 native willow and cottonwood trees and treated 300 acres of saltcedar on the first 5 pilot sites, with 4 new sites in the works. The restoration sites have a range of habitat types, including riparian woodland and dense willow habitat for the federally endangered Southwestern Willow Flycatcher.

The riparian vegetation will increase evapotranspiration, potentially using allocated water; therefore, the IBWC has initiated a public-partnership to develop an Environmental Water Transaction Program. IBWC will purchase over 450 acres of water rights for the restoration sites, both to offset water depletions and to ensure habitat persistence during drought years.

These partnerships are essential for the successful implementation of habitat of the Rio Grande. By the year 2019, the IBWC plans on restoring over 550 acres of native riparian habitat and 2,000 acres of managed grasslands.

Contact: Elizabeth Verdecchia, International Boundary and Water Commission, U.S. Section
4171 N Mesa C100, El Paso TX 79902, elizabeth.verdecchia@ibwc.gov, 915-832-4701

Using Remote Sensing and Ground Measurement to Assess Agricultural Water Use in Middle Rio Grande

Zohrab Samani, Salim Bawazir, R. Skaggs
New Mexico State University, Civil Engineering Dept., 3CE NMSU, Las Cruces, NM 88003
zsamani@nmsu.edu, 575-646-2904

John Longworth
NM OSE

Poster Abstract 5

Agriculture uses more than 90 percent of the water in New Mexico. Middle Rio Grande is a major component of the agriculture in Rio Grande Basin. Remote sensing technology was used combined with ground level measurements to determine spatial and temporal variability of agricultural water use in the area. The results showed that agricultural water use can be estimated through remote sensing with high accuracy. Various alfalfa fields were identified and annual and monthly ET for the individual fields were calculated. The results showed that while the theoretical water use for alfalfa is about 1200 mm, the actual water use varies from 650 mm to 1300 mm with an average of 1050 mm. The results of the remote sensing were compared with local ET flux measurements and ET estimate from crop production function.

Contact: Zohrab Samani, New Mexico State University, Civil Engineering Dept., 3CE NMSU, Las Cruces, NM 88003, zsamani@nmsu.edu, 575-646-2904

Bringing Back the Mosaic in the Middle Rio Grande Bosque

Jennifer F. Schuetz
Bosque Ecosystem Monitoring Program, Department of Biology, MSC 03 2020,
1 University of New Mexico, Albuquerque, NM 87131
schuetz@unm.edu, 505-277-0758

Kim D. Eichhorst
Bosque Ecosystem Monitoring Program, Department of Biology, MSC 03 2020,
1 University of New Mexico, Albuquerque, NM 87131
kimde@unm.edu, 505-277-0758

Poster Abstract 6

The Rio Grande has been changed from a shallow, wide, meandering river that frequently flooded the adjacent bosque (riparian forest), to an incised, straight channel as a result of flood control measures. Lack of flooding has led to a lack of habitat for cottonwood establishment, resulting in aging cottonwood stands with shade-tolerant exotic understory vegetation. This, combined with the predicted changes in precipitation, temperature and river flow, suggests a future with far fewer cottonwoods in the Rio Grande bosque. Creating a mosaic of habitats would allow the bosque ecosystem a greater range of response and higher tolerance to changes in weather patterns due to climate change. Instead of the current cottonwood gallery forest, there should be a patchwork of different-aged cottonwood stands, saltgrass meadows, areas of bare soil, wetlands, shrub thickets, and savanna-type landscapes. The increased resilience and health provided by a mosaic of habitats would increase ecosystem function and allow for less land management.

Contact: Jennifer F. Schuetz, Bosque Ecosystem Monitoring Program, Department of Biology, MSC 03 2020, 1 University of New Mexico, Albuquerque, NM 87131, schuetz@unm.edu, (505) 277-0758

Can Partial Root Zone Drying Conserve Water While Sustaining Chile Yield?

Harmandeep Sharma
New Mexico State University, Las Cruces, 2420 S. Espina St. Apt. 25, Las Cruces, NM 88001
sharmah@nmsu.edu, 575-652-0146

Manoj K. Shukla
Environmental Soil Physics, New Mexico State University, Las Cruces, NM, 945 College Ave, Skeen Hall, P.O. Box 30003, Las Cruces, NM 88003
shuklamk@nms.edu, 575-646-2324

Poster Abstract 7

Water supplies are limited in arid climate and water- saving irrigation methods should be practiced. Three irrigation treatments were assessed for water uptake pattern and yield of chile (NuMex Joe Parker; *Capsicum annuum*) in greenhouse conditions. Drip irrigation treatments applied were (i) water applied at surface standard operating procedure or control (ii) water applied at 100% of control at 20 cm. depth, and (iii) water applied at 70% of control on alternate root compartments at fortnight interval. Continuous measurements of soil water content and soil temperature were carried out using TDR sensors and TMC6-HD sensors respectively. LI-6400XT used for plant physiological measurements. Other plant measurements including stem water potential, plant height, and root length density were also done. To calculate evaporative demands inside greenhouse, meteorological data including net radiation, air temperature, wind speed, and relative humidity was recorded. In both irrigation treatments higher root length seemed to compensate water stress by taking up more water from the water available zone of the root-soil system as was evident from the similar transpiration or photosynthetic rates among treatments. Both irrigation techniques could be adopted as water conservation method in arid environments.

Contact: Harmandeep Sharma, New Mexico State University, 2420 S. Espina St. Apt. 25, Las Cruces, NM 88001, sharmah@nmsu.edu, 575-652-0146

Vegetation Mortality in the Southwest: Testing the effects of heat and drought on plant mortality and survival

Sanna Sevanto
Los Alamos National Laboratory, Bikini Atoll Rd MS J495, Los Alamos, NM 87545
sanna@lanl.gov, 505-664-0232

Nate McDowell
Los Alamos National Laboratory
mcdowell@lanl.gov

Henry Adams
Los Alamos National Laboratory
adamshd@lanl.gov

Adam Collins
Los Alamos National Laboratory
acollins@lanl.gov

L. Turin Dickman
Los Alamos National Laboratory
lee@lanl.gov

Chonggang Xu
Los Alamos National Laboratory
cxu@lanl.gov

Poster Abstract 8

Vegetation is one of the key components of a healthy, sustainable water cycle. Vegetation stabilizes the water cycle by retaining moisture in the soil and by reducing run-off and erosion. It also provides a pathway for returning about half of annual land precipitation back to the atmosphere, helping to control land surface temperature, shorten heat waves and increase precipitation. During the past 20 years, drought-related, regional-scale forest mortality has affected many areas in the Southwest. Current climate scenarios predict even more frequent and severe droughts in this region in the future. Understanding what will happen to our forests under such conditions, and how forest disturbance could be prevented, is therefore essential for maintaining a habitable climate with stable water sources. To understand how drought and heat affect tree physiology and survival, we built an ecosystem scale manipulation experiment in Los Alamos, NM to simulate possible climate change effects in piñon-juniper woodland. Piñon pine and one-seed juniper use different strategies to control water use and photosynthesis during drought. According to current leading hypotheses of plant mortality mechanisms, these alternative strategies differentially affect survival time during droughts of contrasting duration and severity. We use the results from this experiment, to built tree mortality models for an Earth system model to better predict the extent of global tree mortality and its impact to our regional and global climate systems. Here, we present results from the first two years of this experiment and their expected impact on forest transpiration.

Contact: Sanna Sevanto, Los Alamos National Laboratory, Bikini Atoll Rd MS J495, Los Alamos, NM 87545 sanna@lanl.gov, 505-664-0232

Modular Pumped Hydro Energy Storage

Mark L. Bibeault
Los Alamos National Laboratory, Applied Engineering Division,
PO Box 1663, MS J576, Los Alamos, NM 87545
bibeault@lanl.gov, 505-665-1204

Poster Abstract 9

Building and operating "smart-sited", scalable, closed-loop pumped hydro facilities near existing renewable generation sources and transmission lines, yet away from endangered species and environmentally sensitive areas, is a practical approach towards meeting future energy storage needs. Referred to as Modular Pumped Hydro (MPH), the technology is a paradigm shift away from conventional pumped hydro applications which are limited by geography and hydrologic resources, take up to 10 years to permit, build, commission, with initial capital costs exceeding 3 $/W. MPH offers opportunities to reduce permit, build, commission activities through smart siting and properly scaled design to 4 years total, utilizes a very mature, efficient (80% full cycle), reliable, low maintenance, and 4 decade design life technology, with capital costs approaching 2 $/W. MPH has operational characteristics that make the technology very desirable to use, such as the ability to start without grid voltage (i.e. black start), ability to reach full power in approximately a minute from a complete idle condition under emergency conditions, ability to swing from full power production to full energy storage, or vise versa, in less than 15 minutes and operate anywhere in-between at partial load conditions, and ability to both produce and store energy at the same time. MPH produces no emissions or solid waste, utilizes scalable man-made reservoirs with ring berms that are covered and lined resulting in zero net water consumption, and can utilize a variety of brackish or fresh water quality conditions. MPH ultimately provides system flexibility to constantly changing market conditions.

Contact: Mark L. Bibeault, Los Alamos National Laboratory, Applied Engineering Division,
PO Box 1663, MS J576, Los Alamos, NM 87545, bibeault@lanl.gov, 505-665-1204

Using System Dynamics Modeling to Evaluate Environmental Flows in the Rio Chama, NM

Ryan Morrison
University of New Mexico, 1920 Vassar Dr. NE Apt 21, Albuquerque, NM 87106
rmorriso@unm.edu, 971-212-5876

Mark Stone
University of New Mexico, Department of Civil Engineering, University of New Mexico
210 University Blvd NE, Albuquerque, NM 87106
stone@unm.edu

Poster Abstract 10

Managing our water resources requires balancing of the economic, environmental, and social needs of the basin. It is difficult capture the impact of environmental flow alternatives on each of these components using traditional deterministic modeling approaches. System dynamics modeling offers a method of assessing the connections between economic, environmental, and social components of a basin and the impacts of flow alternatives on these components. Given the benefits of using a system dynamics modeling approach, our objective was to develop and demonstrate a stochastic system dynamics modeling framework to evaluate environmental flow alternatives. Specifically, our research examined the influence of flow alternatives on cottonwood recruitment and reservoir storage within the Rio Chama basin, New Mexico, USA. We used the "recruitment box model" to evaluate the impact of three alternatives on cottonwood recruitment within the project reach. We also show that alternatives can be evaluated using comparative metrics, which allow managers to more easily employ an adaptive management strategy for incorporating environmental flows into existing operations.

Contact: Ryan Morrison, University of New Mexico, 1920 Vassar Dr. NE Apt 21, Albuquerque, NM 87106 rmorriso@unm.edu, 971-212-5876

Modeling Potential Impacts of Pumping a Non-Potable Water Supply for the Ochoa Potash Mine

Cheng Cheng
INTERA, Inc, 6000 Uptown Blvd, Suite 220, Albuquerque, NM 87110
cchеng@intera.com, 505-246-1600 x1245

Annelia Tinklenberg
INTERA, Inc, 6000 Uptown Blvd, Suite 220, Albuquerque, NM 87110
atinklenberg@intera.com, 505-246-1600 x1208

Bill Linderfelt
INTERA, Inc, 6000 Uptown Blvd, Suite 220, Albuquerque, NM 87110
blinderfelt@intera.com, 505-246-1600

Peter Castiglia
INTERA, Inc, 6000 Uptown Blvd, Suite 220, Albuquerque, NM 87110
pcastiglia@intera.com, 505-246-1600

Randy Foote
Intercontinental Potash Corp. (USA), 30 Johnson Road, Suite 300, Golden, CO 80401

Terre Lane
Intercontinental Potash Corp. (USA), 30 Johnson Road, Suite 300, Golden, CO 80401

Poster Abstract 11

Competing for limited water supplies in the arid Southwest is a challenge for new mines looking to gain public and regulatory support for proposed projects. Focusing on deep, non-potable groundwater sources for mining and industrial purposes can reduce the competition for limited fresh-water resources in the region. Intercontinental Potash Corp. USA (ICP) is proposing to construct and operate the Ochoa Mine Project (Project), located southeast of Carlsbad, New Mexico. The Project will mine polyhalite to produce sulphate of potash and is estimated to require up to 4,000 gallons per minute of water for processing ore and running the mine facilities. The Capitan aquifer, a non-potable groundwater resource, was selected as a viable option to meet the Project's water needs as well as minimize competition for the limited fresh water resources. ICP drilled and tested two exploratory groundwater wells penetrating the Capitan aquifer approximately 4,500 feet deep. To assess potential impacts on groundwater and surface water within and adjacent to the Capitan aquifer, conceptual and numerical groundwater flow models were developed. This poster will show how the exploratory drilling and modeling re-shaped our understanding of an important aquifer that extends across portions of southeastern New Mexico and western Texas. Our results demonstrate the proposed pumping impacts on nearby surface water and groundwater. As a result of this work, ICP has significantly reduced the risk associated with the water supply for the Project, using a source that will not compete for the limited fresh-water resources in the region.

Contact: Annelia Tinklenberg, INTERA, Inc., 6000 Uptown Blvd, Suite 220, Albuquerque, NM 87110
atinklenberg@intera.com, (505) 246-1600 x12086

Evaluating the Potential for Establishment of Two Aquatic Invasive Plants in New Mexico

Constance Jones
Water Resources Program, University of New Mexico and New Mexico Department of Agriculture,
Water Resources Program, MSC05 3110, UNM
cjones@nmda.nmsu.edu, 505-263-0607

Rebecca Bixby
Water Resources Program, UNM and Department of Biology, UNM,
Department of Biology, MSC03 2020, 1 University of New Mexico, Albuquerque, NM 87131-0001
bbixby@unm.edu, 505-277-3411

Brad Lewis
New Mexico Department of Agriculture and New Mexico State University, New Mexico
Department of Agriculture, Entomology and Nursery Industries, PO Box 30005 MSC 3BA,
Las Cruces, NM 88003-8005
blewis@nmda.nmsu.edu, 702-293-8843, 702-293-8843

Bruce Thomson
Water Resources Program, UNM and Department of Civil Engineering, UNM, Department of Civil
Engineering, MSC01 1070 1 University of New Mexico, Albuquerque, NM 87131-0001
bthomson@unm.edu, 505-277-4729

Poster Abstract 12

The spread of invasive aquatic plants is an issue of growing concern due to their ability to cause significant negative impacts to the water resources and aquatic environments where they proliferate. Adverse effects on the delivery and supply of water can result from invasion by aquatic plants, as well as ecological, economic, and even health-related impacts. The New Mexico Aquatic Invasive Species Management Plan has identified *Hydrilla verticillata* (L.f.) Royle (hydrilla), and *Eichornia crassipes* (Mart.) Solms. (water hyacinth) as potential invasive weeds in the state and called for identification of the water bodies at risk of invasion in New Mexico. The suitable habitats of hydrilla and water hyacinth in the state were predicted using an ecological niche model, the Genetic Algorithm for Rule-set Prediction (GARP). This model uses the known occurrence points of a given species, and the environmental data, such as temperature and precipitation, that affect its distribution, to predict suitable habitat for that species in a new area. Potential habitat for hydrilla was identified in a large portion of the eastern side of New Mexico, as well as regions in the southwestern and northwestern corners. The prediction of suitable habitat for water hyacinth, based on GARP, encompassed almost the entire state. Use of the GARP model will aid in the prevention of the establishment of aquatic invasive plants in New Mexico by identifying potential suitable habitat, allowing water resource managers, regulators and policy makers to better allocate resources to monitor and protect susceptible aquatic environments.

Contact: Constance Jones, Water Resources Program, University of New Mexico and New Mexico Department of Agriculture, NMDA ENI P.O. Box 30005, MSC 3BA, Las Cruces, NM 87131-0001, cjones@nmda.nmsu.edu, 505-263-0607

WITHDRAWN

Aquifer Based Hydroelectic Pumped Storage

William Riley
Aquifer Based Hydroelectric Systems LLC, 400 Prospect St, New Haven, CT 06511
billrileyhere@earthlink.net, 908-229-5300

Poster Abstract 13

Aquifer-based pumped storage is a system in which an aquifer serves as the lower reservoir in a pumped storage system, with ground-level water storage as the upper one. Not all aquifers are sufficiently permeable to be appropriate for this system, but many are. A significant advantage of this approach is that it eliminates the capital cost of the lower reservoir and avoids the topographic limitations of surface-based systems. Ground-level storage can take the form of a purpose-built pond or reservoir (lined and covered as necessary to protect aquifer water quality). Economic and performance modeling indicate that this approach is feasible.

In one approach the upper reservoir can be already built and in place, thus further reducing cost. A typical installation would involve a large pipe with pump-turbine located at ground level below the reservoir, connecting through a manifold to numerous smaller pipe/well bores into the aquifer, each containing a smaller pump-turbine. This combination allows the use of both the head from the reservoir and the additional head from ground level to aquifer level. Suitable treatment is required to insure that aquifer quality is not compromised.

Still another approach would use existing facilities, such as public water supply systems, taking advantage of the system's pumps and storage for electrical storage purpose when they are not needed for their primary mission. In most cases the pumps already in use could be modified to serve as pump-turbines at nominal expense, thus providing extraordinarily low capital cost for a complete system.

Contact: William Riley, Aquifer Based Hydroelectric Systems LLC, 400 Prospect St, New Haven, CT 06511 billrileyhere@earthlink.net, 908-229-5300

Remote-Sensing-Based Evaluation of Relative Water Consumption Between Flood- and Drip-Irrigated Fields in Deming, New Mexico

Amber Whittaker
INTERA, Inc., 6000 Uptown Blvd Ste 220, Albuquerque, NM 87110
awhittaker@intera.com, 505-246-1600

Guillermo Martinez
INTERA, Inc., 1812 Centre Creek Dr., Ste 300, Austin, TX 78754-5153
gmartinez@intera.com, 512-425-2000

David Jordan
INTERA, Inc., 6000 Uptown Blvd, Ste 220, Albuquerque, NM 87110
djordan@intera.com, 505-246-16000

Richard Allen
University of Idaho, 3496 N. 2500 E., Twin Falls, ID 83301
office@allen-engineering.com, 208-423-6601

Poster Abstract 14

A strategy frequently employed to mitigate water supply shortages in agricultural regions is the conversion from traditional irrigation methods to more direct water delivery practices. This study, part of a larger effort by the New Mexico Interstate Stream Commission to understand the environmental and economic impact of irrigation conversion, evaluates relative water consumption of drip irrigation in Deming, New Mexico, using remote-sensing-based techniques combined with ground data collection. Relative temperature differences calculated from satellite data were used as a proxy for water use to show relative differences in crop consumptive use between flood- and drip-irrigated fields. On average, drip-irrigated fields were cooler than flood-irrigated fields, indicating higher water use. More water consumption generally results in more robust crops, and this was confirmed by a higher relative Normalized Difference Vegetation Index (NDVI) for drip-irrigated fields. METRIC surface energy balance modeling yielded higher instantaneous evapotranspiration (ET) for drip-irrigated fields when compared to flood-irrigated of the same crop and corroborated the temperature and NDVI results. Higher water consumption is postulated to occur with drip because water is delivered more efficiently to plant roots, enabling producers to realize greater crop mass with resultant increases in ET rather than losing a percentage as return flow to the aquifer. These results demonstrate a method of evaluating spatial patterns of ET from different irrigation methods using remote sensing techniques and represent a preliminary assessment that can be used by water resources managers to guide policy change to maintain a sustainable water supply.

Contact: Amber Whittaker, INTERA, Inc, 6000 Uptown Blvd Ste 220, Albuquerque, NM 87110, awhittaker@intera.com, 505-246-1600

Evaluation of Geomorphic Mine Reclamation Performance and Models in the Southwestern United States

Colin Byrne
University of New Mexico, 1500 Central Ave SW #123, Albuquerque, NM 87104
cfbyrne@unm.edu, 414-426-3366

Mark Stone
John Stormont
Edward Epp

Poster Abstract 15

The objectives of this study were to assess the performance of geomorphic reclamation in the semi-arid, southwestern United States and analyze the effectiveness of the Water Erosion Prediction Project (WEPP) and Soil, Erosion, Discharge by Computer Aided Design (SEDCAD) models in describing watershed processes on geomorphic reclamation lands. The implementation of geomorphic reclamation is based on the idea that natural landscapes most often evolve over long periods of time under localized conditions. This creates a natural system that minimizes the impact of storm events. In its design, geomorphic reclamation formations are intended to mimic the surrounding natural hydrologic systems and provide stability to a reclaimed landscape that traditional reclamation does not. This two-year study is being conducted at La Plata Mine in northwestern New Mexico with funding from the Office of Surface Mining. The study provides a unique opportunity for researchers from the University of New Mexico to work in partnership with industry personnel from BHP-Billiton - San Juan Coal Company. Researchers are studying three catchments: two reclaimed watersheds and one natural watershed adjacent to the reclamation area. Soil and land cover characteristics were measured using both field experiments and laboratory analysis of site-specific sampling. Monitoring and modeling of the sites began in 2012 and the performances of the La Plata Mine reclamation as well as the two models are being assessed through comparisons of measured runoff volumes, measured eroded sediment, and model predictions.

Contact: Colin Byrne, University of New Mexico, 1500 Central Ave SW #123, Albuquerque, NM 87104 cfbyrne@unm.edu, 414-426-3366

WITHDRAWN

Santa Fe, New Mexico, Water Distribution System—Vulnerability to Climate Change

Donatella Pasqualini
Los Alamos National Laboratory, PO BOX 1663 MS C933, Los Alamos, NM, 87545
dmp@lanl.gov, 505-667-0701

David R. Judi
Los Alamos National Laboratory, PO BOX 1663 MS C933, Los Alamos, NM, 87545
aghassem@nmsu.edu , 575-646-2357

Christina M. Brelsford
Arizona State University

Timothy N. McPherson
Los Alamos National Laboratory

Steve P. Linger
Los Alamos National Laboratory

Hwee Hwang
University of Arizona

Poster Abstract 16

Water supply and distribution systems are critical to sustaining life and economic activity. Water systems consist of both natural and manmade assets, such as rivers, diversions, dams, reservoirs, pumps, and pipes. Disturbing any water system asset may result in system-wide disruptions that have cascading impacts on public health, the economy, and other infrastructures. Threats from climate change have the potential to negatively impact water systems. Examples of these threats include changes in the magnitude and frequency of droughts, potable water availability, water demand, and infrastructure failure. Policy makers are charged with developing strategies to manage, plan, and protect these systems, while maintaining natural resources. Most of the models used to quantify these impacts (e.g., EPAnet) require a considerable amount of data; however, these data are often owned by the utilities and are proprietary in nature. We developed a system-level water system model that describes an urban water system and assesses system vulnerability using only the information usually reported in a city water distribution master plan and based on a limited amount of data. For this poster, we used our model to quantify the implications of a variety of climate scenarios on the water supply of Santa Fe, New Mexico and assessed system vulnerability. These analysis results can support policy makers and stakeholders as they adapt urban water systems in response to climate change.

Contact: Donatella Pasqualini, Los Alamos National Laboratory, PO Box 1663 MS C933, Los Alamos, NM, 87545, dmp@lanl.gov, 505-667-0701

Examining Mesilla Basin Aquifer Pollution Sensitivity Using the DRASTIC Model

Steve Walker
New Mexico Water Resources Research Institute, 1305 Kearny Place, Las Cruces, NM 88007
salto@nmsu.edu, 505-250-9883

Poster Abstract 17

In the Paso del Norte watershed, groundwater is the sole source of fresh drinking water and a majority of the irrigation water. With many lives connected to this natural resource, the need to protect it from pollutants and contamination is extremely important. When visually inspecting the ground, a land owner, planner, manager, or administrator may not know how easily the aquifer under their feet can be polluted, or how easily their activities can affect neighbors around them. The DRASTIC model can be used as a preliminary test to help evaluate areas that may be vulnerable to ground water contamination from sources of pollution. DRASTIC is an acronym for the components of a standardized, risk assessment model used to determine the sensitivity of an aquifer to pollution from a surface contaminant. This DRASTIC model uses ArcGIS to compile data gathered from public sources into ranked layers for seven components. The component layers are hydrogeological factors that affect the capacity of pollutants to reach an aquifer from the ground surface. These factors are: (D)epth to water table, net (R)echarge to the aquifer, (A)quifer media, (S) oil media, (T)opography, (I)mpact of the vadose zone, and hydraulic (C)onductivity of the aquifer. When these weighted and ranked layers are overlaid and added together, a pollution risk surface is mapped over the study area. The final results of this DRASTIC model are used for examining the risk that septic systems in central Paso del Norte pose to the Mesilla Basin aquifer.

Contact: Steve Walker, New Mexico Water Resources Research Institute, 1305 Kearny Place, Las Cruces, NM 88007, salto@nmsu.edu, 505-250-9883

Estimation of Uncertainty in Streamflow Response Based on Hydro-Cluster

Lijuan Jia
University of New Mexico, 417 Harvard DR SE APT.3, Albuquerque, NM, 87106
lijuan@unm.edu, 775-815-2542

Mark Stone
University of New Mexico, MSC01 1070 Civil Engineering Department
University of New Mexico, Albuquerque, NM, 87131
stone@unm.edu, 505-277-0115

Poster Abstract 18

The objective of this research is to investigate parameter sensitivity for discharge responses in the Southwest U.S. on the Gila River Basin within a hydrologic model. Because model parameters can vary both spatially and temporally, an innovative approach was used to simulate parameter uncertainty based on geographic proximity in order to develop regionally-local parameter sets. The Variable Infiltration Capacity (VIC) was used in this study. The results reveal a series of distributed parameter sets based on characteristics that were found to be similar across watersheds (particularly the dryness ratio (evapotranspiration / precipitation)). These similar watersheds were grouped into what we refer to as hydro-clusters. The following questions were then addressed: 1) what are the effects of hydro-cluster (characterized as humid, semi-humid, and dry) to calibrated parameters? and 2) what are the contributions of water balance components to streamflow responses across hydro-clusters? Compared to the traditional method which is calibrated a unique global optimum parameter set for the entire watershed, the improved approach as hydro-cluster evaluations shown improved performance. The implementation also allows for a more accurate approach to considering topographic heterogeneity and the sensitivity of parameters to specific hydrograph periods.

Contact: Lijuan Jia, University of New Mexico, 417 Harvard Dr. SE Apt.3, Albuquerque, NM, 87106
lijuan@unm.edu, 775-815-2542

Engaging Communities of Faith in Watershed Issues

Bob Wesseley
MRG Water Assembly
Wessely@sciso.com

Nancy Carrillo
NM Interfaith Power and Light
nancyeval@gmail.com, 505-934-0680

Elaine Hebard
MRG Water Assembly
ehebard@yahoo.com

John Brown
MRG Water Assembly
john.r.brown2@gmail.com

Poster Abstract 19

In the years following the 2004 Middle Rio Grande Regional Water Plan, advocates have been working to improve the representation of a wide range of values in the water debate given that economic interests alone cannot create sustainable solutions. In the fall of 2013, members of the Middle Rio Grande Water Assembly and Interfaith Power and Light partnered to present one-hour presentations to communities of faith in the Albuquerque Area. We began the 'Water as a Sacred Trust' presentation with detailed scientific information regarding the Region's water budget, historical trends of wet and dry periods, and expected population growth and warming trends. We also described basic features of water law and described the roles of various water decision makers and regulatory players. We introduced audiences to some spiritual values that could provide guidance both in terms of what actions might be taken to improve water sustainability as well as how to implement those actions. Audiences then discussed the values important to them and the actions that best seemed to match them.

At this conference presentation, we will describe the results from the first two presentations to communities of faith; whether they see themselves as having a unique voice in the water debate; and the implications for engaging communities of faith in water advocacy efforts.

Contact: Nancy Carrillo, NM Interfaith Power and Light, 8616 Liberty Dr. NE, Albuquerque, NM 87109 nancyeval@gmail.com, 505-934-0680

Ecophysiological Requirements for Southwestern Vegetation, Gila River, New Mexico

Savannah Martinez
Civil Engineering, University of New Mexico, 6101 Little Joe place NW, Albuquerque, NM 87120
savannahmtz@gmail.com, 505-280-3751

Mark Stone
University of New Mexico
stone@unm.edu

Poster Abstract 20

Riparian zones in the Southwest United States are vulnerable to hydrologic changes resulting from modified watershed conditions and land use. For example, wildfires can have a profound impact on watershed condition and result in drastic changes in the magnitudes of flood flows. Land use changes, such as agricultural and urban development, can impact water quality and increase demand for water extractions. These changes can stress natural ecosystems and result in potentially undesirable shifts in riparian vegetation communities and the species that depend upon them. Thus, increased knowledge of riparian processes and improved predictive models are needed in order to predict and help avoid undesirable changes in riparian conditions. As a first step, this research aims to describe ecophysiological requirements of common southwestern U.S. riparian species. The underlying processes that drive riparian recruitment are a particular focus of this work. This has been accomplished through a thorough literature review and by gathering expert opinions on common riparian species. The results are being incorporated into a Bayesian Believe Network (BBN) in order to predict potential changes in vegetation communities as a result of wildfires, climate change, and potential flow diversions with an emphasis on the Cliff-Gila valley in southwest New Mexico.

Contact: Savannah Martinez, Civil Engineering at the University of New Mexico, 6101 Little Joe Place NW, Albuquerque, NM 87120, savannahmtz@gmail.com, 505-280-3751

Environment- and Landscape-Specific Water Quality Standards (LA-UR-13-27099)

Armand Groffman
Los Alamos National Laboratory Surface Water Program, TA-00, Building 1237, Room 207A,
Drop Point 00123707U, P.O. Box 1663, Los Alamos, NM 87545
groffman@lanl.gov, 505-667-2682

Amanda White
abwhite@lanl.gov, 505-665-6190

Daria Cuthbertson
dariac@lanl.gov, 505-795-8011

Anita Lavadie
alavadie@lanl.gov

Steve Veenis
veenis@lanl.gov, 505-667-0013

Poster Abstract 21

Water quality standards in the United States were initially developed for humid environments with perennial streams and lakes such as the Midwest and East Coast. In the semi-arid to arid west, ephemeral streams dominate the landscape with the exception of drainages emanating from upland features. Ephemeral streams generally do not support aquatic life, but in many cases are assigned water quality standards which were developed for perennial streams that do support aquatic life. The surface water program at Los Alamos National Laboratory is proposing to define environment and landscape -specific local background values for metals and organic compounds in lieu of federal or state standards. This approach is more representative and applies to the environment directly impacting the quality of surface water. Natural background values have been developed for a suite of metals including aluminum, copper, and zinc, and select radioactivity including gross alpha and radium-226 and -228. Although New Mexico Water Quality Standards recognize and accept natural background, anthropogenic background has not been accepted to date although it is globally ubiquitous in the environment. Persistent organic compounds (POCs), including polychlorinated biphenyls (PCBs), accumulate as a result of atmospheric deposition and are not only found in industrial settings, but are observed in ecosystems throughout the Earth. Metals, radioactivity, and POCs contribute to pollutant loading in surface water, are a component of the background environment, and landscape, thus should act as benchmarks on a local scale. This would represent a positive transition to managing surface water quality in the future.

Contact: Armand Groffman, LANL Surface Water Program, TA-00, Building 1237, Room 207A, Drop Point 00123707U, P.O. Box 1663, Los Alamos, NM 87545,
groffman@lanl.gov, 505-667-2682

A Hydrologic Investigation into the Potential Impacts on Riparian Wetlands of the Gila River from the Arizona Water Settlement Act

Jeffrey Samson
University of New Mexico, 210 University Blvd. NE, Centennial 3020, Albuquerque, NM 87106
jsamson@unm.edu, 505-277-2843

Mark Stone
University of New Mexico, 210 University Blvd. NE, Centennial 3020, Albuquerque, NM 87106
stone@unm.edu

Poster Abstract 22

The dynamism of the Gila River, in southwestern New Mexico, USA, has resulted in the creation of a topographically diverse floodplain that supports an array of riparian wetlands. The purpose of this paired wetland study is to investigate the hydrologic processes of two wetlands, to predict their potential responses due to stream alterations as a result of diversions related to the Arizona Water Settlement Act. One site represents a natural wetland and the other a wetland that exists only as a result of an anthropogenic modification to the river valley system. A network of 28 wells and 2 weather stations were installed in early 2013 to provide a high resolution of data on surface water and ground water hydrologic conditions. Phreatic surface contour maps were produced to aid in the visualization of sub-surface gradients. Based on these results, an electrical resistivity investigation is planned to be conducted to help further identify paleoflow channels as well as depth to bedrock and other potential areas of interest. These data will form the development of three dimensional MODFLOW models that will be used to investigate potential future stream flow scenarios on wetland hydrology. The model outputs will be used in tandem with the results of quarterly ecological surveys on vegetation, algae, benthic, and bird communities, to help make predictions of potential hydrologic changes, as well as changes to biotic community structure and function.

Contact: Jeffrey Samson, University of New Mexico, 210 University Blvd. NE, Centennial 3020 Albuquerque, NM 87106, jsamson@unm.edu, 505-277-2843

Effects of Precipitation Manipulation on Carbohydrate Dynamics and Mortality in a Piñon-Juniper Woodland

L. Turin Dickman
UNM, LANL, 1706 Medio, Santa Fe, NM 87501
lee@lanl.gov, 505-660-8450

Nate G. McDowell
LANL

Sanna Sevanto
LANL

Robert E. Pangle
UNM

William T. Pockman
UNM

Poster Abstract 23

Drought induced forest mortality is an accelerating global problem with far-reaching consequences, yet mortality mechanisms remain poorly understood. Depletion of non-structural carbohydrate (NSC) stores has been implicated as a major factor in drought-induced mortality, but experimental field tests are rare. We conducted an ecosystem-scale precipitation manipulation experiment and evaluated foliar and twig NSC dynamics of two co-occurring conifers with different water regulation strategies; the drought-avoiding piñon pine (*Pinus edulis*) and drought-tolerant one-seed juniper (*Juniperus monosperma*). Experimental drought decreased foliar starch in dying trees of both species and increased allocation to glucose and fructose in juniper, consistent with osmoregulation requirements. For both species, average foliar starch concentration between drought treatment onset and date of recorded mortality was a good predictor (R2 = 0.77) of the duration of drought-survival. These results along with observations of limitations to photosynthesis and growth implicate carbon starvation as an important process during mortality of these two conifer species.

Contact: L. Turin Dickman, UNM, LANL, 1706 Medio, Santa Fe, NM 87501,
lee@lanl.gov, 505-660-8450

Farm Water Budgets for Semiarid Irrigated Floodplains of Northern New Mexico: Characterizing the Surface Water-Groundwater Interactions

Karina Gutierrez
NMSU, 2610 Fairway Dr. Unit C, Las Cruces, NM 88011
kgutier@nmsu.edu, 575-650-1640

Alexander G. Fernald
New Mexico State University

Carlos G. Ochoa
Oregon State University

Steven J. Guldan
New Mexico State University

Poster Abstract 24

With the recent projections for water scarcity, water balances have become an indispensable water management tool. In irrigated floodplains, deep percolation from irrigation can represent one of the main aquifer recharge sources. A better understanding of surface water and groundwater interactions in irrigated valleys is needed for properly assessing the water balances in these systems and estimating potential aquifer recharge. We conducted a study to quantify the parameters and calculate the water budgets in three flood irrigated hay fields with relatively low, intermediate and, high water availability in northern New Mexico. We monitored different hydrologic parameters including total amount of water applied, change in soil moisture, drainage below the effective root zone, and shallow water level fluctuations in response to irrigation. Evapotranspiration was calculated from weather station data collected in-situ using the Hargreaves-Samani equation. Previous studies in the region have estimated deep percolation as a residual parameter of the water balance equation. In this study, we used both, the water balance method and actual measurements of deep percolation using passive lysimeters. Preliminary analyses for the three fields show a relatively rapid movement of water through the upper 50 cm of the vadose zone and a quick response of the shallow aquifer under flood irrigation. In addition, results for deep percolation disagree between the estimated approach using the water balance equation and the measured method from the passive lysimeter. Further results from this study will provide a better understanding of surface water-groundwater interactions in flood irrigated valleys in northern New Mexico.

Contact: Karina Gutierrez, NMSU, 2610 Fairway Dr. Unit C, Las Cruces, NM 88011,
kgutier@nmsu.edu, 575-650-1640

Estimating Available Saline Water Resources in Aquifers of New Mexico Using GIS

Racheal Jones
New Mexico State University, 2610 Fairway Dr., Unit C, Las Cruces, NM, 88011
jonesra@nmsu.edu, 360-223-0335

Kenneth C. Carroll
NMSU

Michelle Chapman
NMSU

Mick O'Neill
NMSU

Alexander G. Fernald
NMSU

Poster Abstract 25

It is currently believed that there are roughly 15-billion acre-feet of saline groundwater available in New Mexico aquifers, an estimate first published in 1962 by the New Mexico Office of the State Engineer. This estimate is based on 50-year old, reconnaissance-level investigations even though it is still a widely-published statistic. This research seeks to answer the question of whether or not 15-billion acre-feet of available saline water resources is a reasonable estimate for New Mexico. This research will collect, synthesize, and analyze existing well data housed by municipal, state, and federal agencies. Well data will also be collected from non-governmental agencies, regional and site specific reports. Methods used to answer the "15-billion acre-feet" question will include mapping and analyzing synthesized well data in ArcGIS 10.2. Geology data will be used in conjunction with well data to determine where saline groundwater exists and to estimate the availability of saline groundwater. The goal of this research is to provide updated information regarding the total quantity of saline groundwater available in New Mexico and to provide a starting point for water managers at all levels to assess the viability of their saline groundwater supplies.

Contact: Racheal Jones, New Mexico State University, 2610 Fairway Dr., Unit C, Las Cruces, NM, 88011 jonesra@nmsu.edu, 360-223-0335

Bayesian Network as a Decision Support System for Multi-Objective Flood Management

Hamed Zamanisabzi
NMSU, 416 McArthur Dr., Las Cruces, NM, 88001
hzamani@nmsu.edu, 915-207-0241

James Phillip King
NMSU
jpking@nmsu.edu

Delbert Humberson
NMSU
dghumber@nmsu.edu

Poster Abstract 26

In this study, a Bayesian Network is used as a decision support system for multi-objective management of stochastic floods in the Sunland Park area (Diez Lagos) of southwest New Mexico. Bayes Theorem assists decision making by providing a rigorous framework for describing how beliefs should be altered in light of given evidence and uncertainty. This research utilizes the Bayesian interpretation of probabilistic consequences of stochastic floods, and focuses on the dynamic Bayesian Network's ability to obtain correct results for various flooding conditions under all related uncertainties to optimize the utility of the physical system's performance. Using a Bayesian Network as a decision support tool allows for effective multi-objective management. The objectives of the Diez Lagos facility are protecting property from flood damage, increasing usable water supply from the Rio Grande, mitigating E. coli contamination associated with storm water and maintaining riparian habitat in the study area. The most important advantage of applying a Bayesian Network to flood management is the prediction of realistic outcomes for floods with different return periods, which makes it a powerful decision support system.

Contact: Hamed Zamanisabzi, NMSU, 416 McArthur Dr., Las Cruces, NM, 88001, hzamani@nmsu.edu, 915-207-0241

Response of Piñon and Juniper Respiration to Drought and Warming

Adam Collins
Los Alamos National Laboratory, University of New Mexico, MS J495, Los Alamos, NM 87545
acollins@lanl.gov, 505-665-1597

Nate G. McDowell
Los Alamos National Laboratory, MS J495, Los Alamos, NM 87545
mcdowell@lanl.gov, 505-665-2909

Michael G. Ryan
Colorado State University, Natural Resource Ecology Laboratory
Colorado State University, Fort Collins, CO 80523-1499
Mike.Ryan@colostate.edu, 970-217-5798

William Pockman
University of New Mexico, MSC03 2020, Biology,
1 University of New Mexico, Albuquerque, NM 87131-0001
pockman@unm.edu, 505-277-2724

Poster Abstract 27

Drought and temperature-induced tree mortality is believed to be occurring globally, though the physiological mechanisms underlying documented mortality events are not well understood. Mortality event outcomes often include vegetation shifts which can alter land surface – atmosphere interactions and change the hydrologic cycle. Pinon pine (Pinus edulis) and oneseed juniper (Juniperus monosperma) are widespread species in New Mexico and known to be susceptible to mortality due to altered precipitation and temperature. Respiration is a key component of the tree carbon budget and its response to abiotic stress is thought to play a role in mortality or survival. The ability of these species to acclimate respiration to altered temperature and/or precipitation is a key model parameter, but is currently not known. A careful examination of the response of pinon and juniper respiration to increased temperature and drought conditions is thus a necessary step in predicting their future distribution in a changing environment.

We established a rainfall and temperature manipulation experiment in a pinon-juniper woodland near Los Alamos, NM. In-situ trees were exposed to one of five treatments: Heat (+5 deg C), Drought (-40% rainfall), Heat+Drought, Ambient Control, and Chamber Control. CO2 efflux measurements were conducted on the bole of each tree once per month between June 2012 and October 2013.

In pinon, the Heat and Drought+Heat treatments showed the highest efflux. In juniper, the highest rates were in the Drought treatment. Conversely, pinon Drought+Heat showed thermal acclimation while juniper exhibited acclimation in both the Heat and Drought+Heat treatments.

Contact: Adam Collins, Los Alamos National Laboratory, University of New Mexico, MS J495, Los Alamos, NM 87545, acollins@lanl.gov, 505-665-1597

Adaptive Terrain Systems for Drylands

James M. Brooks
Soilutions, Inc., P.O. Box 1479, Tijeras, NM 87059
jim@soilutions.net, 505-228-2881

Michael Young
Soilutions, Inc., P.O. Box 1479, Tijeras, NM 87059
michael.m.young@gmail.com, 505-228-2881

Brent Tanzy
US Bureau of Reclamation

Richard Luthy
Stanford University

J. Phillip King
New Mexico State University

Poster Abstract 28

Here is something meaningful, even transformative, that you can create, at any scale, with resources you now have at hand -- a common-sense method to control how desert land responds to extreme, often violent effects produced by the changing climate.

Using simple earthworks and methods, you'll create a system of networked surface flows. These systems survive catastrophic weather events and continue to function even when they are overwhelmed. And they are simple to maintain and repair.

These aren't tricks or isolated "BMPs;" they are easily-constructed terrain features interwoven to build on one another's assets and become more robust over time, as your site naturally matures.

The poster will illustrate the techniques in general with examples of completed work, work underway, and drawings.

Contact: Michael Young, Soilutions, Inc., P.O. Box 1479, Tijeras, NM 87059, michael.m.young@gmail.com, 505-228-2881

Central Palomas Basin Aquifer Investigation

Erek H. Fuchs
NMSU, Water Science and Management, 4200 North Valley Drive, Las Cruces, NM 88007
ehfox584@gmail.com, 575-639-4464

James Witcher
Witcher and Associates, Las Cruces, NM
jwitcher@zianet.com

Poster Abstract 29

New Mexico experiences periodic and severe drought of decadal length. Farmers in the Hatch-Rincon Valley along the Rio Grande in southern New Mexico are especially impacted by the current severe and sustained drought because of the unique geology of the immediate area that does not allow significant augmentation of water for irrigation from pumping groundwater. Groundwater that is readily accessible is currently deteriorating in quality as salinity is increasing in the shallow Rio Grande alluvium aquifer. The economy in the Hatch-Rincon Valley is highly dependent on irrigated agriculture in the immediate area.

In response to this apparent crisis, interests in the Hatch-Rincon Valley have been investigating the potential of a groundwater drought reserve. Earlier studies suggested, but did not investigate in detail the possibility of a significant resource, the Central Palomas Basin Aquifer (CPBA). A preliminary geologic cross-section model has been developed by Dr. John Hawley. Surface resistivity and EM geophysical surveys and water chemistry analysis are in progress by David Hyndman and James Witcher to define the CPBA, a buried and confined fluvial channel predating the Rio Grande. Investigation is designed to define and characterize this aquifer as an emergency supply during extreme drought by applying existing water rights of the water users in the Hatch-Rincon Valley. Much work is yet to be performed to fully quantify the aquifer but it may represent an important undeveloped shallow potable groundwater system in New Mexico.

Contact: Erek H. Fuchs, NMSU, Water Science and Management, 4200 North Valley Drive, Las Cruces, NM 88007, ehfox584@gmail.com, 575-639-4464

Has State Water Policy Kept Pace with Water Realities?

Rebecca Wacker
University of New Mexico, 3 Lobelia Lane, Sandia Park, NM 87047
rebecca.wacker@gmail.com, 505-401-6172

Poster Abstract 30

New Mexico has a long history of recurring drought conditions due to continental positioning. Water shortage is an on-going issue for New Mexicans and has been for as long as people have lived in this region. In order to address water management practices, a number of groups have been tasked to provide recommendations toward sustainable growth and management of uncertain resources. In 2003, Governor Richardson's administration developed a list of target areas to address. They include 1) development of state wide, regional, and community water plans that are integrated, 2) address "indiscriminate permitting of domestic wells" 3) coordination of ongoing water issues with other states, Mexico, and Native Americans, 4) implement riparian clean-up, 5) creation of water banks for depositing unused water rights without losing such rights, 6) utilize technology and brainpower of national labs and state universities to explore conservation programs, desalinization, arsenic removal, water supply security, water quality monitoring systems, and advanced irrigation technology, and 7) upgrade the water rights file database to track 100 years of water rights ownership in the state (Lucero et al 2003). Additional groups such as Citizen Forums 2007 and 1000 Friends of New Mexico have also presented recommendations. Ten years after these targets were identified is enough time to provide good indication of progress made toward such goals. This research seeks to evaluate such progress and identify opportunity for additional implementation.

Contact: Rebecca Wacker, University of New Mexico, 3 Lobelia Lane, Sandia Park, NM 87047
rebecca.wacker@gmail.com, 505-401-6172

Sustainable Drinking Water Sources

Dennis McQuillan, dennis.mcquillan@state.nm.us, 505-827-2140
NMED Drinking Water Bureau, PO Box 5469, Santa Fe, NM 87502-5469

Matt Holmes, matt@nmrwa.org
New Mexico Rural Water Association, 8336 Washington Pl. NE, Albuquerque, NM 87113

Blanca Surgeon, BSurgeon@rcac.org
Rural Community Assistance Corporation, PO Box 2621, Las Vegas, NM 87701

Joy Esparsen, jesparsen@nmcounties.org
New Mexico Association of Counties, 444 Galisteo St., Santa Fe, NM 87501

Regina Romero, RRomero@nmml.org
New Mexico Municipal League, 1229 Paseo de Peralta, Santa Fe, NM 87501

John Longworth
New Mexico Office of the State Engineer, 407 Galisteo St., Santa Fe, NM 87504

Poster Abstract 31

Groundwater depletion, drought, wildfires, floods and other hazards pose increasing challenges to public water systems in New Mexico. To protect citizens and communities, the collaborators recommend the following:

- If possible, water systems should keep two or more sources of water supply in operable condition so that failure of one source will not create an outage.
- Static and pumping water levels, production rates, and specific conductance should be monitored for indications of groundwater depletion.
- Mandatory and voluntary water conservation programs, including metering and pricing water service according to cost and usage, should be discussed with the decision making body and community.
- Periodic water audits and leak detection should be performed.
- Emergency Response Plans should include emergency contacts, a list of potential alternative water sources, and instructions on how and where water tankers, approved by the NM Environment Department, can transfer potable water into the system. Water systems are encouraged to participate in the Water and Wastewater Agency Response Network (WARN) to facilitate communication and resource sharing in emergencies.
- Where appropriate, partnership of small rural systems into larger regional systems should be encouraged to increase operational and financial efficiency.

In addition, the partner agencies can provide technical and managerial assistance with Source Water Protection actions to mitigate these risks. Funding opportunities are available for many of these recommended actions. A Source Water Protection Atlas http://gis.nmenv.state.nm.us/SWPA/ , and a Bibliography of N.M. Geology http://geoinfo.nmt.edu/libraries/gic/bibliography/home.cfm , can provide useful information for exploration of new water sources, and for assessing vulnerability to both natural and manmade contamination.

Contact: Dennis McQuillan, New Mexico Environment Department, NMED Drinking Water Bureau, PO Box 5469, Santa Fe, NM 87502-5469, dennis.mcquillan@state.nm.us, 505-827-2140

Benefit Sharing Opportunities in Transboundary Basins: Evidence from the Amu Darya

Shokhrukh-Mirzo Jalilov
New Mexico State University, Dept. of Agricultural Economics and Agricultural Business
PO Box 30003, MSC 3169, Las Cruces, NM 88003-8003
Ph: 575-646-4773, Fax: 575-646-3808
sjalilov@nmsu.edu, 575-405-6277

Saud A. Amer
US Geological Survey, 12201 Sunrise Valley Dr., Reston, VA 20192
samer@usgs.gov

Frank A. Ward
New Mexico State University, Department of Agricultural Economics and Agricultural Business
PO Box 30003, MSC 3169, Las Cruces, NM 88003-8003
fward@nmsu.edu

Poster Abstract 32

This article examines impacts of infrastructure, water allocation protocols, and climate variability on economic outcomes in the Amu Darya Basin for the countries of Afghanistan, Tajikistan, Turkmenistan, and Uzbekistan. Its aim is to identify policies that could lead to basin-wide opportunities for economic benefit sharing to occur, in which the economic welfare of all riparians is improved. We examine the development of storage infrastructure and the allocation of water within the Basin. An empirical optimization model is developed and applied to identify opportunities for improving the welfare of these four riparians that share the basin's waters. An analysis is presented that characterizes politically constrained and economically optimized water-use patterns without and with new reservoir storage capacity in place. The analysis describes a program that could improve economic welfare in all four nations. It takes into account potential impacts of water shortages from drought or climate variability. Results indicate that a combination of targeted water storage infrastructure and efficient water allocation can produce outcomes for which added economic benefits exceed incremental costs for each riparian. Results identify opportunities to foster cooperation among riparian nations through development of water storage infrastructure and associated efficient water allocation that improves the economic welfare for each riparian nation in a basin. Patient and deliberate negotiation will be required to transform potential into actual gains for all countries.

Contact: Shokhrukh-Mirzo Jalilov, New Mexico State University, Dept. of Agricultural Economics and Agricultural Business, PO Box 30003, MSC 3169, Las Cruces, NM 88003-8003, 575-646-4773, Fax: 575-646-3808, sjalilov@nmsu.edu, 575-405-6277

A Study of Selenium in Irrigation Networks in the Animas and San Juan River Watersheds

Andrew Martinez
Spatial Applications Research Center, NMSU, 1316 McArthur Dr, Las Cruces, NM 88003
anpama99@nmsu.edu, 575-640-0398

Mark Heil
Habitat Management, Inc.

Randy Carr
Spatial Applications Research Center, NMSU

Christopher Brown
Spatial Applications Research Center, NMSU

Poster Abstract 33

Selenium (Se) contamination in Northwest New Mexico is a concern among many stakeholders in the San Juan and Animas River Watersheds. As part of the outcome of a court settlement, New Mexico State University's Spatial Applications Research Center (SpARC) was contracted to conduct research into potential Selenium loading and transport in irrigation networks in the San Juan Watershed. Specifically, we explored the Hogback and Gadii'ahi irrigation districts that draw water from the San Juan River. To gather data on the Se contamination, we conducted fieldwork, collected samples from the main irrigation canal, and had these samples analyzed by a laboratory with much experience in Se studies. The first set of results came back as non-conclusive because levels of selenium in the samples were below the levels of detection. We also examined potential Se loading that may be due to the area's cretaceous soils. These soils are high in Se content and are being exposed due to geologic processes. This exposure has the potential to discharge Se into the irrigation fields via rain runoff from the hills through the drainage and irrigation ditches that the people have created. The project is set to continue through the end of 2014, and we will be back in the field in the 2014 irrigation season to conduct more soil and water samples and analysis. Data from these sampling runs will then be analyzed for the spatial extent of SE loading through use of geographic information systems tools.

Contact: Andrew Martinez, Spatial Applications Research Center, NMSU, 1316 McArthur Dr, Las Cruces, NM 88003, anpama99@nmsu.edu, 575-640-0398

Water Appropriation Systems for Adapting to Water Shortages in Iraq

Dina Salman
Water Science and Management Program, New Mexico State University, Dept. of Agricultural Economics and Agricultural Business, PO Box 30003, MSC 3169 Las Cruces, NM 88003-8003
dinasalm@nmsu.edu, 915-226-5028

Saud A. Amer
US Geological Survey, 12201 Sunrise Valley Dr., Reston, VA 20192
samer@usgs.gov

Frank A. Ward
New Mexico State University, Department of Agricultural Economics and Agricultural Business
PO Box 30003, MSC 3169, Las Cruces, NM 88003-8003
fward@nmsu.edu

Poster Abstract 34

Climate change and population growth have intensified the search internationally for measures to adapt to fluctuations in water supplies. An example can be found in the Lower Tigris-Euphrates Basin where recent water supply reductions have resulted in high economic costs suffered by irrigation farmers. Losses to irrigators in this basin have made a compelling case to identify flexible measures to adapt to water shortage. Few published studies have systematically examined ways to enhance the flexibility of water right systems to adapt to water shortages. This paper examines how profitability at both the farm and basin levels is affected by various water appropriation methods. Four water allocation methods are compared for impacts on farm income under three water supply scenarios. Results show that a (1) proportional sharing of water shortages among provinces and (2) unrestricted water trading perform as the top water appropriation methods. The shadow price of water for irrigation rises from zero at a full water supply level to $ US 91 per thousand cubic meters when supply falls to 20 percent of full levels. Results carry important implications for the design and efficient implementation of water appropriation systems in the world's irrigated regions.

Contact: Dina Salman, Water Science and Management Program/NMSU, 3650 Morning Star Dr. Apt# 703, Las Cruces, NM 88011, dinasalm@nmsu.edu, 915-226-5028

The Future of Energy and Water Nexus Under Climate Change in the Southwest

Donatella Pasqualini
Riccardo Boero
Nathan Urban
Los Alamos National Laboratory, DSA-4, MS C933, P.O. Box 1663, Los Alamos, NM 87545
dmp@lanl.gov, 505-667-0701

Poster Abstract 35

Climate change has been increasing current stresses on water supply making freshwater one of the most valuable resources particularly in areas vulnerable to drought such as the Southwest. Being electricity generation the biggest users of freshwater in the USA, water, energy and climate have become three critical intrinsically linked factors. Each year, the U.S. Energy Information Administration projects and analyzes the future of energy production in distinct regions of the United States under several economic scenarios. These scenarios support the evaluation of policy proposals in terms of energy security and emissions. Our research coupled these energy scenarios with predictions by global circulation models to analyze the water-energy nexus. Specifically, we quantified the stress imposed on fresh-water availability by energy production in the Southwest under different climate scenarios. Our analysis accounts for the uncertainties derived by climate models and technologies adopted in energy production. We analyzed the impact of different policies scenarios under the climate scenarios developed by Intergovernmental Panel on Climate Change in the Southwest area of the USA. Results are captured on a monthly basis and projected to 2040.

Contact: Donatella Pasqualini, Los Alamos National Laboratory, DSA-4, MS C933, P.O. Box 1663, Los Alamos, NM 87545, dmp@lanl.gov, 505-667-0701

How to Utilize Water Availability for Prosperity in the MRGV

Navida Johnson
University of New Mexico, School of Architecture & Planning, 931 Buena Vista Dr. SE #D-202
Albuquerque, NM 87106
ngrogan@unm.edu, 505-264-5901

Poster Abstract 36

Water is New Mexico's most precious natural resource. We must remain aware that New Mexico is a desert state and that our finite supply of water not only serves our communities but Southern Colorado near the New Mexico border as well as El Paso, Texas, and northeastern Mexico. In the future, it is very likely we will be faced with a reduction in surface water supply. More specifically, this will impact future economic, ecological and social relationships that encompass the Middle Rio Grande Valley, (MRGV). In order to make sure this region sees a prosperous future this project will deliver key facts, simulated results (from climatic, geographical, and land use scenarios), and tips that inform stakeholders and communities alike what challenges must be taken into consideration in order to accomplish the following goals:

- Meet compact obligations,
- Provide resources to communities,
- Value water utilization, production and quality,
- Decrease groundwater depletion, and
- Sustain the economy.

The 21st century has experienced several of the hottest and driest years on record. Many sources of climate projections suggest that these patterns of arid conditions will become the norm for the Southwest region throughout this century. This project will employ the Middle Rio Grande Cooperative Water Model. This software program is a resource management and educational tool that provides recommendations for balancing water use in the Middle Rio Grande region. With additional guidance implementing water model projections, improved planning methods could show us how to decrease groundwater depletion while sustaining and improving our state's economy.

Contact: Navida Johnson, University of New Mexico, School of Architecture & Planning,
931 Buena Vista Dr. SE #D-202 Albuquerque, NM 87106, ngrogan@unm.edu, 505-264-5901

Incipient Motion of Mixed Load Sediments on the Rio Chama

Angela Gregory
University of New Mexico, 320 Solano Dr. NE, Albuquerque, NM 87108
agregory@unm.edu, 575-644-5808

Poster Abstract 37

Discharge and sediment supply are the primary controls for river adjustment. Modifications to these controls are directly linked with changes in dynamic equilibrium conditions and can negatively impact the ecosystem. The result of control modifications typically involves changes in hydraulic geometry, decrease in heterogeneity, bed armoring, disconnection of floodplains, vegetative establishment and ecological impacts. Environmental flows provide water managers with a tool that can positively aid the physical and ecological needs of the river.

The Rio Chama, located in northern New Mexico, is controlled by three dams and reservoirs. Additionally, the San Juan-Chama Project delivers an estimated 96,500 acre-feet of water to the river. Due to the management of the river, the variability and peak flows of its hydrograph have been decreased and base flows have increased. Of particular importance to this project was the reach between El Vado dam and Abiquiu dam, where two sites (Archuleta and Cebolla) were studied.

The objective of this study was to determine the environmental flows required to mobilize the channel bed. This research suggested that there is a strong connection between channel geometry and the ability to transport sediments at a given flow. Furthermore, the results showed that the most effective use of environmental flows for sediment transport would resemble a natural flow regime in terms of variability. Variability of flood size would accomplish movement of a broad range of sediment size classes as spatial conditions changed with distance downstream of a dam.

Contact: Angela Gregory, University of New Mexico, 320 Solano Dr. NE, Albuquerque, NM 87108
agregory@unm.edu, 575-644-5808

Implementing "Public Welfare" by Valuing Unpriced Benefits and Costs in Water Governance

John R. Brown
New Mexico Water Dialogue, PO Box 1387, Corrales, NM 87048
john.r.brown2@gmail.com, 505-898-9551

Poster Abstract 38

Water may be viewed as a commodity or as a collective good. In the former, "the market" sets a price dependent on negotiations between potential buyers and sellers. In a "perfect" market, all participants are fully informed and have relatively equal power in reaching agreement. Potential sellers can walk away from a bad deal. In the real world of water transfers this isn't the case. Water markets are "thin"; transaction costs are high; sellers are under financial stress and relatively weak; and externalities are ignored. This almost always means that the causal arrow points in one direction: rural sellers and urban buyers. This is often described as moving water to its "highest and best" uses.

The frame changes when we treat water as a collective good. Its value is no longer simply a function of price. Water can be valued, not just for what it does, but for what it is. Through collective action – changing public policy on a broad range of issues like minimum stream flows, utility rates, and zoning – policy actors establish rules setting limits on market operations. The range of water-related values people hold may include a preference for non-monetized goods such as sustainable social-ecological systems. Democratic processes, including robust public participation in water planning, provide a corrective to the excesses of "free" markets. This presentation models how the balance between market and collective decisions may shift toward the latter under conditions of increasing scarcity.

Contact: John R. Brown, New Mexico Water Dialogue, PO Box 1387, Corrales, NM 87048, john.r.brown2@gmail.com, 505-898-9551

Water Supply Reliability for Energy Development Demands: Adaptation for Potential Climate Change

Richard Middleton
Dan Levitt
Cathy Wilson
Andrew Wolfsberg
Earth and Environmental Sciences, Los Alamos National Laboratory
awolf@lanl.gov, 505-667-3599 (w), 505-699-0995 (c)

Poster Abstract 39

Climate-Energy-Land-Water (CLEW) interactions present a complex set of competitive demands and impacts on water resources. Planning for water-intensive energy production—including electricity, biofuels, and unconventional fossil fuels—requires understanding critical basin-scale processes in order to provide quantitative predictions for integrated assessment in all sectors including energy, agriculture, municipal, and environmental demands. In this study, we examine Colorado River dynamics and storage capacity to provide water for new energy demands under current and future climate conditions.

We constructed an integrated framework to assess the impacts of climate change and variability on energy production and water demand in the Upper Colorado River Basin. The framework analyzes the interactions between climate, land, energy, and water (CLEW) processes. For example, projected climate change impacts annual snow pack development (extent, depth, time of melting), which affects vegetation through evapotranspiration, which influences regional hydrology, ultimately impacting water availability for energy development or other demands. The framework is used to model energy resiliency and response to climate change, including developing new storage capacity to manage reduced and irregular river flows. The framework also incorporates water rights in order to understand long-term management of the river while balancing impacts of climate change and water demands for energy, agriculture, environmental, and municipal use.

Contact: Andrew Wolfsberg, Deputy Division Leader, Earth and Environmental Sciences, Los Alamos National Laboratory, awolf@lanl.gov, 505-667-3599(w), 505-699-0995(c)

GPS Surveying Application in Water Conservation

Franck O. Kapoko Kamtchang
2460 Fairway drive Apt C, Las Cruces, NM 88011
kapoko@nmsu.edu, 575-621-1283

Poster Abstract 40

The use of GPS for positioning and mapping has been rapidly increasing since its introduction in the early 1980's. GPS surveys provide reliable sources for accurate 3D information, particularly for water-level monitoring applications. GPS surveys are conducted in either static or RTK modes. Data collected in the static mode, simultaneous between two stationary receivers, for at least 15 minutes, depending on baseline length, cancel most of the systematic errors at both stations through differential techniques. Using nearby control points, less than 30 km in length, with known coordinates can provide an accuracy of less than 5 cm.

This poster presents a ground survey carried out at 3 locations in northern New Mexico, Alcalde, El Rito and Rio Hondo. The task involved monitoring water level through a GPS survey. This was done by determining the elevation of wells, USGS gauges, and acequia, etc. To assess the GPS measurements, we used different GPS observation sessions for the same points. In addition, a level survey was conducted for several points to determine the differences in elevations between these points. A comparison was made between both the GPS and the level measurements and insignificant differences were found.

Contact: Franck O. Kapoko Kamtchang, 2460 Fairway drive Apt C, Las Cruces, NM, 88011, 575-621-1283, kapoko@nmsu.edu

Association Between Drinking Water and Urinary Arsenic Concentrations: A Meta-Analysis of Biomonitoring Results in New Mexico

Leilani Schwarcz
Miriam Wamsley
Barbara Toth
Heidi Krapfl
NM Department of Health, 1190 St. Francis Drive, Suite N1300| Santa Fe, NM 87505
https://nmtracking.org/water, SF: (505)827-2461, ABQ: (505)222-8667

Poster Abstract 41

In New Mexico, along the Rio Grande Rift Valley, arsenic concentrations in groundwater range from < 1 µg/L to 600 µg/L. Approximately 90% of New Mexico's drinking water supply is from groundwater. The presence of arsenic in drinking water is a potential public health concern in areas of New Mexico where concentrations in groundwater are above the EPA maximum contaminant level (MCL) of 10 µg/L. The objective of this meta-analysis was to evaluate the association between arsenic in drinking water concentrations and arsenic body burden as measured by urinary arsenic levels among participants of biomonitoring projects in New Mexico.

We utilized data from three New Mexico Department of Health biomonitoring projects conducted from 2004 through 2012, which included volunteer participants residing in 76 communities. For this meta-analysis, 1013 adults were identified as eligible participants. They provided samples of their drinking water, a spot urine sample and completed an exposure assessment survey. Drinking water and urine samples were analyzed for total arsenic. Sample collections and analytical methods applied were similar among the biomonitoring projects, therefore, the testing results were pooled for meta-analysis. A multiple regression model was developed to evaluate the effect of drinking water arsenic concentration on urinary arsenic concentration, with adjustment for potential variables such as age, sex, dietary supplement use, tobacco use, fish/seafood consumption, and daily water consumption.

The final regression model is presented, including adjustment for variables along with correlation coefficients, and assumptions. Exposure to arsenic through drinking water can be controlled and minimized by consumers' health behavior changes. Future groundwater arsenic mapping or predictive arsenic groundwater transport models are needed to identify potential excessive arsenic exposure from groundwater sources used for drinking water.

Contact: Miriam Wamsley, MWR | Private Well Epidemiologist, Environmental Health Epidemiology Bureau| NM Department of Health, 1190 St. Francis Drive, Suite N1300| Santa Fe, NM 87505 https://nmtracking.org/water, SF: (505)827-2461, ABQ: (505)222-8667

Participant List

Leili Abkar
New Mexico State University, WERC

Joseph Affinati
University of New Mexico

Jennifer M. Allred
Office of the State Engineer

Greg Alpers
PVACD

Mikal M. Altomare
PNM

Kurt S. Anderson
New Mexico State University

Mark S. Anderson
Philmont Scout Ranch

Stephen Archuleta
Taos County

Rebecca Armenta
New Mexico State University

Elisa Arviso
Navajo Environmental Protection Agency

Kate Ayala
University of New Mexico

Scott Backhaus
Los Alamos National Laboratory

Daniel Bailet
EPCOR Water

Adam S. Baker
Baker Law Office

John E. Balliew
El Paso Water Utilities

Aron Balok
PVACD

Dawn K. Begay
Navajo Environmental Protection Agency

Darren P. Begay
Navajo Environmental Protection Agency

Ophelia A. Begay
State of Arizona

Robert P. Berrens
University of New Mexico

Laura M. Bexfield
US Geological Survey

Mark L. Bibeault
Los Alamos National Laboratory

David E. Bishop
NM Environment Department

Rico Blea
Office of the State Engineer

Daniel Bloedel
USDA/NRCS

David Bollschweiler
New Mexico State University, Retired

Claudia Borchert
County of Santa Fe

Paul Bossert
Office of the State Engineer

Nathan Bracken
Western States Water Council

Tom D. Brandt
NM Environment Department

Hilary Brinegar
Marron and Associates

John R. Brown
NM Water Dialogue

Cathrynn N. Brown
State Representative - District 55

Ayesha Burdett
NM Museum of Natural History & Science

Darcy S. Bushnell
Stell Water Ombudsman Program Director

Greg Bushner
Vidler Water Company

Colin Byrne
University of New Mexico

Jacob D. Caldwell
Caldwell Law Firm

Chris Canavan
NM Environment Department

Susan Carley
Citizen

Rick Carpenter
City of Santa Fe

Nancy Carrillo
Apex Education

Ann Carter
Office of the State Engineer

Lowell Catlett
New Mexico State University

Frank Chaves
Pueblo of Sandia

Cheng Cheng
INTERA Inc.

James A. Chiasson
NM Environment Department

Merle Chischilly
Navajo Environmental Protection Department

Kenneth R. Churan
Office of the State Engineer

Don Cole
City of Las Vegas

Adam D. Collins
Los Alamos National Laboratory

Filberto Cortez
US Bureau of Reclamation

Jean M. Coulton
Citizen

Robert Coward
Consultant

Doug Crosby
Office of the State Engineer

Elzbieta H. Czyzowska-Wisniewski
University of Arizona

Desa Daniel
NMSU Water Science and Management

Richard Davidson
Alamosa Land Institute

Tessa T. Davidson
Davidson Law Firm, LLC

Ray Dean
Trustee, Town of Carrizozo

Lee T. Dickman
Los Alamos National Laboratory/UNM

Carolyn Donnelly
Bureau of Reclamation

Dale M. Doremus
NM Interstate Stream Commission

Elizabeth Driggers
Office of Senator Tom Udall

Marcia B. Driggers
City of Las Cruces

Stephanie D. DuBois
NM Environment Department

Dave Dubois
New Mexico State University

David M. Ely
US Geological Survey

Katie Emmer
THEMAC Resources Group

Gary Esslinger
Elephant Butte Irrigation District

Michelle Estrada-Lopez
US Bureau of Reclamation

Jennifer Faler
US Bureau of Reclamation

Mike Fallwell
PVACD

Sam Fernald
NM Water Resources Research Institute

Seth Fiedler
NRCS/USDA

John Fleck
Albuquerque Journal

Linda Fluk
Self-Employed

Robert Flynn
New Mexico State University

Jean E. Foster
NM SWCS

R. Bruce Frederick
NM Environmental Law Center

Erek H. Fuchs
New Mexico State University

Juan Garcia
El Rito RWWA

Delfred Gene
Navajo Environmental Protection Agency

Eric Ghahate
North Central NM Economic Development District

Petuuche Gilbert
Pueblo of Acoma

Leonard Gilmore
University of New Mexico

Bill Goebel
Vermejo Conservancy District

Moises Gonzales
University of New Mexico

Rhea Graham
US Bureau of Reclamation

Michael C. Greene
PNM

Angela Gregory
University of New Mexico

Donna J. Griffin
City of Albuquerque

Armand Groffman
Los Alamos National Laboratory

Ryan Gronewold
US Army Corps of Engineers

Daniel Guevara
NM Environment Department

Steve Guldan
New Mexico State University

Mark Gunn
US Geological Survey

Karina Y. Gutierrez-Jurado
New Mexico State University

Grace Haggerty
NM Interstate Stream Commission

Em Hall
University of New Mexico

Mike Hamman
Bureau of Reclamation

Adrian Hanson
University of Minnesota Duluth

Steve Harris
Rio Grande Restoration

Steve Hartman
Vidler Water Company

Richard S. Hawkins
US State Department, retired

John W. Hawley
Hawley Geomatters/NM WRRI

Martin J. Haynes
SCM Partners

Mark L. Heil
Habitat Management, Inc.

Shelly Herbst
Marron and Associates

Steven L. Hernandez
Law Office of Steven L. Hernandez

Matt Holmes
NM Rural Water Association

Alan Hook
City of Santa Fe

Mary Humphrey
Humphrey & Ode PC

Lela Hunt
Interstate Stream Commission

Shokhrukh Jalilov
New Mexico State University

Roy Jemison
USDA Forest Service

Lijuan Jia
University of New Mexico

Michel Jichlinski
Augustin Plains Ranch

Navida C. Johnson
University of New Mexico

Randy Johnson
Johnson and Associates

Dudley Jones
Carlsbad Irrigation District

Constance L. Jones
University of New Mexico

Alvin Jones
PVACD

Racheal Jones
New Mexico State University

David Jordan
INTERA Inc.

Juan Juanico
Pueblo of Acoma

Judith L. Kahl
NM Environment Department

Ed Kandl
US Bureau of Reclamation

Franck Olivier Kapoko Kamtchang
New Mexico State University

Paul Karas
CDM Smith

Susan Kelly
Lawyer

Dan Keppen
Family Farm Alliance

Naima Khan
New Mexico State University

Sharon Kindel
Office of the State Engineer

Richard Kreiner
TetraTech

Leslie Kryder
City of Las Cruces

Walter Kuhn
Citizen

Greg Lewis
NM Interstate Stream Commission

Amy Lewis
ACL Hydrology

Andrew L. Lieuwen
Water Utility Authority

Christina S. Little
Interagency Council of Las Cruces

William M. Little
City of Las Cruces

Beiling Liu
NM Interstate Stream Commission

Dagmar Llewellyn
US Bureau of Reclamation

Lee D. Lockie
Citizen

Julie R. Maas
NM Interstate Stream Commission

Raymond Madson
DACC/NMSU

David Maidment
University of Texas at Austin

Julie Maitland
NM Department of Agriculture

Kent Malmquist
Office of the State Engineer

Josh Mann
Bureau of Reclamation

Rebecca L. Martin
New Mexico State University

Ramona Martinez
Office of the State Engineer

Palemon Martinez
Taos Valley Acequia Association

Savannah Martinez
University of New Mexico

Andrew P. Martinez
New Mexico State University

Art B. Mason
Citizen

Stephen D. Mastovich
Office of the State Engineer

Connie Maxwell
Alamosa Land Institute

Patrick McCarthy
The Nature Conservancy

Franklin D. McCasland
Arch Hurley Conservancy District

Edward N. McCorkindale
University of New Mexico

Joseph McGinn
Pueblo of Santa Ana

Yvette McKenna
US Bureau of Reclamation

Dennis McQuillian
NM Environment Department

Esteban Medina
City of Las Vegas

Erwin A. Melis
John Shomaker & Associates, Inc.

Dwight Menefee
PVACD

Richard Middleton
Los Alamos National Laboratory

Cindy M. Mitchell-Martinez
PNM

Samantha R. Montano
Office of the State Engineer

Paul Montoia
City of Farmington

Philbert Morgan
Navajo Environmental Protection Agency

Ryan R. Morrison
University of New Mexico

Mark Murphy
Hassayampa Associates

Wendell Murphy
Navajo Environmental Protection Agency

Cindy Murray
V.W.E. Partners

Nathan C. Myers
US Geological Survey

Bill Netherlin
PVACD

Mary Neu
Los Alamos National Laboratory

Christina Noftsker
Office of the State Engineer

Connie Ode
Humphrey & Ode PC

Adrian Oglesby
Middle Rio Grande Conservancy District

Darryll Olsen
Pacific NW Project

A.J. Olsen
PVACD

Fernando Ortiz
City of Las Cruces

Jeremy Osborne
Alpha Reclaim Technology

Josh D. Page
University of New Mexico

Laura Paskus
Reporter

Donatella Pasqualini
Los Alamos National Laboratory

Howard D. Passell
Sandia National Labs

Maxine N. Paul
University of New Mexico

Greg Pederson
US Geological Survey

Olga Pedroza
City of Las Cruces

Roger Peery
Shomaker & Associates

Page Pegram
NM Interstate Stream Commission

Andrea Pollock
NM Environment Department

Kris Polly
Water Strategies, LLC

Jennifer L. Pope
Adelante Consulting, Inc.

Jens Proche
Aquatic Informatics

Evans Ralston
New Mexico State University

Rob Randall
US Fish and Wildlife Service

Kristin E. Reardon
UC Davis

Steve Rice
US Geological Survey

Ken Rice
Bureau of Reclamation

Elizabeth H. Richards
RKR Farms, LLC

Rob Richardson
Bohannan Huston

Adam Ringia
Pueblo of Laguna

José A. Rivera
University of New Mexico

Jesse D. Roach
Sandia National Labs

Wayne Robbie
USDA Forest Service

Maria Del Pilar Rodriguez
University of New Mexico

Gabriel Romero
Taos County

John T. Romero
Office of the State Engineer

F.R. Bob Romero
El Valle de Los Ranchos Water & Sanitation District

Mark W. Rozman
Author

Dina Salman
NMSU Water Science and Management

James Salopek
Elephant Butte Irrigation District

Lauren Salvato
University of New Mexico

Zohrab A. Samani
New Mexico State University

Jeffrey Samson
University of New Mexico

Blane M. Sanchez
NM Interstate Stream Commission

Rudy S. Sanchez
District 39 - Doña Ana/Grant/Sierra

Charlie Sanchez Jr.
Valencia Soil & Water Conservation District

Ray S. Sandoval
Office of the State Engineer

Rolf Schmidt-Petersen
NM Interstate Stream Commission

Thomas J. Schmugge
NM Water Resources Research Institute

Jennifer Schuetz
Bosque Ecosystem Monitoring Program

Andrew Schuler
University of New Mexico

Krista M. Schultz
NM Environment Department

Gerald Schultz
NM RC&D

Erika Schwender
NM Environment Department

Reagan Scott
Alpha Reclaim Technology

Caroline Scruggs
University of New Mexico

Scott Sensanbaugher
City of Rio Rancho

Ryan J. Serrano
Office of the State Engineer

Herman Settemeyer
TX Commission on Environmental Quality

Sanna Sevanto
Los Alamos National Laboratory

Nabil Shafike
NM Interstate Stream Commission

Harmandeep Sharma
New Mexico State University

Christopher Shaw
NM Interstate Stream Commission

John W. Shomaker
John Shomaker & Associates

Chemanji Shu-Nyamboli
Pueblo of Laguna

Duncan Sill
North Central NM Economic Development District

Michelle K. Silver
Navajo Environmental Protection Agency

Amanda M. Simmons
University of New Mexico

Milan Simonich
Texas/New Mexico Papers

Erica R. Sinkey
Vidler Water Company

Wayne Sleep
NRCS/USDA

James Smith
Office of the State Engineer, Retired

Dick Smith
PVACD

Virginia L. Smith
Adelante Consulting, Inc.

Elizabeth A. Smith
NMSU Climate Center

Brian K. Snyder
City of Santa Fe

Gill M. Sorg
City of Las Cruces

Chris Stageman
NM Interstate Stream Commission

Chase Stearnes
University of New Mexico

Daniel Stephens
Daniel Stephens & Associates

James Stewart
Citizen

Cindy Stokes
NM Interstate Stream Commission

John M. Stomp
ABCWUA

Mark C. Stone
University of New Mexico

Cody L. Stropki
SWCA Environmental Consultants

Enid J. Sullivan
Los Alamos National Laboratory

April Jean Tafoya
UC Davis

Valerie Tannie
Navajo Environmental Protection Agency

Frederic Tate
TX Commission on Environmental Quality

George A. Taylor
LWV Los Alamos

Kathleen K. Taylor
LWV Los Alamos

Andrea C. Telmo
NM Environment Department/CPB

Matthew R. Thompson
Bohannan Huston

Sophia S. Thompson
University of New Mexico

David C. Thompson
New Mexico State University

Bruce Thomson
University of New Mexico

Armer Tim
North Central NM Economic Development District

Dorothy Timian Palmer
Vidler Water Company

Stacy Timmons
NM Bureau of Geology

Annelia Tinklenberg
INTERA Inc.

Mark J. Toledo
Navajo Environmental Protection Agency

David Torres
NM Environment Department

Martin C. Torrez
NM Environment Department

Tanya Trujillo
Colorado River Board of CA

Ted J. Trujillo
County of Rio Arriba

William M. Turner
WaterBank

John Tysseling
Moss Adams, LLP

John Utton
Sheehan & Sheehan

Paul van Gulick
Eastern NM Water Utility Authority

Vicente Vargas
NMSU Government Relations

Elizabeth Verdecchia
International Boundary and Water Commission, US Section

Scott Verhines
New Mexico State Engineer

Rebecca A. Wacker
University of New Mexico

Whitney Waite
The Waite Company

Steve Walker
NM Water Resources Research Institute

Charles Walter
NM Museum of Natural History & Science

Miriam L. Wamsley
NM Department of Health

Ryan Ward
NM Department of Agriculture

Laura Watchempino
Pueblo of Acoma

Larry Webb
City of Rio Rancho

Linda S. Weiss
US Geological Survey

Robert M. Wessely
Las Vegas Community Water Board/Middle Rio Grande Water Assembly

Peter T. White
Attorney

Kaye Whitefoot
Dairy Producers of New Mexico

Amber Whittaker
INTERA Inc.

Stephen L. Wilmeth
Doña Ana Soil & Water Conservation District

Michel Wingard
University of New Mexico

Peter Wirth
State Senator - District 25

Jeff M. Witte
NM Department of Agriculture

Charles A. Wohlenberg
Office of the State Engineer, Retired

Marian Wrage
City of Rio Rancho

Melissa Yazzie
Navajo Environmental Protection Agency

Lydell Yazzie
Navajo Environmental Protection Agency

Michael Young
Soilutions, Inc.

Katherine Yuhas
Water Utility Authority

Hamed Zamanisabzi
New Mexico State University

Yizhi Zhao
New Mexico State University