PROCEEDINGS OF THE 65TH ANNUAL NEW MEXICO WATER CONFERENCE

Meeting New Mexico's Pressing Water Needs: Challenges, Successes, and Opportunities

NM WRRI REPORT NO. 411



OCTOBER 26-29, 2020

VIRTUAL CONFERENCE WEBINAR

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65th Annual
New Mexico Water Conference

NM WRRI Report No. 411

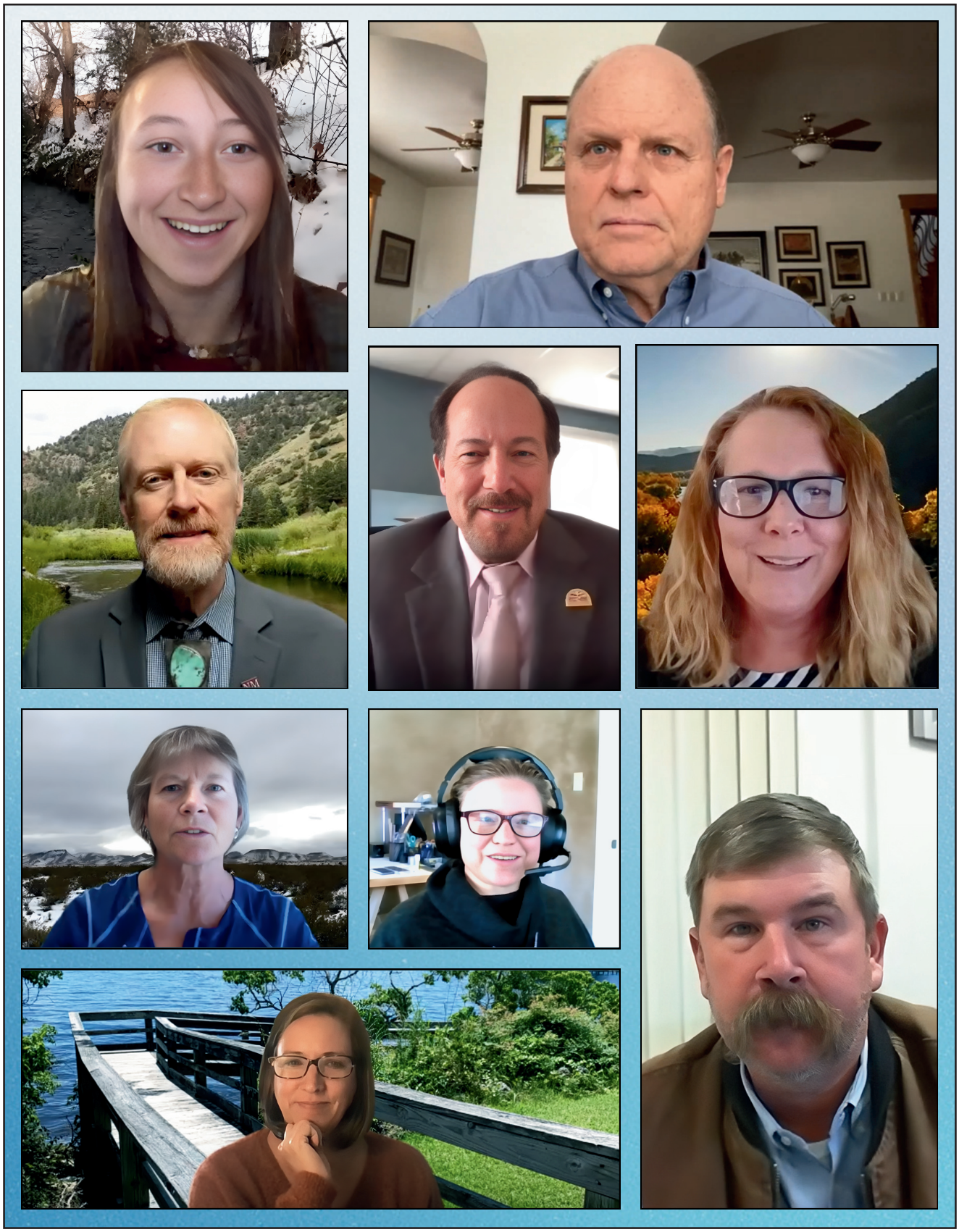
Meeting New Mexico's Pressing Water Needs: *Challenges, Successes, and Opportunities*

October 26-29, 2020
Virtual Conference Webinar

Hosted by:

NEW MEXICO
WATER RESOURCES
RESEARCH INSTITUTE

Over 250 participants from around New Mexico and the region joined in NM WRRI's first ever all-virtual webinar.




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Bruce Thomson, The University of New Mexico
Alex Rinehart, New Mexico Tech
Pei Xu, New Mexico State University
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2020 NM WRRI Water Conference Advisory Committee

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Aron Balok, Pecos Valley Artesian Conservancy District
Katrina Bennett, Los Alamos National Laboratory
Daniel Cadol, New Mexico Institute of Mining and Technology
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Peter Castiglia, INTERA Inc.
Caren Cowan, NM Cattle Growers' Association
John D'Antonio, Jr., NM Office of the State Engineer
Kristina Eckhart, NM Office of the State Engineer
Gary L. Esslinger, Elephant Butte Irrigation District
Amy Ewing, Daniel B. Stephens and Associates, Inc.
Paula Garcia, New Mexico Acequia Association
Ryan Gronewold, U.S. Army Corps of Engineers
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Bruce Thomson, The University of New Mexico
Vince Tidwell, Sandia National Laboratories
Stacy Timmons, NM Bureau of Geology & Mineral Resources
Lani Tsinnajinnie, The University of New Mexico
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Program

Meeting New Mexico's Pressing Water Needs: *Challenges, Successes, and Opportunities*

October 26-29, 2020
Zoom Webinar

Tuesday, October 27:

10:50 am **Greeting**
Sam Fernald, NM WRRI Director

10:55 **Congressional Video Statements**

11:00 **Welcome and Introduction**
Dan Arvizu, Chancellor of New Mexico State University

11:05 **Keynote Presentation**
Tom Udall, U.S. Senator

11:20 **Water Abundance and Shortfall in New Mexico from a Statewide Water Budget Perspective**
Sam Fernald, NM WRRI Director
This session will include a video tour of water budget components viewed around New Mexico as well as live polling of conference attendees

11:40 **Giveaway Drawing and Break**

12:00 pm **Session 1: International Water Scarcity Challenges**
Moderated by **Sam Fernald**, NM WRRI Director

Tom Udall, U.S. Senator
Jeffrey Max Jones, former federal senator for the State of Chihuahua
Mike Muller, University of the Witwatersrand
Rubén Chávez Guillén, former groundwater manager for CONAGUA (Mexico)
Christopher Wilson, Mexico Institute at the Woodrow Wilson International Center for Scholars

1:15 **Session 2: Spotlight on Navajo Nation and the Nexus of Coronavirus and Water**
Moderated by **Cyrytal Tulley-Cordova**, Navajo Nation Department of Water Resources

Jonathan Nez, President of the Navajo Nation
Amber Kanazbah Crotty, Navajo Nation Council Delegate
Mark Begay, To'Hajiilee Chapter President
David Harvey, Indian Health Service

Breakout Session: Building Tribal Water Capacity Through Partnerships

2:15 **Giveaway Prize Drawing and Webinar Evaluation**

2:30 pm **Adjorn**

Wednesday, October 28:

10:55 am **Webinar Participation Guidelines**

11:00 **Update from the Office of the State Engineer**
John D'Antonio, Jr., New Mexico State Engineer

11:20 **Session 3: Water Use and Conservation**
Julie Valdez, New Mexico Office of the State Engineer

11:40 **Session 4: High-Recovery Desalination to the Rescue: Making an Alternative Water Resource a Reality**
Ronit Erlitski, AdEdge Water Technologies

12:00 pm **Giveaway Drawing and Break**

12:30 **Session 5: Evaluating Water Policy in New Mexico**
Moderated by **Aron Balok**, Pecos Valley Artesian Conservancy District
Rep. Melanie Stansbury, NM House District 28
Rep. Derrick Lente, NM House District 65

1:15 **Session 6: New Perspectives on Water Data**
Moderated by **Stacy Timmons**, New Mexico Bureau of Geology and Mineral Resources
Ashley Ward, Internet of Water
Meredith Lee, West Big Data Innovation Hub
Adel Abdallah, Western States Water Council

2:00 **Giveaway Drawing and Webinar Evaluation**

2:15 **Virtual Poster Session, Part 1**
Poster Presenters will be available for one-on-one discussion in individual virtual breakout rooms available to conference participants

3:45 pm **Adjourn**

Thursday, October 29:

9:30 am **Virtual Poster Session, Part 2**
Poster Presenters will be available for one-on-one discussion in individual virtual breakout rooms available to conference participants

10:55 **Webinar Participation Guidelines**

11:00 **Albert E. Utton Memorial Water Lecture**
Michael L. Connor, WilmerHale LLP, former U.S. Deputy Secretary of the Interior

11:45 **Session 7: Impacts in New Mexico of Revised Clean Water Act Jurisdiction**
Shelly Lemon, New Mexico Environment Department
Justin Riggs, U.S. Army Corps of Engineers

12:30 pm **Giveaway Drawing and Break**

12:45 **Session 8: Watershed Restoration in New Mexico**
Moderated by **Connie Maxwell**, NM WRRI

Laura McCarthy, New Mexico State Forester
Collin Haffey, The Nature Conservancy
Zach Libbin, Elephant Butte Irrigation District

1:45 **Session 9: Produced Water Research in New Mexico**
Moderated by **Robert Sabie**, NM WRRI

Part A: New Mexico Universities Produced Water Synthesis Project
Stephanie Russo Baca, Utton Transboundary Resources Center
Martha Cather, Petroleum Recovery Research Center, New Mexico Tech
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Saeed Langarudi, New Mexico State University

Part B: New Mexico Produced Water Research Consortium
Rebecca Roose, New Mexico Environment Department
Mike Hightower, New Mexico Produced Water Research Consortium

3:10 **Giveaway Drawing and Webinar Evaluation**

3:15 **Closing Reflections by the Water Conference Advisory Committee**

3:45 pm **Adjourn**

Water Abundance and Shortfall in New Mexico from a Statewide Water Budget Perspective



Alexander "Sam" G. Fernald, New Mexico Water Resources Research Institute

Alexander "Sam" G. Fernald was appointed director of the New Mexico Water Resources Research Institute (NM WRRI) in July 2013 after having served as interim director since January 2011. As director, he leads the Institute in its mission to develop and disseminate knowledge that will assist the state, region, and nation in solving water resources problems. Dr. Fernald is also the program chair of the Water Science and Management Graduate degree program, where he establishes, initiates, and leads all academic, programmatic, budgetary, administrative, and instructional aspects of the program. Additionally, he is a professor of Watershed Management in the Department of Animal and Range Sciences at New Mexico State University.

Dr. Fernald's earned degrees include a 1987 B.A. in international relations from Stanford University, an M.E.M. in 1993 in water and air resources from Duke University, and a Ph.D. in watershed science from Colorado State University in 1997. He was also a National Research Council Postdoctoral Fellow from 1997-2000 for the U.S. EPA.

New Mexico Water Resources Research Institute collaborated with New Mexico Tech, the New Mexico Bureau of Geology and Mineral Resources, the U.S. Geological Survey, and the New Mexico Office of the State Engineer, to put together the New Mexico Dynamic Statewide Water Budget (NMDSWB) that brings together the main fluxes and storage components of water in New Mexico at four different scales: counties, planning regions, river basins, and the state. The green rectangle in the middle of Figure 1 corresponds to about 3.7 million acre-feet of water use a year. This information is prepared for the Office of the State Engineer's Water Use by Categories Report. This model compiles about 30 million data points to show the historic period from 1975 to 2018, and estimates some future changes until 2099.

For example, it is really important to understand groundwater storage as illustrated in Figure 2. If you compare Lea County (shown in blue) with Socorro County

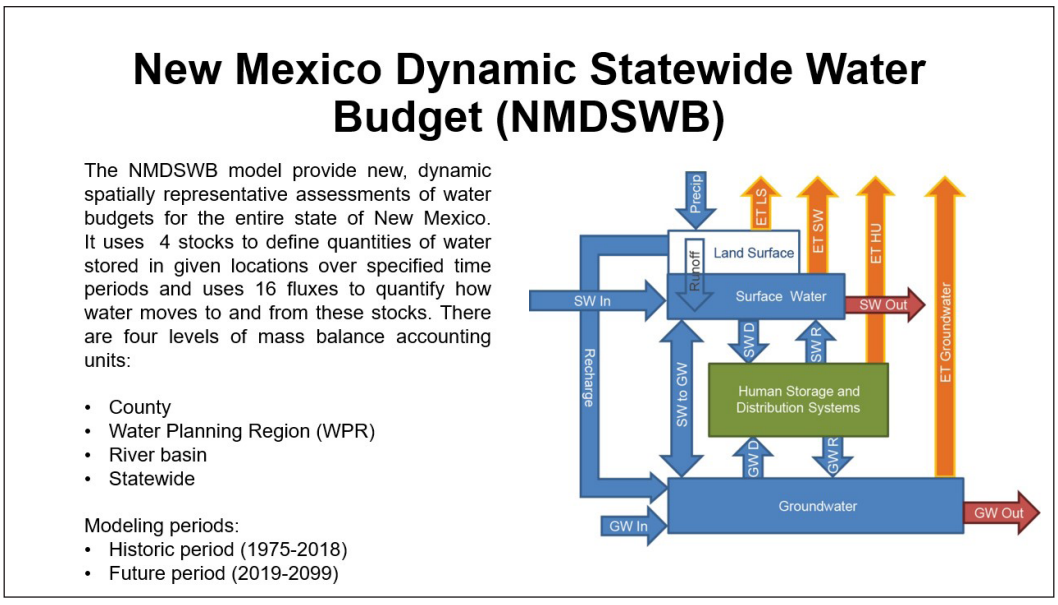


Figure 1. The New Mexico Dynamic Statewide Water Budget (NMDSWB).

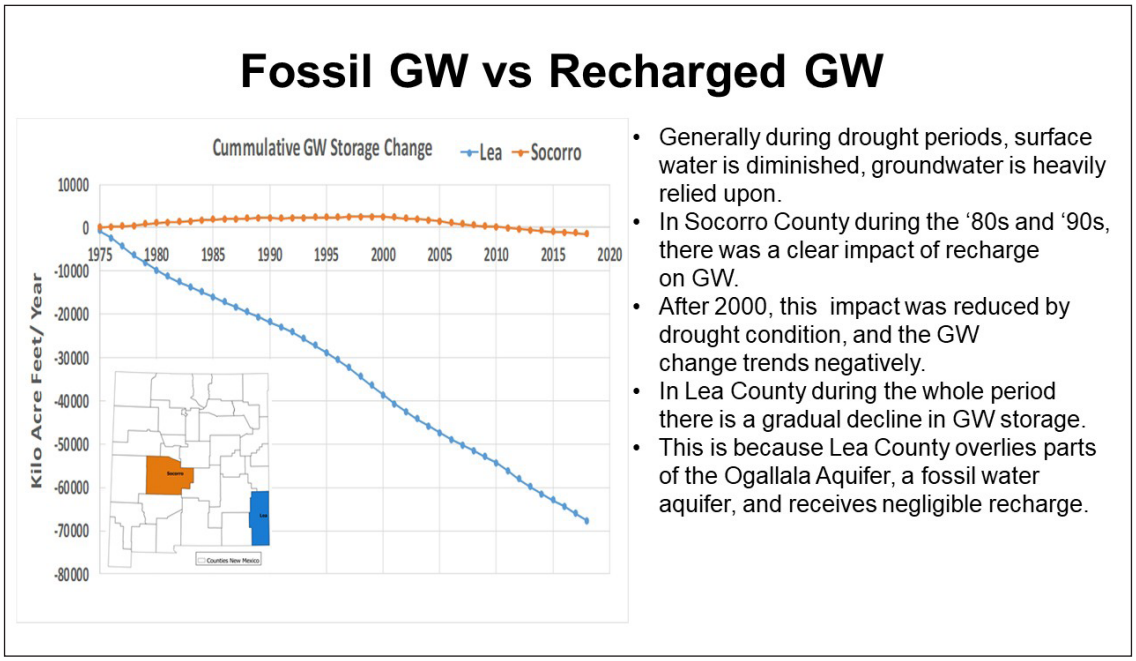


Figure 2. Fossil groundwater versus recharge groundwater in Lea and Socorro Counties.

(shown in orange), you see that Lea County does not have access to a river that recharges groundwater. The aquifer is essentially leftover fossil groundwater, and you will see this continual decline because there is essentially no recharge. On the other hand, if you look at Socorro County, where the Rio Grande is running through the county, we see gradual increases in groundwater storage until the 90s, when that turned around and we saw gradual decreases. Therefore, it is very important to consider recharge when you think about groundwater.

Figure 3 is another picture depicting groundwater depletions in the basin. The Rio Grande is outlined in black, and it fluctuates from year to year. We had more of a declining trend in the 90s, with Rio Arriba County showing little fluctuation and a general long-term equilibrium in groundwater storage. In Bernalillo County, there was depletion until the San Juan–Chama Project diversions began, and then there was less depletion. For the lower Rio Grande in Doña Ana County, we see decreasing groundwater storage and ongoing fluctuations. Different fluctuations occur depending on where you are in the state.

Senator Udall’s comments on the changes in runoff are reflected in Figure 4. In Doña Ana County (shown in orange), we see fewer surface water withdrawals starting in the late 90s and 2000s. Because less surface water is available, there is a concomitant increase in groundwater withdrawals. Surface water withdrawals in Bernalillo County (shown in blue) increased due to the San Juan–Chama diversion, which led to reduced groundwater withdrawals. Over this same period in Rio Arriba County (shown in green), groundwater withdrawals were unchanged.

Using the NMDSWB, Figure 5 shows that total surface water and groundwater withdrawals for agriculture in Doña Ana County decreased from 1975 to 2018. Return flows, where water goes back to the river through surface water or groundwater, have declined because of changing evapotranspiration and changing irrigation technology. It does not make sense to have as much flood recharge if you are pumping groundwater. Interestingly, depletions (shown in green), that is, the actual water consumed and sent back to the atmosphere, are more or less stable, allowing us to use that information to guide our planning.

Figure 6 shows predicted groundwater storage change. Groundwater diversions (upper right) indicate that high-efficiency agriculture uses less groundwater. By anticipating the future impacts of climate change and variability, we can make a difference with high-efficiency agriculture and reduce our long-term groundwater storage depletion. We can use this research to guide our policy, our technology, and our changes. That concludes my brief tour of the NMDSWB.

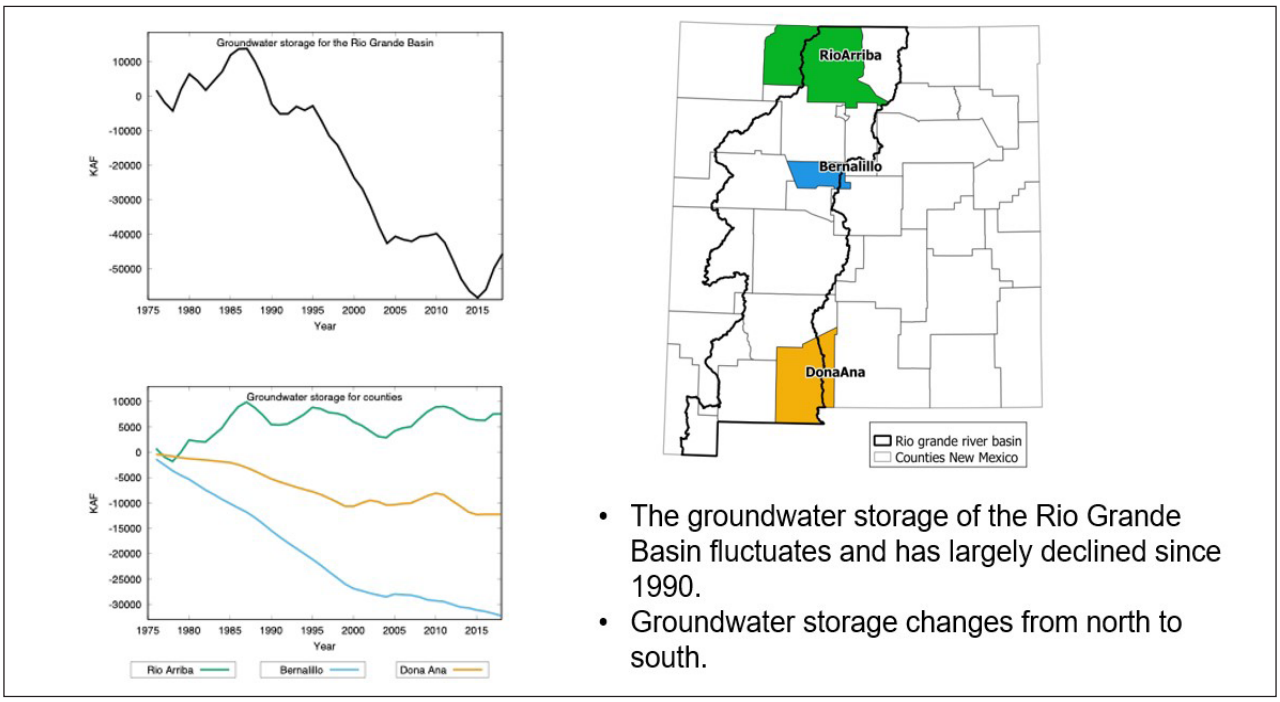


Figure 3. Groundwater depletion in counties.

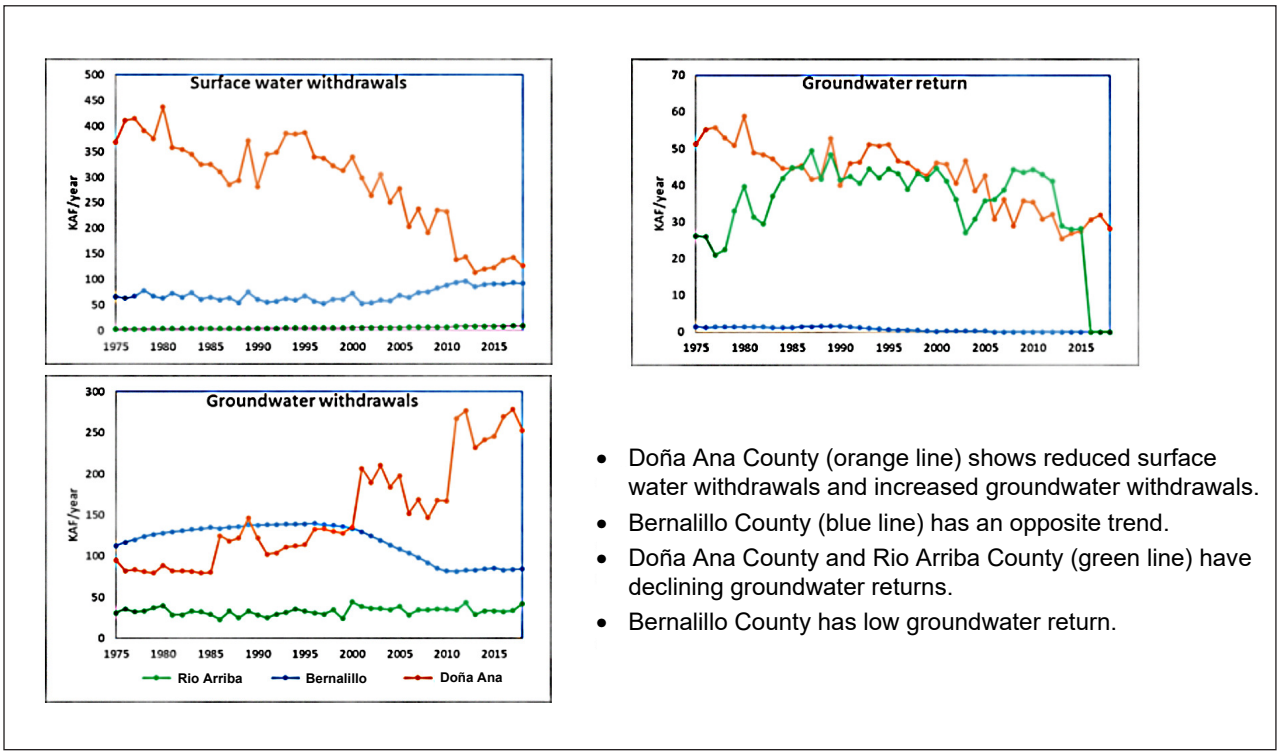


Figure 4. Surface and groundwater withdrawals in Rio Arriba, Bernalillo, and Doña Ana Counties.

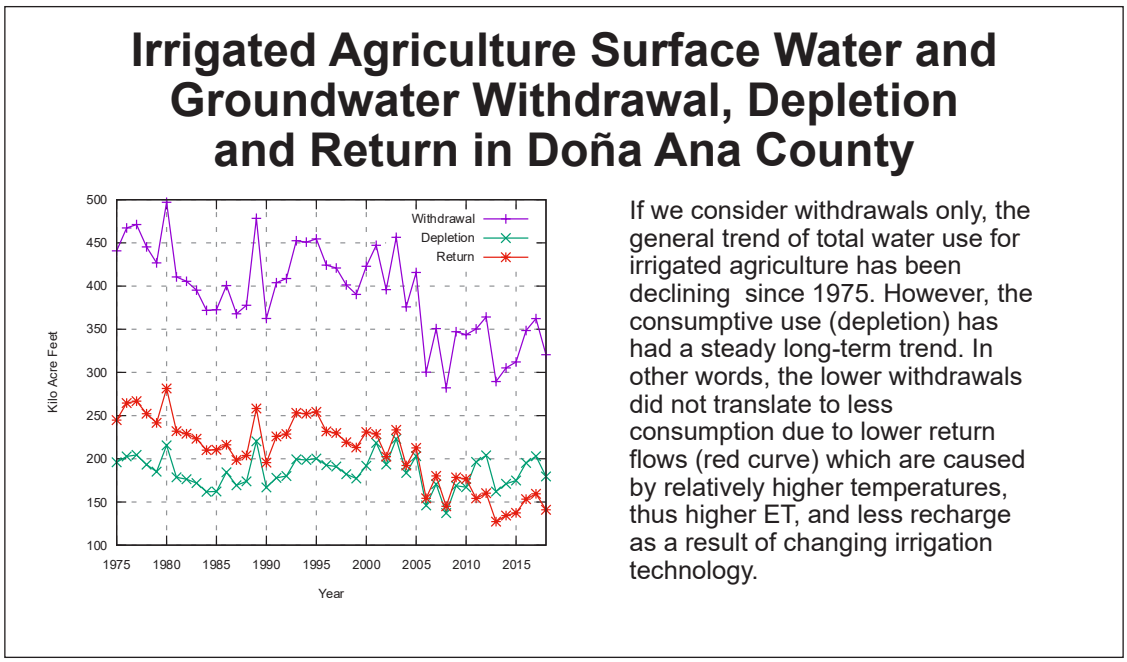


Figure 5. Groundwater withdrawal, depletion, and return in Doña Ana County.

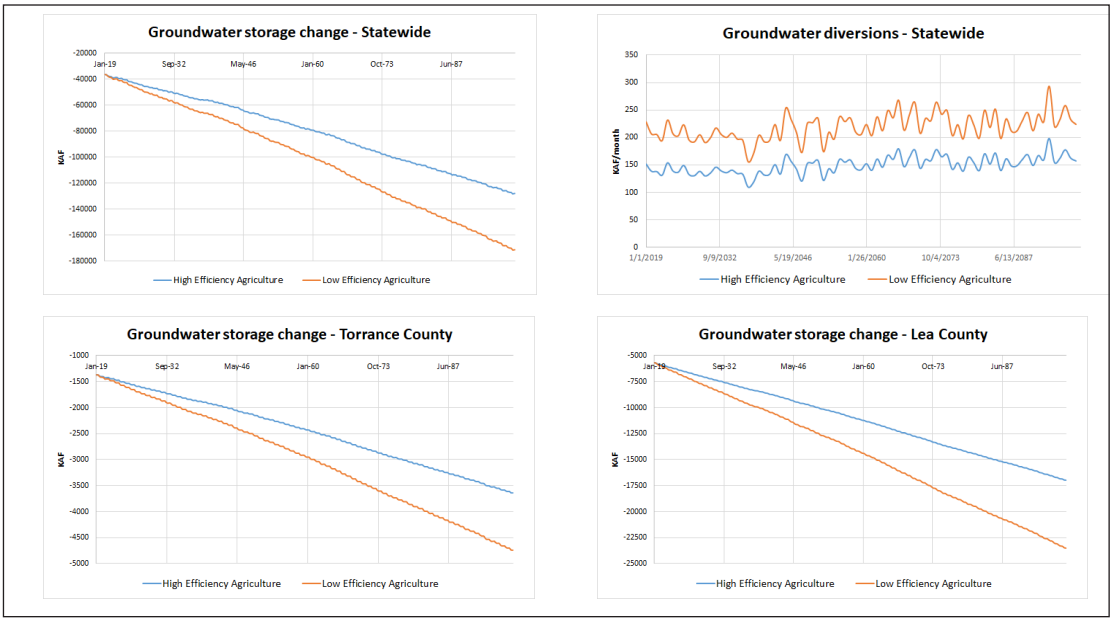
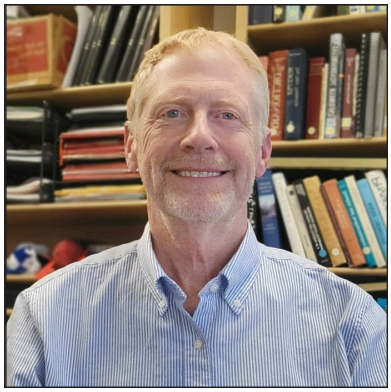


Figure 6. Predicted groundwater storage change (2019–2099).

International Water Scarcity Challenges



Moderated by Alexander "Sam" G. Fernald, New Mexico Water Resources Research Institute

Alexander "Sam" G. Fernald was appointed director of the New Mexico Water Resources Research Institute (NM WRRI) in July 2013 after having served as interim director since January 2011. As director, he leads the Institute in its mission to develop and disseminate knowledge that will assist the state, region, and nation in solving water resources problems. Dr. Fernald is also the program chair of the Water Science and Management Graduate degree program, where he establishes, initiates, and leads all academic, programmatic, budgetary, administrative, and instructional aspects of the program. Additionally, he is a professor of Watershed Management in the Department of Animal and Range Sciences at New Mexico State University.

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Editor's Note: This panel discussion was transcribed from the speakers' remarks made at the conference. No follow-up was made with the panelists and the editor assumes responsibility for any transcription or editing errors.

I'd like to introduce the members of this panel and tell you a little bit about what's happening. We have some delivery issues you might have heard about with the United States and Mexico pertaining to the Rio Grande. There will be ongoing discussions about surface water deliveries and future challenges with groundwater in terms of internationally shared water resources. Senator Udall mentioned his support of the Transboundary Aquifer Assessment Program when he spoke earlier. This panel was brought together in an effort to look ahead and consider how we can take some of our research perspectives to meet international water scarcity challenges with science and policy.

First, I will introduce our panelists and then provide discussion questions. Senator Tom Udall has been a U.S. Senator since 2009, after two decades as a U.S. Representative for New Mexico. Senator Udall will be joined by Jeff Jones, who served in the Mexican government as a federal Congressman, a Senator, and the Undersecretary of Agribusiness Development in Mexico's Secretariat of Agriculture. Mr. Jones is from Chihuahua, and we thank him for joining us. Mike Muller is a civil engineering professor at the Wits School of Governance in South Africa. He was previously a member of the Global Water Partnerships technical committee from 2005 to 2011, and director general of South Africa's Department of Water Affairs from 1997 to 2005. Rubén Chávez Guillén is a civil engineer who has held offices in Mexico in various water resources positions, most recently as director of groundwater for CONAGUA (the National Water Commission) in Mexico. He is now a consultant and working member of the Mexican Geohydrological Association, and also works as a committee member of the Association of Mexican Civil Engineers. Finally, Chris Wilson will round out our panel. Chris is the deputy director of the Mexico Institute at the Woodrow Wilson International Center for Scholars where he leads the institute's programming on regional economic integration and U.S.-Mexico border affairs. He has authored a number of reports on the U.S.-Mexico border.

In the same order as the introductions, our panelists will reflect on some of the questions put together to guide this discussion while also allowing time for open discussion. Starting with Senator Udall: From your perspective, what are the impacts of water scarcity and how has water scarcity affected your work?



Tom Udall, U.S. Senator

Tom Udall has earned a reputation as a principled leader who has the integrity to do what is right for New Mexico and our nation. Tom began serving as a U.S. senator in 2009, after two decades of public service as a U.S. Representative and New Mexico's state attorney general. He was reelected to the U.S. Senate in 2014 and is now New Mexico's senior senator.

Tom earned his undergraduate degree at Prescott College and obtained a Bachelor of Laws degree from Cambridge University in 1975. He graduated from the University of New Mexico Law School in 1977. Tom then served as a law clerk to chief justice Oliver Seth of the U.S. Tenth Circuit Court of Appeals and became a federal prosecutor in the U.S. Attorney's criminal division. As chief counsel to the New Mexico Department of Health and Environment, he fought for stronger environmental and health protections.

Tom is married to Jill Cooper, who is a former attorney and a longtime advocate for the arts. They have one grown daughter, Amanda, and they live in Santa Fe.

Editor's Note: This panel discussion was transcribed from the speakers' remarks made at the conference. No follow-up was made with the panelists and the editor assumes responsibility for any transcription or editing errors.

Thank you so much for that question, Sam. It's great to be here with all of these panelists. First of all, I think you have to start with water scarcity. It constricts almost everything, not just our present but our future. One of the best ways to put policy into action in that regard is to be frugal with the resource. On the individual level, that means we have to reduce our per-person consumption as much as possible. Our cities are currently doing this. In New Mexico, cities look at per-gallon per-person use and say, "We're doing a better job compared to other cities." It gets a little bit competitive. This is a great thing in the public sector. In the private sector, this means that farmers and companies have to figure out how to operate more efficiently. Government also has to invest in infrastructure, such as desalination in some cases and, in other cases, pipelines to distribute water.

One of the things that I've seen in our tri-state region of New Mexico, Texas, and Chihuahua, is how dwindling supplies are subject to international treaties. This raises tensions between farmers and the government on both sides of the border between Mexico, the United States and between our bordering states. It's obvious and absolutely clear that we need good science to advise and guide our policy makers to mitigate these tensions and build cooperation. I have tried to aid in this by pushing for funding from Congress to study the impacts of pumping on shared aquifers across international borders.



Jeffrey Max Jones, Former Federal Senator for the State of Chihuahua

Jeffrey Max Jones has served in the Mexican government as federal congressman (1997–2000), federal senator (2000–2006), and undersecretary of agribusiness development (2006–2009) at Mexico's Secretariat of Agriculture. During this period, he was part of the upswing of the political transition from the 71-year, single-party control over the executive and legislative branches to the current scenario, with its evolved, competitive electoral system.

A native of Nuevo Casas Grandes, Chihuahua, Mexico, he grew up in a family involved in several agribusiness operations in northwestern Chihuahua. Upon graduating from Brigham Young University in 1982 (international relations), he returned to Mexico as an entrepreneur during the inflationary eighties, and during his business career, he became frustrated with the government's irresponsible monetary policies leading to a 12-year stint in politics. As senator, Jeff presided over the Border Affairs Committee. As undersecretary at the Ministry of Agriculture, he focused on prospective planning and modeling, market development, and rural finance. Jeff is an avid defender of limited government and the crucial role of open markets in the development of any nation.

He is fluent in English and Spanish, and is currently back in the private sector where he has been involved in a new start-up called Enerlogix Solutions, an energy management company betting on the opening of Mexico's new energy market. Previously he helped two US venture capital and private equity funds get established in Mexico. Jeff is a pilot and enjoys riding horses on his cattle ranch. He and his wife, Michelle, are parents to four daughters and four grandchildren.

I think this is one of the critical issues in any of these debates in this region where there is increasing economic activity, particularly in an area like Ciudad Juárez. I think the unclear policy for handling water needs to be addressed to be able to understand what to do about water scarcity.

I first became involved with this issue when I was a federal congressman and senator from 1997 to 2006. There was an issue with the farmers complaining about the cost of electricity that they were paying for their aquifer. They were asking for a very low rate for electricity, it was 14 cents in pesos. The argument I made at that time was that the problem we had was not the price of electricity, because it was, and continues to be, a very minimal cost. It's really the only cost to use water here. In Mexico, it's around two to three cents a kilowatt hour in terms of dollars. The problem, I argued at the time, was that we didn't have control over the aquifers. We were putting more and more wells into these aquifers that were overexploited, and the wells would need to be deeper every year. Going deeper into the aquifer meant an increasing exponential cost to pulling water out from the aquifers. So, my argument was that we needed to regulate aquifers to drop the cost of electricity on water, a scarce resource, otherwise we are not going to have good solutions. At the time, we worked on three basic issues that I felt were important. One was to put more of the decision-making power into the hands of local people. We created what we call the COTAS, (Comités Técnicos de Aguas Subterráneas), which are the groundwater councils, so that local water users would have part of that decision-making power. This is one of the great problems that we have in Mexico because water is a national issue and there is no local control over it. Of course, the ones really interested in that decision-making process are the local people, but that is an issue that still has not been addressed.

The other thing that we were working on at the time was getting good information to make well-informed decisions. While working to get these COTAS created, we also worked on geohydrological studies for each of the closed aquifers. Getting good, solid information so that you know exactly the capacity of each of these aquifers was a major challenge as well.

The third element that we were working on was to find out exactly how much we were extracting from these aquifers, that is, how many wells there were in these aquifers, so that people were well informed on their resources.

The issue was how you administer a resource. If you don't know how much you have and you don't know how much you're taking out of those aquifers, you've got a serious problem. There were challenges to each of those issues. I'll be glad to comment on those as needed, but these were some of the issues that we were working on.

Generally speaking, I think a problem that we have in Mexico is the lack of democratic institutions in terms of making these types of decisions. The fundamental problem you'll see in the Rio Grande Basin (or the Rio Bravo, as it's called in Mexico) and the water in Chihuahua and Boquillas is the lack of democratic decision-making. Not only with the closed aquifers that are controlled by the COTAS, but also with the waters in the Consejo de Cuenca, or the basin council, which is dysfunctional. It

frustrates a lot of people because there is no good, solid debate over these issues and how to handle them. In the case of the Rio Bravo Cuenca, or basin, it's not an international issue, but an issue of the users that have rights along that river, and that's where it needs to be solved. Some of the root users happen to be on one side of the border, and some of the users happen to be on the other side of the border. But there needs to be a high-quality debate and good institutions for looking at the technical challenges that there are and for making decisions.

I believe one of the big issues that we have here in Chihuahua in this current crisis is the very centralist perspective of the federal government making decisions without taking into account the perspectives of the people that are the users of this water. That's when you get into trouble.



Mike Muller, University of the Witwatersand

Mike Muller a professional civil engineer and visiting adjunct professor at the Wits School of Governance, advises many public and private organizations on water and development issues. As a national planning commissioner (2010–2015), he focused on infrastructure, environment, and regional development issues. He chaired the World Economic Forum's Agenda Council on Water (2012–2014) and was a member of the Global Water Partnership's Technical Committee (2005–2011). As Director General of South Africa's Department of Water Affairs and Forestry (1997–2005), Mike led the development of new policies, legislation, and programs in water resources and services that provided safe water to over 10 million people and reached over 90 percent of South Africans by 2012. He was a cofounder of the Mvula Trust (1992) and managed water supply and sanitation programs and utilities, coordinating donor-funded projects and running an innovative urban sanitation program for the Mozambican government (1979–1988). Current research interests include water governance and management at different scales, the contribution of water to regional development, and challenges of managing climate variability and change.

Good evening to you from Johannesburg. Thank you very much for the invitation.

One always wonders what there is that we can talk about from so far away about something as very complicated and local as water. Listening to Jeff talk about the problems of groundwater basins across communities reminds us that water is a very local issue. What we found in South Africa is that we were able to start from scratch, considering we had the good fortune of having quite a large political change in 1994, and we were able to rewrite a lot of our legislation and our policy. Additionally, we were able to learn from a lot of the efforts and mistakes, as well as the successes, of lots of other people. I think it was one of the water lawyers, Joe Sax, who said, "I wouldn't follow any one particular model from the USA. We can provide you with 50 different examples of the mistakes you can make." We certainly took this to heart and worked quite closely with Bruce Babbitt when he was Secretary for the Interior. I'm also grateful to Ambassador Delano Lewis, who had served two years here as an ambassador ahead of the World Summit on Sustainable Development. We really did learn a lot, and I hope we've actually demonstrated it. What we've managed to do, as opposed to what we wanted to do, is another matter.

Turning to scarcity, I work quite a lot in the sub-Saharan African continent. I'm also involved in the very contentious Nile dispute. One of the things we learned is that water scarcity is quite a complex issue. The first kind of scarcity we have is the kind you've been discussing, where there really just isn't enough water for the people who are trying to do things with it. You then have to create some sort of arrangement to share water because that's all there is. Physical water scarcity is a concern in many places, but across Africa there are many places that have plenty of water, and yet the farmers can't get reliable irrigation and people can't get reliable drinking water. This is economic scarcity.

Taking a look at the water world maps, we can see places where water is physically scarce, like New Mexico, and those places where water is economically scarce, such as southern and eastern Africa. Southern and eastern Africa have plenty of water, but do not have the resources to move it. Of course, you can have the water and you can have the money, but you also need management, and that includes governance. I understand the challenges of governance in Mexico well after listening to Jeffrey Jones. In fact, we consulted with CONAGUA when we were busy developing water laws. You can have as much money and as much water as you like, but if your institutions aren't working, you won't create any progress. It is important for us to understand that scarcity has these different dimensions: it's physical, economic, and institutional.

We also must recognize the problems that we create for ourselves by scale. By scale, I'm talking about the geography. We use the watershed as a scale for our analyses very often, but there are other scales. Senator Udall, you don't represent a river, you represent the state, a very proud state. The political scale is also important. Yet, there is a third scale also represented on the panel, and that is the *problem shed*. There, you have a set of physical systems that cross a couple of political boundaries, and somehow you need to get the physical system working together with the political boundaries. It is sometimes quite useful to say, "Here's the problem shed. This is the boundary around the people who we are going to have to work with." I have found that concept to be very useful, particularly in a changing world, because what you find is that the watersheds might stay constant, but the problem sheds are changing all the time, and we need to consider this.

In dealing with scarcity, I always like to think about the different scales and what kind of scarcity we're trying to deal with. I find your challenges there in the southwestern United States very interesting. You have groundwater, you have inter-basin transfers, and you have international cooperation. You've chosen your problem shed well. You can't complain of a shortage of challenges, but you seem to be on your way to dealing with them. So, it's very exciting to listen in.



Rubén Chávez Guillén, former Groundwater Manager for Conagua (Mexico)

Rubén Chávez Guillén is a civil engineer with a master's degree in hydraulics from the National Autonomous University of México (UNAM). From 1968 to 2018, he held a position at the Department of Water Resources (SRH), Department of Agriculture and Water Resources (SARH), and National Water Commission (CONAGUA), where he participated in the execution and validation of aquifer studies at a national level and collaborated in the development of legal regulations related to water resources. He represented the CONAGUA in national and international events on topics such as climate change, transboundary aquifers, unconventional and geothermal reservoirs, artificial recharge, and others. He taught courses on hydrogeology and related disciplines at the College of Engineering of UNAM (1969–1984), courses in graduate programs in the Mexican States of Chihuahua and Nuevo Leon Universities, and courses, seminars, and conferences on water resources at Monterrey Institute of Technology and Higher Education (ITESM). He is a consultant and an active member of the Mexican Geohydrological Association and committee member of water resources in the Association of Mexican Civil Engineers (CICM).

Editor's Note: This paper transcribes the speaker's remarks from the conference. No follow-up paper was submitted, and the remarks were edited for publication by the editor. The speaker did not review this version, and the editor assumes responsibility for any transcription or editing errors.

Good day to everyone. Thank you for the invitation to talk about scarcity. As the first speaker already mentioned, there is no doubt that this scarcity is going to affect all sectors, directly or indirectly. All of us absolutely depend on the availability of water. Water is life, and in a scarcity scenario, it's obvious that it is going to be a factor that limits economic development and development in general. And not just in the future, it even compromises current development, especially in regions where the impacts of climate change will accentuate scarcity. In particular, if we look at the northern strip of Mexico bordering the United States, where we share various sources of surface water and groundwater, there is no doubt that it is one of the most problematic zones in the world in terms of water resources. This is because this area is in one of the largest desert zones in the world. Therefore, we can talk about natural-occurring water scarcity and the fact that groundwater in this northern strip is almost non-renewable. We would have to learn how to regulate this non-renewable resource to a human water consumption scale. Managing this resource would mainly depend on proper administration.

Fortunately, after 40 years of collaborating with the Mexican Hydrologic Authority, one can say that this issue has received some attention. Not as much as one would hope, but some, if only intermittently. Hot spots, or potential areas of conflict that could possibly cause transboundary effects, were identified. Specifically, the Hueco Bolson in Ciudad Juárez/El Paso was identified a long time ago as one of the most problematic zones. At

the same time, the Lower Colorado River Basin, where we have very specific problems in the management of surface water and groundwater, was identified. There we are talking about natural-occurring scarcity because precipitation in Mexico is 100 millimeters per year. Consequently, natural recharge would be almost null if we did not have the water allocation from the Colorado River that pertains to us in accordance to the corresponding international treaty. Therefore, the management of surface water and groundwater is essential. It has presented us with very specific situations, not only technically, but also in administrative, legal, and, of course, political aspects. I believe, in this scenario facing the threat of climate change, it is almost certain that various sections of the border will have accentuated scarcity. Thus, we need to start taking measures to address these growing problems. Yet, here we are faced with divergent perspectives from different sectors. On one hand, you have those who doubt the existence of climate change. Then, you have those who see it as a very futuristic problem, not one that we should worry about right now. And then, you have those who see it with short-term vision. "Yes, it's true that it can exist. But it will start affecting us in 30, 40, 50 years, so why do we let it distract us? Let's solve our current problems." That's a great mistake because if we do not learn how to manage this resource, we are going to face gradual scarcity; its effects are already here.

We need to prevent it from a technical perspective, but society also needs to be aware and informed about the status of their resources because, ultimately, they are the ones that will be affected. Those of us who work in technical studies or regulations sometimes see it as a general, national, and not a local problem. As someone mentioned before, it is the local population who will have to be responsible for the stewardship of this resource. We can get the best research, the most comprehensive research, the most appropriate laws, but if the water users do not comply with the measures, then a sustainable environment would be unattainable. This is my input for now. Thank you.



Christopher Wilson, Mexico Institute at the Woodrow Wilson International Center for Scholars

Christopher Wilson is deputy director of the Mexico Institute at the Woodrow Wilson International Center for Scholars, where he leads the institute's research and programming on regional economic integration and U.S.-Mexico border affairs. He is the author and editor of numerous reports, including *Growing Together: Economic Ties between the United States and Mexico* and the *State of the Border Report*. Chris has testified before the United States Congress and is regularly consulted by national and international media outlets regarding U.S.-Mexico relations. He has written opinion columns for the Wall Street Journal, Politico, CNN, and Reuters, among others. Chris previously worked as a contractor doing Mexico analysis for the U.S. military and as a researcher at American University's Center for North American Studies. In Mexico, he worked at an international trade consultancy and with American students studying regional political and social issues. He is a member of the Transportation Research Board Committee on International Trade and Transportation, one of the National Academies of Sciences, Engineering, and Medicine technical committees. Chris completed his MA in international affairs at American University, focusing on U.S. foreign policy and U.S.-Mexico relations.

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Thank you, Sam, and thank you very much for the invitation. We're really excited at the Wilson Center to be partnering with you all to try to take on what I consider to be a significant and very complex issue. Thank you, Senator Udall, for being a part of this, and thanks to all of my fellow co-panelists. It is really an honor to share this forum with you all.

For those of you who are unfamiliar, the Wilson Center is a nonpartisan think tank in Washington, D.C. It also serves as the memorial of President Woodrow Wilson, who worked extensively in both academia and public policy. In his memory, the Center strives to bring those worlds together. We were recognized as the number one regional studies think tank by the Think Tanks and Civil Societies

Program of the University of Pennsylvania. I work in the Center's Mexico Institute, which focuses on U.S.-Mexico relations.

Water issues are huge along the U.S.-Mexico border, the region I study. As others have noted, water scarcity is a natural phenomenon, particularly in the desert ecosystem that dominates the region. It's sort of normal and natural, and in some ways is long lasting, but in other ways, it's becoming more pressing than ever. Population growth in border communities is outpacing national averages on both sides of the border. Industrial and agricultural use of water is significant and increasing. Climate change is exacerbating droughts and changing the water flow patterns. The Colorado River rarely reaches the Gulf of California anymore, and the Rio Grande has at times failed to make it to the Gulf of Mexico. These are really serious issues. We have aquifers being depleted faster than they are recharged, affecting both the quality of water and its availability.

At the Mexico Institute, we work with a binational advisory board that includes current and former ambassadors, former leaders of the North American Development Bank, and leading experts in U.S.-Mexico relations. For the last several years, they've been telling us that this set of transboundary water issues is the most important one that is not being talked about enough in Washington and in Mexico City. Our goal is to increase dialogue on the topic and strengthen cooperation by finding ways to improve, not only the way we work across the U.S.-Mexico border, but also the way we communicate. What I've learned is it's going to take a lot more communication than just international cooperation to solve these issues. It's very much about connecting local level end users and stakeholders to the federal process and both interstate and international negotiations. In the United States, we have interstate compacts on water. This is such a complex, multilayered issue that it is very challenging to solve.

We recently saw the complexity of this challenge firsthand. The United States and Mexico have a water treaty going back to 1944. This treaty requires regular transfers of water. We just finished, about a week ago, a five-year cycle. Mexico was behind on its transfer of water as the year closed. The plan was to release water from the Rio Conchos in Chihuahua into the Rio Grande; however, local farmers and activists took over the La Boquilla Dam to stop the transfer from happening. In a conflict with the National Guard in Mexico, one of the protesters was killed. It's kind of a cry for help and an example of the challenge in front of us. The incident highlighted the tensions between local water users and federal authorities, and the importance of maintaining positive relations with both the U.S. federal government and the State of Texas, where most U.S. water end users reside. These events illustrate a map of all the different levels of not only those actors involved in this really tragic incident, but also those actors that need to be present and involved in the conversation in order to have things end differently. Remarkably, the water transfer issue was solved in a very cooperative fashion. A new agreement was just negotiated, and there was some creativity in terms of how and where the water would be transferred. That was really good to see. We saw that you can solve these problems if you bring together the right set of people. For the Mexican government, that meant negotiating with the State of Texas, not just with the federal government. This is something they're not as accustomed to doing, given the way water is managed in Mexico at a more national level.

With groundwater, I think this becomes even more challenging. There is no treaty for groundwater. We don't have an established framework for cross-border management of this shared resource. The result is a classic tragedy of the commons. Everyone is acting in their own direct interest and is taking as much water as they need. Until what? Until it's all gone? I think we need to act before that happens. This gives us an opportunity, like Mike was mentioning, to learn from all the mistakes as they rewrote laws in South Africa. The fact that groundwater is unregulated right now means that we have the chance to get it right. We have the chance to create structures that address those needs that Jeffrey brought up of having the local level users become a part of the negotiation and the process for management. In the places where we've seen success along the U.S.-Mexico border, there have been some really interesting things happening along the Colorado River demonstrating that bottom-up, stakeholder-driven approaches supported by national governments can lead to meaningful agreements.

Let me stop there for now. I believe this is a really great space to be working in, and I'm really happy to be doing it with the New Mexico WRRI.

Fernald: Thanks so much, Chris. Just for your information, this panel won't stop here. Chris is alluding to our proposals for an ongoing four- or five-year project to try and bring universities across the border together to add information and even contribute policy and education to make changes to the situation. This goes back to Senator Udall's idea that we move from information into action. We will be acting on these panelists' great thoughts.

I'd like to conflate our second question since we had eight other questions that we won't have time for. What are the biggest challenges to achieving a less water-scarce future? How do we overcome these challenges? And if I could add question three, how are these exacerbated by climate change? Then, question four in terms of opportunities, are there places for international policy

versus local community action? If you could comment on research areas that we may prioritize or how science might help this situation. Senator Udall, please.

Sen. Udall: Thank you, Sam. First of all, I think we all know our biggest challenge in this water-scarce future is climate change and global warming. This is having a huge impact on all of our systems across the board. For us here in the United States, I would say our biggest challenge over the last four to six years is getting the President and Congress on the same page to finally address the threat of climate change. If we don't do that, we know we're going to continue to see droughts and wildfires. All our current models indicate that with the course we're on, we'll see stream flows decline 10 to 20 percent over the next 50 to 70 years. The public really understands this, there's no doubt about that. That's why we need politicians to be bold and to act responsibly, to lead on this issue. I think the pandemic we're in right now has shown us that we better recognize that we're going to need to step up and have that international cooperation when it comes to dealing with these disparities and issues. An individual country can solve climate change within their borders, maybe, but climate change is never going to be solved unless we work around the world.

I will then mention one other issue when you talk about challenges. I think climate change affects the foundation of water supplies such as the amount of precipitation and the amount of snowpack that forms in the spring. We are going to need to look across the board with water at how climate and global warming will impact the foundation of supplies, and then at how we push forward to break through those kinds of issues. I was very interested to hear the talk about how this issue has come between Mexico and the United States and how it led to farmers taking over the dam. We need to work closer together so this kind of tragedy doesn't happen. We need to recognize that individuals may see things differently, but if we share the knowledge, share the science, we can get to the same place and we can cooperate to get things done. Thank you, Sam.

Fernald: All right. If we can move on to our next panelist, Jeffrey Max Jones.

Jones: Something very important in public policy, and particularly in these types of complex issues, is modeling different scenarios. In this case, it would be our aquifers and basins. It's important to be able to sit down with the water users of our aquifers and government institutions and determine what to do. The role of academia is to bring objectivity to these discussions. My experience in government has been that whenever you get politicians involved in a discussion, be these from the United States, Mexico, or any other country, they tend to speak to their constituents and look to what is the politically correct thing to say, according to their constituency. In other words, their messages tend to be very politicized.

Again, the role of academics and the technical side of this is to bring objectivity to these discussions to ensure they are based on facts. If there were a good model of the transborder rivers, basins, and we had functional councils, really interesting things could be identified. We could then look at various what-if scenarios, their corresponding consequences and how these would affect all the stakeholders and water users. This would give people an improved ability to be empathetic of the other stakeholders and also to be informed regarding the best policies for solving those issues and challenges. What are options A, B, and C and their intended consequences? What do we do about these consequences? If we choose to move deeper into the age of information, we now have an opportunity that wasn't available when these treaties were signed in 1944 and 1906. We now have the ability to insert thousands of variables into an equation, and then ask, what if? If X or Y happened, then what would we do? The unintended consequences could be detected before they happen, and preventive policies could be implemented that would mitigate these consequences before they turn into a crisis, like what has happened recently with the water from the Conchos tributary. If I could make one suggestion, it would be to develop really good modeling for these different aquifers and basins, in order to look at scenarios, and draft possible solutions and policy. If a good model were developed, we would be able to look at various hypothetical scenarios, and then create effective policies to address these challenges. Again, what is needed is good, sound technical information that we would put together in a model, which would allow us to produce varying scenarios in order to develop and consider different possible policy solutions.

Fernald: Really nice. Please, Mike.

Muller: Listening to you, I think it comes back to what I said. We look different, but our problems are often the same. Tomorrow morning there is a session organized by WaterNet in southern Africa. It brings together the 10 countries of southern Africa and the water resource schools from different universities. We've got a system going where the master's degree programs in some of these water resource schools are shared across countries. For example, one module happens in a country, and another module happens in a separate country. There is a groundwater module that happens in South Africa.

What you get from this is a community of young scholars, and they are going to become practitioners in many cases. They are used to collaboration, have been through the same curriculum, and have a common understanding and a similar approach to different problems. Quite often students come from different countries, but they share the river and talk about it as a common problem. You establish relationships, a bit like what Christopher Wilson had said.

All the old ambassadors, or rather I could say all of the old heads in departments, are my current network. I know all the old heads of departments from water resources across the region. You become a very powerful network that can understand the problem without many conflicts, obviously because you've got politicians and constituencies behind you. Universities are very well placed to be able to build collaborative partnerships with the goal of finding ways of common learning. Let's learn together. Let's look at the same river from different perspectives. Sooner or later in 10 years' time, when we're the heads of departments, or in 20 years' time, when we're senators, we will have a much better understanding of each other and of the problems that we have. This is one area where I think relationships can be very important.

But I'm nervous about this idea that we can inform the discussion objectively. We are in a world in which experts are not particularly valued. They need to be trusted before they become valued. We need to find ways as academic experts—and I'm happy I can wear a practitioner's, academic, and citizen's hat—to have the conversation across different communities, in dialogues people can understand.

Models can help, but often it takes work to explain them to people. We run the water resources of central South Africa on a 14- or 15-dam system that is based on a fantastic model. When I was in Boulder a couple of years ago, people were still talking about our multiyear stochastic model that we use to run our systems. I asked people in the street, "Do you think we're out of water because it is the end of the dry season here?" And they said, "The dam is only 30 percent full." To which I responded with, "The system is 70 percent full, so what is the problem?" They said, "We don't care about the system because our water comes from that dam." It takes quite a lot of work to explain to people that their water security comes not from one dam, but actually multiple dams, which provides more security and more water. It is hard to get that message across. This brings up the question of how do we get the language correct for the right group of people?

I said to Sam that I wasn't going to talk about the Egyptian argument and everything that is happening up in the north end of the continent, which is a long way from where I am. But one of the important bits of language we've learned in the global water discussion is this concept of shared benefits. My colleagues who have done some work on the Nile and I have looked very carefully at the question. How can you develop this water when you have countries of 100 million people short of water and development? How do you convince them that if I use my water, they won't have less? The current project was very carefully conceived. You build a dam on the frontier. You can't use the water in your own country, you can only generate electricity. You tell the country downstream, "We're going to manage the flooding for you, and we're going to give you cheap electricity." They say, "Hey, that's not bad. We understand those benefits. You mean we don't have to build a new dam to expand our irrigation?" Which is, in fact, the truth in Sudan.

Then, you get to the difficult one. You go and look at Egypt, and they have always had this wonderful river flowing there, and they say, "What's in it for us?" We say, "Well, you can lower your big Aswan Dam, which evaporates about three meters a year in that desert heat, because we can guarantee up on the hill much lower evaporation. We can actually have more water in the system. But by the way, you are going to need to use your water more efficiently." South Africans are now worried because they've discovered the Egyptians using their water efficiently, and instead of growing rice, sugar, and cotton, they're growing oranges. They're competing with South African oranges on the market, and people here are very upset.

I say that this is the best piece of news I've heard for a while. The Egyptians have learned to get more production, more jobs, and why have they done that? Because they realized they were going to have to share the resource. Now they are beginning to find ways of doing it and using that water more effectively, and it all came out of the discussion of shared benefits. That discussion has taken 25 years, by the way. We hosted the ministers of the 10 Nile countries in South Africa back in 1998 to begin on a confidence-building process, and 25 years later, it is a work in progress. If you get the language right and you get the interests understood, you can bring people forward. The language of shared benefits, like 'I'll benefit this way, you'll benefit that way,' can be developed by working together and understanding each other's problems. That would be my contribution at this point.

Fernald: Thank you very much. Estimado Chávez Guillén, por favor.

Guillén: Thank you. Yes, indeed, it is a growing problem that should be addressed by applying all the aspects of water governance. Of course, this must come from a proper understanding of the resource and its sources. This requires strong binational collaboration, or more, if shared criteria exists with various countries. In our case, and in regards to Mexico's northern border with the U.S., logically, we would have to proceed with this knowledge, which fortunately is considered acceptable by our part. Surely it is even more acceptable in part by the U.S. due to their greater economic capacity, greater resources and greater participation from their border universities.

Nevertheless, Chris Wilson expressed an opinion that suggested we are starting from scratch. In reality,

I disagree with that opinion because, like I said before, since the 1970s, Minute 242 of the International Boundary and Water Commission between Mexico and the U.S. set limits on water extraction between Arizona and Sonora. That same minute included a commitment to exchange information across the border about any projects that could somehow affect the neighboring country. Of course, this minute is not as formal as a treaty. However, under the legal protections of that minute and that commitment, some binational border programs have been carried out intermittently since then, with the cooperation of border universities.

We have identified the most serious cases, as I mentioned before, the Hueco Bolson in Ciudad Juárez/El Paso, the Mesilla Bolson, and the Nogales/Nogales, Santa Cruz, San Pedro, and downstream Piedras Negras, and others. This identification led to focused studies that have progressed, however, they have not led to binational regulations. They have, nonetheless, led to a fairly acceptable, shared understanding that tends to become the models that Mike pointed out. This certainly would be an ideal tool that we could use: have a model of the aquifers we share, or at least, a model of their bordering sections since, in various cases, aquifers are extensive and they cover very large portions of a country. A comprehensive model, perhaps, is not feasible in the short-term. However, a model of the bordering sections would be, certainly, ideal in preventing or correcting transboundary effects.

This is the technical side, and then, we have social participation because, like you all know, governance is more than just the technical side. The knowledge of aquifers should be the basis of management, and I believe it is, but there is more than just the technical aspect. There are socioeconomic, political, environmental and legal aspects that complicate the situation. In the case of climate change, it is obvious that its most immediate effects are on ecosystems. These are the natural outfalls of aquifers and they are the most susceptible to any reduction in water levels. Springs, watersheds, flow rates, base flow of the river and riparian vegetation, are all automatically eliminated. Similarly, sectors with lower economic capacity that depend on very shallow water sources will be sensitive to overexploitation. All of this will be exacerbated by climate change.

On the Mexican side, we can say that there has been much attention to social participation by law. Numerous basin councils and technical groundwater committees have been established, but it has been very difficult for us to provide for them because there's no continuity in their representation. There are representatives from the different user sectors, but over a certain period of time, and with the change of boards, all this continuity is lost. However, they are established, and operate under regulations.

A lot of the achievements in this field are included in the publications of the UNESCO and SARM program, which you are surely familiar with, the Transboundary Aquifers of the Americas. Within the different global programs, one case stood out due to its climate and development level – the border strip between Mexico and the U.S. This is a good reference because it includes the achievements and shared knowledge that was accomplished with the participation of the USGS, CONAGUA, and various transboundary universities. To this date, this program continues to receive attention, and the intention is to formalize certain information exchange projects on the principle of non-intervention to neighboring countries. So, I think that there is something very important ahead, and finally, I think that effective social participation is essential, just like Mike pointed out. Indeed, we can have great, comprehensive research, but these studies will be useless if we, as technical advisors, do not have the ability to explain to the water users in simple, accessible terms what is the status of their water sources and the risks of not complying with technical measures and recommendations. Thank you, Mike.

Fernald: Muchas gracias. Chris Wilson.

Wilson: Thanks, Sam. Rubén is absolutely right to point out that it's not that there is zero treatment of groundwater at the binational level because there absolutely is. The Transboundary Aquifer Assessment Program is a great tool to be creating data and improving understanding of what is happening in the binational aquifers. I would just suggest that we're far from where we need to be in terms of having transboundary, international management of resources. We have a lot of work ahead of us still. I'll just make a couple of comments about this, how we can do things a bit better from my perspective, and where science fits into that.

It seems to me that the big-picture question here, and it has been talked about a lot already, is making sure that you have the right people in the room when management decisions are being made. That means having local-level voices in the room, having stakeholders be a part of the process, and having a structured process to have their input filter up into higher-level negotiations. But on the part of science, I think it means something important too. It's easy to say, and it's absolutely correct, that scientists need to be providing information and data so that good decisions can be made. We can ask questions: Who are the users? How much water is being lost to evaporation or seepage? How much water is in our aquifers? How are they recharged? What's the quality? There are all sorts of obvious questions that scientists can help us answer, and their findings can be input for good policymaking. I believe it is also important to say that it's not enough to have scientists make contributions and walk away from the conversation; they need to stay in the room as the discussion continues. They need to be a part of the discussion with the policy makers,

because politicians, for all the heat that they get, are really good at balancing the set of interests brought before them.

When industry groups show up and present their concerns, and when cities show up and talk about their concerns, people like Senator Udall can make informed decisions about how to manage that. Let's make sure that those scientists are another group of people that are showing up to be involved in the conversation. It shouldn't be a one-off transfer of the model, do what you want with it, but rather having scientists stay so that when a policy proposal is put forward, they can react to that and say what it might mean.

I'm hopeful this leads us to a cycle that leads to better science as well. The more that the scientists are in the room for policy discussions, the more informed they will be to formulate their next research question. This will lead them when they come back in the room and have an even more useful set of data that is tailored not just to the environmental situation but to the political dimensions of the challenge as well. I think we can have a back and forth that is really useful in this sense. Additionally, I would suggest—and this is something that I'm really excited about in terms of the project that we're embarking on, Sam—that it takes a coming together of not just the hard scientists but also the social scientists to break apart disciplinary boundaries to help understand how decision-making structures meet with scientific or physical realities leading to decision-making and management processes, water use, and everything of this nature. Thanks.

Fernald: Wonderful. Thank you so much. We have a question that maybe just one or two people could answer. From Elena Ferdinand: Do you see modeling as a way to combat toxic pollutant plumes in the aquifers and rivers? Jeffrey Jones, I believe you mentioned models, or would somebody else want to address that question?

Jones: One of the best experiences I had in the Mexican Senate was being part of the creation of a working group called NAAMIC (North American Agrifood Market Integration Coalition.) Those were, by far, the best bilateral or trilateral meetings that I was ever involved while working in government, both in the executive and the legislative branch. We did precisely this, namely, we brought together stakeholders, government officials, and academicians and technical people from Mexico, Canada, and the USA, to look at different issues regarding the increase of agrifood market integration in North America. We had some extremely good discussions, but today, as I was listening to our discussion, it has occurred to me that this is something that we need to do for water resources and issues. We need to create a "North American Water Resource Coalition" beyond just the border region, though it could begin there. Several different water projects and policies could be identified and discussed, with many possible outcomes.

Of course, the political aspects of this would need to be updated and considered, but there was a project in the 1960s called NAWAPA (North American Water and Power Alliance.) It contemplated bringing fresh water all the way from Canada to the Rio Grande/Rio Bravo Region. I realize that politically speaking, Canada has since established some very restricted water laws, but if we could do some modeling and show the win-win scenarios for different policy decisions related to this, about how to use water better, how to get more water, I believe it would be tremendously effective and mutually advantageous. Factors could be inputted into the model such as the social factors mentioned earlier by Chris Wilson, like the environmental impacts, along with everything else that needs to be considered. When we talk about creating a knowledge-based economy it is absolutely necessary to include academicians who can help bring objectivity to our discussions. In my previous bilateral or trilateral meetings without academia or stakeholders present, but only with politicians from different countries, politics prevailed without objective technical information, and we didn't seem to advance much. However, if we could do something like NAAMIC, again, if we created a North American Water Resource Coalition, and analyzed these issues by modeling different scenarios, and their impacts on the environment, the economy, and society, we would have more intelligent options on the table. This would create more effective discussions and foster additional creative ideas.

Sen. Udall: Sam, to follow up on what Jeffrey Jones said, I think part of the question, too, was about pollution plumes and modeling. We've had a lot of experience with this in the Southwest, for example, thousands and thousands of gallons of jet fuel leaked into an aquifer. The pollution plume was moving toward city wells. The Air Force was responsible for remediation and established a model to predict how far the plume would get. The model gave everybody a comfort level. The Air Force was able to show how it was working, how many gallons they were pumping, how fast they were cleaning it up. So, I agree with Jeffrey Jones that modeling can really make a difference. The biggest challenge is getting the population to buy into the model and to understand the science to be willing to go along with it.

Fernald: Thank you very much. Panelists, if you could please give a 60-to-90-second vision or parting words of wisdom or inspiration on this topic, starting with Senator Udall.

Sen. Udall: I think one of the things that inspires me about this panel, and what we've talked about, is what happened when John Wesley Powell came to the West as an explorer. Of course, Native Americans were here earlier, but he came and stated that this is an arid region, with scarce water, and we need to focus on watersheds;

whether they're international or domestic, we would reap shared benefits, as Mike Muller was talking about. If people share a resource, they then see shared benefits. There is a lot of work that we can do in terms of working together to protect our watersheds and make them last and grow for future generations. Thank you.

Fernald: Wonderful. Thank you very much. Next, Jeffrey Jones.

Jones: Another successful institution that I followed and participated in while I was in the Senate, was the Energy Council. I believe it started in Texas, and then it expanded to other U.S. energy-producing states, including New Mexico, and it's an institution that continues to be effective. Again, we need to do something like this for water. We need to create an institution where we come together, like the Energy Council comes together, four times a year. They have different issues that they discuss and review. But again, something like this might be very beneficial for institutionalizing water management and looking at different issues from many different perspectives. Water is obviously a complex issue, but it is also the lifeblood of this region, here in the middle of a large desert. We need to have water as a top priority in everything that we do. When we invite decision-makers from government into these discussions, the real reason that they are invited, which we don't say out loud, is to educate them about what the real issues are. Other stakeholders get to participate and get educated as well. I believe Chris Wilson is completely right; you have to have representatives from all sectors sitting at the table looking at the issues more closely. Once everybody is sharing and discussing ideas, and looking closely at what-if scenarios, additional ideas would come forth, ideas never imagined or considered possible. This would be wonderful for this region, and I strongly believe that it's time to do something along these lines for water management.

Fernald: Really nice. Thank you. Mike Muller, please.

Muller: Sam, thanks very much for having me on. Just as a last thought, we're really pleased always when we hear people in the USA talk about climate change. When I had some engagements with your State Department, they told me that those were two words they could never put together. Having said that, I actually worry in some parts of the world that the focus on climate change is distracting people from the present challenges, and allowing them to say "we can't handle this; we can't do anything." What I'm doing tomorrow, at the southern African meeting, is saying, "Can we please concentrate on managing our climate variability today? Do we have enough data to do that? Do we have enough understanding? Do we have enough of the models that we need to explain what's happening?" I've been doing some case studies, and I have found where water managers have a really good handle on how they are managing today's variability and today's challenges, they're actually pretty well placed for dealing with those future challenges of climate change. They are sourcing the data they believe is necessary.

In 2020, I would like to see us recognizing that we are pretty good as water managers in many parts of the world at managing climate variability. If we put more effort, get more data, make our models work better, and talk about it more, we'll do two things. First of all, people will understand what we're talking about. Why did it rain so hard last night? We've never had a flood like that. People notice these things, and it enables us to start talking about how things are actually changing, but it also implies that we can do something about it today. That's a last thought from my side. It's always wonderful sharing other people's problems. It makes us feel so good knowing we're not the only ones with them. I appreciate that and good luck to you all because you've got a few challenges across that border.

Fernald: Very good. Thank you so much. Estimado Señor Guillén.

Guillén: Yes, of course, models are a very important goal. They have progressed, but a lot is still required in order to have representative binational models. A good model would have to rely on highly appropriate and reconciled monitoring programs to have more information on levels, quality, restrictions, relationship with surface sources, etc. It's obvious that no matter how good software is, if we feed it unrepresentative data, we get false results. So, we need to ensure their models are properly validated.

Once we achieve this, we can analyze the different scenarios including the worst-case scenario due to climate change, zero recharge. On the other hand, it is obvious that we need to focus on the development of new water sources like artificial recharge and desalination of sea water and brackish water that exist in the various desert aquifers.

This will allow us to prepare and work in the social and political sectors of this issue. In general, social willpower does not exist. Water users resist extraction controls, they do not comply with official regulations, and political willpower only focuses on the short-term. There is no long-term vision. We need to raise awareness. There is

much left to do. I am grateful for the opportunity to share this with you. Thank you.

Fernald: Muchísimas gracias. Chris, in a few words.

Wilson: I began speaking about how the rivers hadn't reached the ocean in several of the previous years. Let me end by pointing to what happened with Minute 319, which was a U.S.-Mexico cooperation that allowed the Colorado River to once again reach the Gulf of California in 2014. It showed us what is possible when civil society is involved in the conversation, and when policy makers from both governments work hard together. We've done so many creative, amazing things across the border, like allowing Mexican water to be stored in U.S. infrastructure. There is no end to the things that we can do if we allow ourselves to think creatively, constructively, and cooperatively. I believe if we simply apply the lessons we've been teaching ourselves over the last several years, there's plenty of space to solve the problems in front of us too. Thank you again for the invitation today.

Fernald: Wonderful. What a great panel. Very impressive and really inspirational. Thank you once again.

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Spotlight on Navajo Nation and the Nexus of Coronavirus and Water

Editor's Note: The following is a transcription of the panelists' remarks made at the conference. No follow-up was made with the panelists and the editor assumes responsibility for any transcription or editing errors.



Moderated by Crystal Tulley-Cordova, Navajo Nation Department of Water Resources

Crystal Tulley-Cordova is an enrolled member of the Navajo Nation. She is a principal hydrologist in the Water Management Branch of the Navajo Nation Department of Water Resources. She has a doctoral degree in geology and an interdisciplinary graduate certificate in sustainability from the University of Utah. She has a Master of Water Resources in hydro science and a Bachelor of Science in earth and planetary sciences from The University of New Mexico. Crystal hopes the knowledge and experiences she gained over the years will help her assist Navajo communities to use their current knowledge about water to build sustainable water projects, seek funding for water-related research, and protect and manage water resources across the Navajo Nation.

Yá'át'ééh. Shí éí Crystal Tulley-Cordova *yinishyé* [*speaking in Navajo*]. Thank you for this opportunity to participate in this event today. It's important that I identify myself by presenting my clans for the Navajo leadership who are in the audience. To give a brief background: the Navajo Nation spans over 27,000 square miles in the Four Corners region of the United States. It is the largest land-based tribe and the second largest populated tribe. In 2010, over 332,000 Navajos lived throughout the United States. Of the 332,000, over 173,000 Navajos lived on the Navajo Nation, according to the Census count.

It's important for us today to be able to evaluate the nexus between COVID-19 and water. In many media outlets, you have read and heard many stories about the nexus between COVID-19 on the Navajo Nation and the lack of water infrastructure. However, the quantified studies related to evaluating socioeconomic factors as well as looking at energy, food, and water (namely, household drinking water access) are still ongoing. It's important that although these challenges have been brought on by COVID-19, there have also been opportunities that have been created that include research opportunities, like the ones that are ongoing now, and others through the Coronavirus Aid, Relief, and Economic Security Act, also known as the CARES Act. Throughout this time, we've created and strengthened relationships and partnerships with academic, state, and federal entities and nongovernmental organizations.

This afternoon, you will hear a variety of perspectives. We are pleased to be able to have our president, Jonathan Nez, speak, and we also have on the panel Delegate Amber Kanazbah Crotty, who is representing the chapters of Cove, Toadlena/Two Grey Hills, Red Valley, Sheepsprings, Beclabito, Tse'alnaozt'i'i, and Gadiiahi/To'Koi. We also have Mark Begay, who is a chapter leader. He's a community leader and well operator in his community of To'Hajiilee. We also have Captain David Harvey from the Indian Health Service (IHS). We have 30 minutes for this panel discussion, and so I ask that the panelists be brief in their comments to these questions. If we have time available, we will be open to questions from the audience. I would also like to encourage you to stay for an interactive breakout session. We will break out into four different groups to be able to see how we can build tribal water capacity through different partnerships with nongovernmental organizations, led by Emma Robbins, and with academic institutions, led by Nikki Tulley from the University of Arizona. One group, led by Captain David Harvey, will look at federal relationships and how those can be strengthened. The tribal community's aspect will be led by Dr. Lani Tsinnajinnie from The University of New Mexico.

Now we'll go ahead and start with President Nez. The first question is: what are some examples of short- and long-term water-related responses you have been a part of to address COVID-19 on the Navajo Nation?



Jonathan Nez, President of the Navajo Nation

Jonathan Nez currently serves as the President of the Navajo Nation. He was born in Tuba City, Arizona, and raised in Shonto, Arizona, on the Navajo Nation. He is married to Phefelia Herbert-Nez and they have two children, Christopher and Alexander. He is the son of John H. Nez and Mabel H. Nez. His grandfather, H.T. Donald, was the former Navajo Nation Council Delegate for Shonto, and his grandmother was Mae Donald from Shonto.

President Nez is of the Áshįįhí Clan (Salt People) and born for the Ta'neeszahnii Clan (Tangle clan). His maternal grandfather's clan is Tódích'íi'nii Clan (Bitter Water Clan) and his paternal grandfather's clan is the Táchii'nii Clan (Red-Running-Into-The-Water Clan).

Jonathan Nez started his term as president of the Navajo Nation on January 15, 2019. He also previously served as Vice President of the Navajo Nation from 2015 through the end of 2018, and as the Shonto Chapter Vice President, an elected member of the Navajo Nation Council representing the chapters of Shonto, Oljato, Tsah Bi Kin and Navajo Mountain, Navajo County Board of Supervisor for District 1, and Vice President of the Navajo Nation. President Nez holds a Bachelor of Science degree in Political Science and a Masters of Public Administration, both from Northern Arizona University

Good afternoon, everybody. Thank you, Dr. Tulley-Cordova, Sam, and everyone for putting on this water conference. It was good to hear from my good friend, Senator Udall, a previous panelist. Thank you for the question.

What has transpired through this pandemic has enlightened, or reengaged, the partnership to begin to provide clean water to our Navajo citizens, with the national media attention that tribes including the Navajo Nation, have received. Around 30 to 40 percent of our Navajo people do not have running water, and so that is a major concern, especially now that we are in election season. By this, I mean we are using the national media attention to remind our federal partners that there were promises made when we signed treaties with the federal government. I appreciate Emma Robbins, who is with DigDeep, being on the call and part of this conference. DigDeep is a very good example of a nonprofit partner. I call them friends of the Navajo Nation, who help provide clean drinking water and livestock water (we're in a drought right now) to major communities and small rural communities throughout the Navajo Nation.

Short and long-term water-related responses: I don't think we can distinguish them. The long-term is trying to get running water to the 30 to 40 percent of our citizens that don't have it, and right now, what we have are some funds that have come from the federal government. We're utilizing those CARES Act dollars to put some major infrastructure projects here on the Navajo Nation, and I do have an update. With the CARES Act funding, over $130 million was set aside from the $714 million to develop water infrastructure and to hook up homes to the major trunk lines in our area. If you want to call that the short-term, that's the short-term. Regarding the major trunk lines, we just recently celebrated the opening of the Cutter Lateral, which is the result of the Navajo Nation San Juan Water Rights Settlement and part of the Navajo-Gallup Water Supply Project. There are two laterals: one is the Cutter Lateral coming from the Cutter Dam, and the other is the San Juan Lateral. The Cutter Lateral just opened and it took a lot of time to get water into those communities on the eastern part of the Navajo Nation. I'm happy to report today that it was turned on. So, there is now water going into these rural communities. As many of you may know, if you have driven between Gallup and Shiprock, the pipes for the San Juan Lateral are being placed into the ground to bring water from the San Juan River into Gallup. So, the next process is to branch that off and provide water to homes and use it for economic development. Building the laterals was a major milestone. That same model can be used in the Western Navajo Pipeline.

There are many examples of projects that we've been a part of. I have been a part of the Manymules Waterline Project up on top of Black Mesa, and then, of course, the Western Navajo Pipeline. We're praying that with a new direction, a new administration, one day we'll have the new Navajo-Ute Water Rights Settlement Act in place to bring water into the Ute portion of the Navajo Nation.

That was quick, but I don't want to take too much time. I know there are many questions, but those are things that we're working on right now, short-term and long-term. I think they are one and the same for us here on the Navajo Nation. Thank you.



David Harvey, Indian Health Service

Capt. David Harvey is a Commissioned Officer of the U.S. Public Health Service and is currently assigned to the Indian Health Service as the Deputy Director of the Division of Sanitation Facilities Construction (SFC). He provides leadership and oversight on data generated, guidelines, and interagency coordination for an environmental health program supporting American Indian, and Alaska Native Tribes with needs identification; and then, the planning, design, and construction of water, wastewater, and solid waste facilities. Nationally, the SFC Program employs a professional, technical, and administrative staff of over 500 individuals; and in FY 2021, the program has been appropriated over $300 million in funding for the construction of $3.1 billion for sanitation facilities from identified needs.

In April 2020, CAPT Harvey co-led the formation of the, Navajo Nation COVID-19 Water Access Coordination Group (WACG), with the Navajo Nation Division of Community Development. The mission was to increase access to quality water to mitigate the spread of the virus across the Navajo Nation, which was experiencing high incidences of infections, and was estimated in April 2020 to have had over 9,600 homes with no access to piped water, representing over 20% of the population on the Navajo Nation.

The WACG includes members from the Navajo Nation Government, Navajo Nation Utility and Construction Authorities, U.S. federal government, and non-profit organizations. The WACG is focused on identifying, acquiring, prioritizing, and using available resources to increase access to quality water for tribal homes using data to identify and design interventions.

CAPT Harvey is a registered Professional Engineer in the State of Maine. He also holds a Bachelor of Science degree from the University of Maine, a Master of Science degree from the University of Connecticut, both in Civil Engineering, and a Master of Public Health degree from Johns Hopkins University Bloomberg School of Public Health. In 2019, he was named by Johns Hopkins University as a Bloomberg American Health Initiative Fellow, and is currently pursuing a Doctor of Public Health Degree.

Thank you, Dr. Cordova. Thank you, everyone, for inviting me here. It's an honor to be part of a distinguished panel like this today. I've been involved in helping to facilitate partnerships between the Indian Health Service (IHS) in the Navajo Nation and other federal agencies, universities, and nonprofit organizations to address the water-related needs on the Navajo through the 22-member Navajo Nation COVID-19 Water Access Coordination Group. This group is co-led by the IHS and the Navajo Nation Division of Community Development and has been meeting on a regular basis to collaborate on emergency water access response needs and to develop long-term solutions guided by research to address the household lack of water access. The group has assisted with developing recommendations to the Navajo Nation for emergency actions to increase water access to homes with no private water. It has streamlined the reviews and funding document approval to ensure funds were quickly available to take action from the IHS CARES Act funds. It has also identified external resources for staffing and funding to support public communication regarding the projects external to the CARES Act funds. In addition, it has created a venue for universities to share ideas around current and future water research, both to evaluate the mission outcomes and to examine other water-related issues in order to promote knowledge and recommendations toward addressing long-term actions to improve water access.



Mark Begay, To'Hajiilee Chapter President

Mark Begay is a dedicated leader and Marine Corps veteran who serves as the President of the To'Hajiilee Chapter, a satellite community of the Navajo Nation located 24 miles west of Albuquerque. He has been instrumental in addressing the community's critical water issues, advocating for the construction of a 7.3-mile water pipeline to bring fresh water to To'Hajiilee. His efforts have included negotiating easements with private landowners and collaborating with engineers and local authorities.

Begay's leadership has been marked by his commitment to ensuring a sustainable future for To'Hajiilee residents, particularly during the ongoing coronavirus pandemic. His vision and perseverance have brought hope to the community, aiming to replace the aging and unreliable water system with a more dependable solution.

Thank you for inviting me. It's an honor to be here at the 65th Annual New Mexico Water Conference. I want to thank honorable President Nez for joining us today and all the participants. Regarding short-term water projects, we've been working with the Centers for Disease Control. They helped us set up a watering point beside the chapter house. As part of the CARES Act that the president just mentioned, seven homes far from the trunk line are going to receive cisterns. They're supposed to be out there today evaluating the homes, but because of the weather, they had to reschedule. I want to thank the IHS for that effort.

As for long-term water projects, we're having a lot of water issues out there and we're working on the long-term solution. As you read in the newspaper and social media, To'Hajiilee has an ongoing water crisis. Within the last five years, we had three outages because the water has an elevated number of secondary contaminants including iron sulfate and hydrogen sulfate. Due to the contaminants, the water has a bad taste and odor, and it is also very corrosive. It degrades the metallic components of our wells.

In To'Hajiilee, like in many small communities across New Mexico, we are facing an unprecedented public health crisis with the COVID-19 pandemic. The difference is that To'Hajiilee may soon have to fight this pandemic without one of the most basic weapons in our arsenal: safe drinking water. Right now, 10 percent of our individuals are testing positive. That means three to five out of 50 tests are positive. Our community has six wells, but five of them have been abandoned because the groundwater is so corrosive that it eats up the well from the inside. Our last remaining well, well number five, has failed three times, and when that happens people must haul water, the school closes, and the health clinic closes until the Albuquerque Bernalillo County Water Utility Authority sends an emergency tanker truck. I'll say that again: the health clinic closes when there's no water. It's just a matter of time before it fails again. But if we do not have a water supply online when that happens, the 2,000 people who live here will be without water.

We have analyzed all these options. The best way is to build a pipeline from Albuquerque through the CARES Act. Thanks to the Navajo Nation, we were able to secure $2 million for our easement. We have three property owners that are involved, and two of them are willing to let us have an easement, but the third one is Western Albuquerque Land Holdings. Their land manager is Garrett Development Corporation. They're the only ones standing in our way of having this future water supply for To'Hajiilee. Thank you.

Tulley-Cordova: Thank you, Mr. Begay. We'll go to the last question: What are some successes that you have experienced during the pandemic that could benefit future work happening in the communities you represent, President Nez?

President Nez: I want to mention again what Captain Harvey said earlier about the partnership of the Navajo Nation and the IHS's COVID-19 water access mission. There are over 20 partners collaborating on getting this funding spent by December 30, 2020. That's a monumental task that we have, especially when it comes to $714 million. There is other funding that went to other federal agencies, and $5 million of IHS's CARES Act allocation went to this project. I am inspired to see this type of federal partnership happening, where you get 37,000 water storage containers going out to our citizens across the Navajo Nation. As you know, we're in a drought right now. I visited a few of the water access points where we have been handing out food, water, and hygiene kits throughout our Navajo Nation and the only issue I've been told about was that the water hoses were a little smaller compared to the big water hoses citizens use. These hoses are used for clean drinking water that's being set up for the Navajo people. These transitional watering points can serve over 12,000 people in that region. They don't have to haul water from 20, 30, 40 miles away. It gets a little closer now for a lot of our people, and we're looking

forward to the continuation of that partnership. I think that's a success story that we need to highlight, especially when collaboration between two federal agencies (IHS and Bureau of Indian Affairs) and the Navajo Nation Division of Community Development facilitated these discussions that have brought water closer to our Navajo people. So, that sets us up now and for any type of infrastructure bill that may be coming through the pipes from the federal government after the election or during the next congressional sessions. Thank you, Dr. Cordova.



Amber Kanazbah Crotty, Navajo Nation Council Delegate

Amber Kanazbah Crotty is a dedicated member of the 24th Navajo Nation Council. She represents the districts of Beclabito, Cove, Gad Íí'áhí, Red Valley, Tooh Haltsooí, Two Grey Hills, and Tsé Ałnáozt'i'íi1. As a council delegate, she serves on the Budget and Finance Committee and the Naabik'íyáti' Sexual Assault Prevention Subcommittee.

Amber is known for her work in strengthening responses to sexual violence, improving data sharing and cross-deputation with outside agencies, and enhancing sexual assault laws on the Navajo Nation. She is of the Kinyaa'áanii Clan, with her maternal grandfather being Deeshchii'nii, and she hails from Tó Halstooí (Sheep Springs, NM).

In addition to her legislative work, Amber advocates for various vulnerable groups, including domestic violence victims, sexual assault survivors, LGBTQ2Si individuals, and those facing mental health issues. She is a strong proponent of the principle "Ałchíní bá a'nít'á – Do it for the Children."

Tulley-Cordova: We will now proceed with Amber Kanazbah Crotty. The question is, what are some successes that you have experienced during the pandemic that could benefit future work happening in your community?

Kanazbah Crotty: Thank you for the question. In terms of some of the successes is the need, the absolute need, for data-driven decision-making. What we've seen in the past, especially when it comes to water and working with our federal partners at IHS and our Navajo Nation partners, is when we do this prioritized listing we know that IHS has a funding formula that just doesn't work for our communities. It is not only a matter of having Congressional leadership fix those federal funding requirements but also a matter of empowering the communities at the chapter level. As nonprofits move in, as chapter leadership comes in, we are doing those individual assessments. Now we know there are new homes, so we're building up a database to fill in the gaps in IHS's information. It's bringing in this knowledge from our Navajos in the private sector and developing a dynamic intersection towards a future in which it's not enough just to have clean water as a human right. Now I'm working with the Army Corps of Engineers. They're doing a watershed study for my district. They'll also be helping us along Highway 491, identifying the areas that we need to manage as we build this lateral pipeline. For all nonprofits online, I appreciate your service. I recognize that the Navajo Nation government is not the easiest to work with, but hang in there. You're doing good work. *Ahéhee'*.

Tulley-Cordova: Thank you, Delegate Crotty. Captain Harvey?

Harvey: Thank you, President Nez, for acknowledging the hard work of the Water Access Coordination Group and the efforts we put out there. We have run some numbers over the short distances that we've created because of the installation of these points. Initially, it was around 52-miles roundtrip that people living in the 59 chapters without a permanent water source would have to travel, and now it's down to 17. So, we've reduced the trip by 35 miles, which is a significant outcome. The key to that success was the collaboration of that over 20-member Navajo Nation COVID-19 Water Access Coordination Group, but also to establishing clear goals and objectives upfront. The Centers for Disease Control assisted with that when they were first invited to participate by President Nez and Vice President Lizer. We set a clear vision and goals with the group, and we worked through them.

We've also developed communication projects about products that are locally focused, including Navajo-language translations of information that are available on the website. We are currently still recording some of that information so that it can be available to access on the Navajo Safe Water website (https://navajo-safe-water-2-navajosafewater.hub.arcgis.com/) as well. I believe that

communication has brought the community to buy-in. The tremendous support by chapter leaders has been seen by the IHS field teams. These teams have been very successful in connecting with leaders to get input on the intervention, provide one-on-one training and to answer questions about how to work with the intervention even during the difficult times of COVID-19. So, those are great successes in overcoming great challenges and I'm honored to be part of that.

Tulley-Cordova: Thank you for that, Captain Harvey. Mr. Begay, we'll end with comments from you. What are some of the successes that you've experienced during during the pandemic that can help you with your future efforts post-pandemic to help your community?

Begay: One of the successes before the pandemic hit was a To'Hajiilee water improvement project with the collaboration of the Navajo Nation Department of Water Resources, our engineers, Souder, Miller & Associates, IHS and other different entities. We're very grateful to the Tribal Infrastructure Funds (TIF). New Mexico is the only state that has that source available to Indian communities. And thank you to Lynn Trujillo, our state representative, and our Navajo Nation leaders. We were able to do a preliminary engineering report, funded through TIF, which included To'Hajiilee water improvements, Albuquerque-To'Hajiilee water transmission, and all the as-built. One of the things happening in To'Hajiilee was that our pipes were so outdated. I'm happy to say one of the big successes was that we went through the planning stage, the design stage, and now, finally, we're in the construction phase. We just recently picked a contractor. MBS Construction is going to perform almost $3 million worth of much-needed upgrades in our water system. Also, eight miles of our main line with six-inch asbestos cement is going to be replaced. As you know, it's a health hazard if you're working on it, and you must have different ways of protecting yourself. In addition, we received $500,000 in funding for our project from the CARES Act. There are so many things to talk about, but we're short on time. So, I want to thank everybody here. We're doing our best in To'Hajiilee, and as a final thought, we really need our clinic expanded. It's getting too small. We're doing a lot of testing here and we're trying to control the virus. Thank you again.

Tulley-Cordova: Thank you for that, Mr. Begay. I hope today our participants had the opportunity to listen to community, executive, and legislative perspectives on the nexus between COVID-19 and water on the Navajo Nation, and how we've been able to work collaboratively on many projects in challenging times.

Update from the Office of the State Engineer



John R. D'Antonio Jr., New Mexico Office of the State Engineer

New Mexico State Engineer John R. D'Antonio is a registered professional engineer in New Mexico with a BSCE from The University of New Mexico. He has worked for the U.S. Army Corps of Engineers as a hydraulic design engineer and as a project manager for MILCON and Civil Works projects. Recruited as a Water Resources Manager for the Office of the State Engineer (OSE) in 1998, D'Antonio managed the largest District OSE Office for the next three years. From 2001 to 2011, he served as Director of the Water Resource Allocation Program (OSE), Cabinet Secretary of the NM Environment Dept, and NM State Engineer/Secretary of the Interstate Stream Commission (ISC). During his tenure as State Engineer, D'Antonio was Secretary of the ISC, Chairman of the Water Trust Board, the Governor's Water Infrastructure Investment Team, and the Governor's Drought Task Force. He also served as the NM Commissioner to the Rio Grande, Costilla, and Upper Colorado River Compacts.

Editor's Note: This paper transcribes the speakers' remarks from the conference. No follow-up papers were submitted, and the remarks were edited for publication by the editor. The speaker did not review this version, and the editor assumes responsibility for any transcription or editing errors.

This is one of my favorite conferences of the year, and even under challenging circumstances, NM WRRI has been able to set this conference up and allow everybody to participate. It's great that we are able to use technology to continue forward. I'm going to get right into my presentation to highlight a few significant developments taking place.

I want to stress early on that the Office of the State Engineer/Interstate Stream Commission (OSE/ISC) has been active and involved during this pandemic. Quite frankly, we're going through two different emergencies with respect to our staff. We are experiencing the effects of the current pandemic along with the challenges for our water supply. Water supplies have been identified as a critical component to public health and safety. We continue to service New Mexicans through our seven district offices. Operations such as issuing domestic wells or well driller permits cannot just stop because of the ongoing pandemic. We have water masters out in the field and support staff in order to examine diversions. We have other operations at various dams and facilities, such as the Los Lunas Silvery Minnow Refugium. For the most part, all of our programs including our Water Resource Allocation Program, dam safety, hydrology, litigation, adjudication, and ISC programs are all continuing their work. These programs all together involve 219 people that are now teleworking either full or part-time.

I am going to quickly go through the state budgeting process because the pandemic has created notable budget impacts. Earlier in 2020, during the special legislative session, our office's general fund was reduced by 4 percent. OSE/ISC has been asked to cut another 5 percent from available budgets next year. A hiring freeze has been implemented and positions have been eliminated. This is a really critical point: we've had 81 vacant positions, and many of these positions have been vacant for two years, mostly due to hiring freezes. As a result, the Department of Finance and Administration has reduced our authorized positions from 342 to 317. We've dropped 25 positions, thus reducing our vacancy rate from 23.7 to 17.7 percent. That's not an ideal way to reduce vacancies, so that is a concern for our offices.

Agency trust fund solvency—or insolvency—is also a problem. We live through our administration and many of our operations rely on the Rio Grande Income Fund and the Irrigation Works Construction (IWC) Fund. The blue line in Figure 1 is the total revenue from these two funds. It goes from fiscal year (FY) 2010 to FY 2022. You can observe a gap in revenues between $10 and $15 million, although revenues have decreased a little bit in the past couple of years, while our expenditures have shot up. In FY 2019, there are a couple of additional hands in the cookie jar, so to speak, including the forestry fund at $2.5 million a year, and an increase in money going to the acequia programs and infrastructure. You can see there is a drop in our trust fund balance in FY 2022.

This is a problem and the state legislature has recognized it as such. OSE/ISC have come up with a five-year plan to reduce our reliance on these trust funds. However, under the current budget cycle and the state revenues

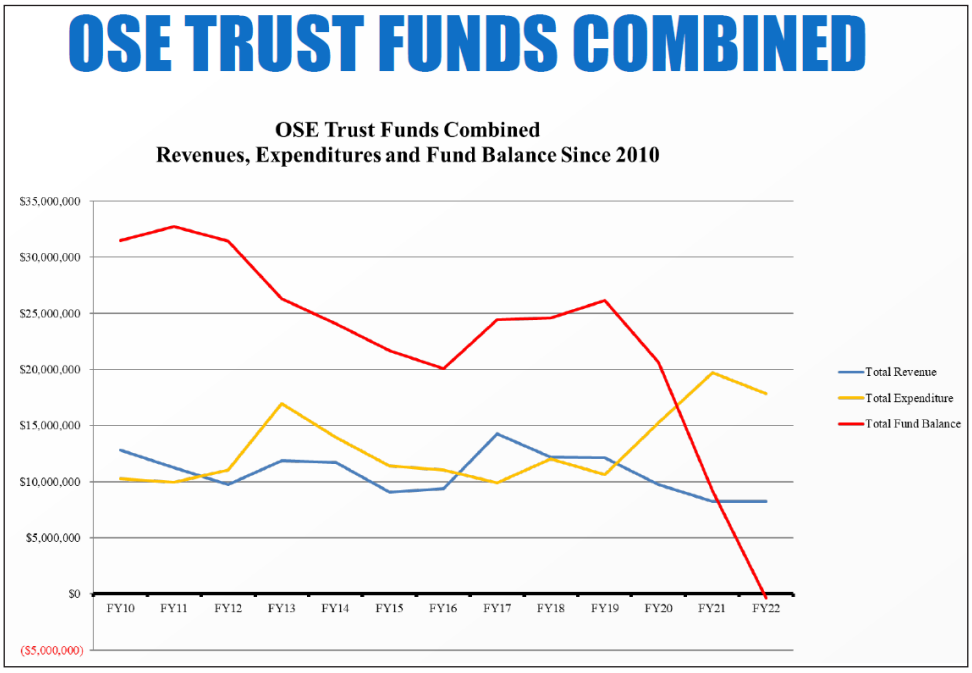


Figure 1. OSE trust funds combined, fiscal years 2010–2022.

from oil, gas, and gross receipts tax, we're not certain it's going to happen soon enough. Importantly, we're trying to get back $9 million of general funds within the next five years and foster awareness of our fiscal needs. Along with these measures, we feel there has to be a new way of governance. OSE/ISC are becoming more entrepreneurial, and we are striving to be innovative with our use of technology and data analytics in order to solve complex problems. We're implementing additional internal performance standards which are not necessarily reported out to the Legislative Finance Committee or the Department of Finance and Administration, but help us keep track of what we're doing and the progress we're making, while establishing meaningful metrics within our agency programs. As we move forward in administrating our policies, we will do so with openness and transparency. We have to identify the most high-priority issues and then reallocate some of our funding to address them. To make our work more efficient, we are also referring back to project management plans and identifying milestones and deliverables.

I mentioned issues that OSE/ISC have experienced from the pandemic, but this current drought and water emergency affects all of us in the state. The effects of the pandemic along with the current drought have been a double whammy for our agency. At the time of our Statewide Drought Task Force meeting on September 30, 2020, 67 percent of our state was in severe drought. Now 84 percent of the state is in drought. In water year 2020, precipitation has been 55 to 85 percent of normal, with half the basins receiving less than 50 percent of their normal precipitation. Stream flows are 5 percent to 81 percent of average in 18 of 21 river basins. Additionally, 80 percent of the state received less than half its normal rainfall during the monsoon season. Our reservoirs are below 20 percent of average storage. Looking to the winter of 2021, there is a greater likelihood of drier than average conditions because of the La Niña forecast.

Looking at the U.S. Drought Monitor in Figure 2, you can see the D2 to D4 status in dark orange, which is categorized as "severe to exceptional drought." When that status is over 50 percent in the state, we engage the Drought Task Force; we were at 67 percent. Three weeks later, as of October 13, 2020, the percentage of the state in severe drought status or higher went from 67 percent to 84 percent (Figure 3). You can see these pockets of D4 status, which is categorized as "exceptional drought," developing all over the state, and it's progressively getting worse.

Worsening drought is not unique to New Mexico. Figure 4 is dated by about a month, and I expect that these conditions have worsened. You can see the entire Southwest region was in about a 72 percent drought status.

Viewing the three-month outlook in Figure 5, there is a bullseye right on New Mexico related to above average temperatures. In terms of precipitation probability, the majority of the state of New Mexico is under that B category, which is the below average precipitation outlook.

Figure 6 is the drought briefing from the Drought Task Force meeting, illustrating climate showings from mid-September to the end of December 2020. This dark brown color is concerning, as it shows drought persists in this

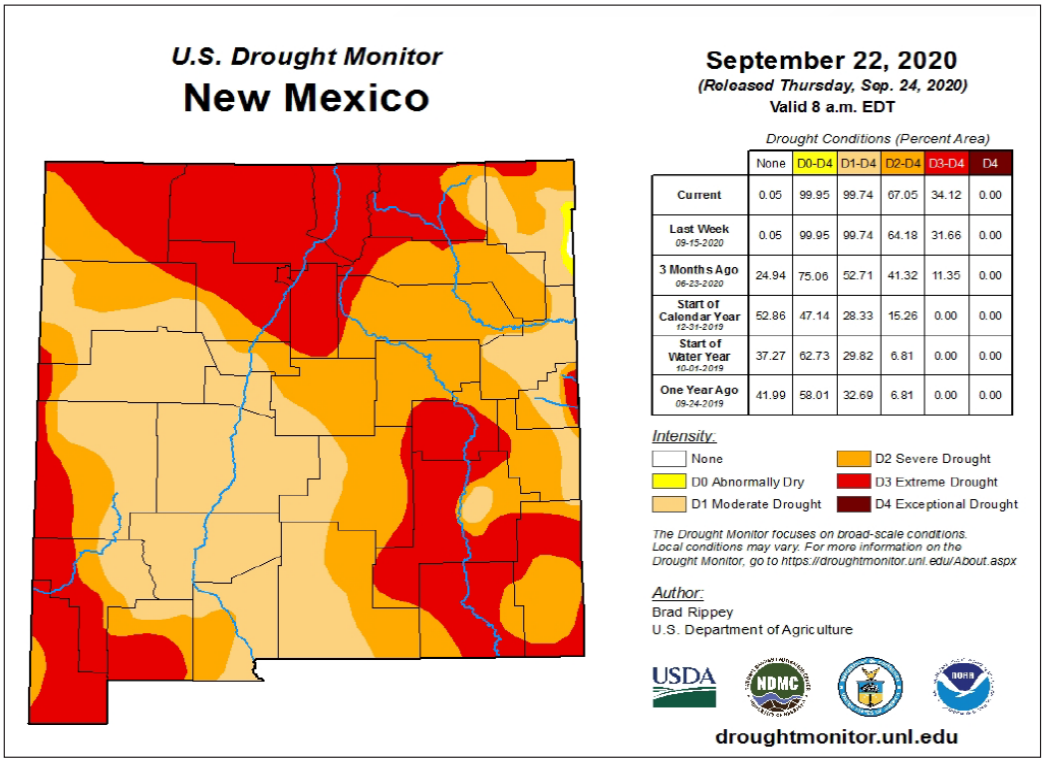


Figure 2. U.S. Drought Monitor for New Mexico, September 22, 2020.

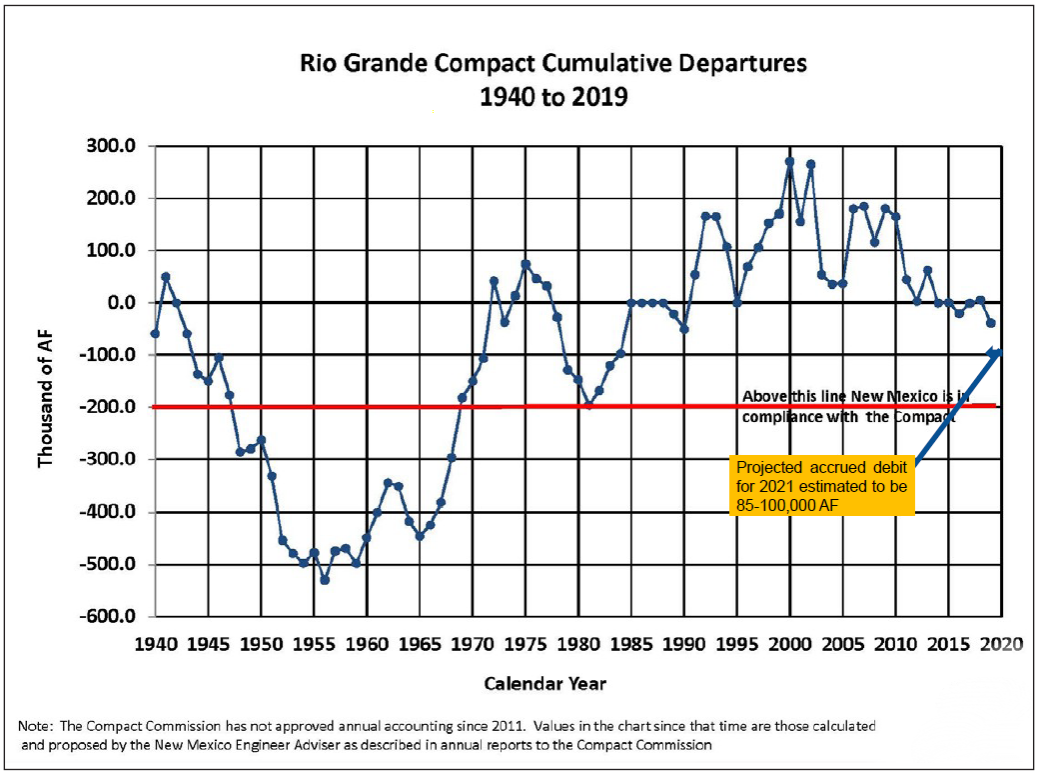


Figure 3. U.S. Drought Monitor for New Mexico, October 13, 2020.

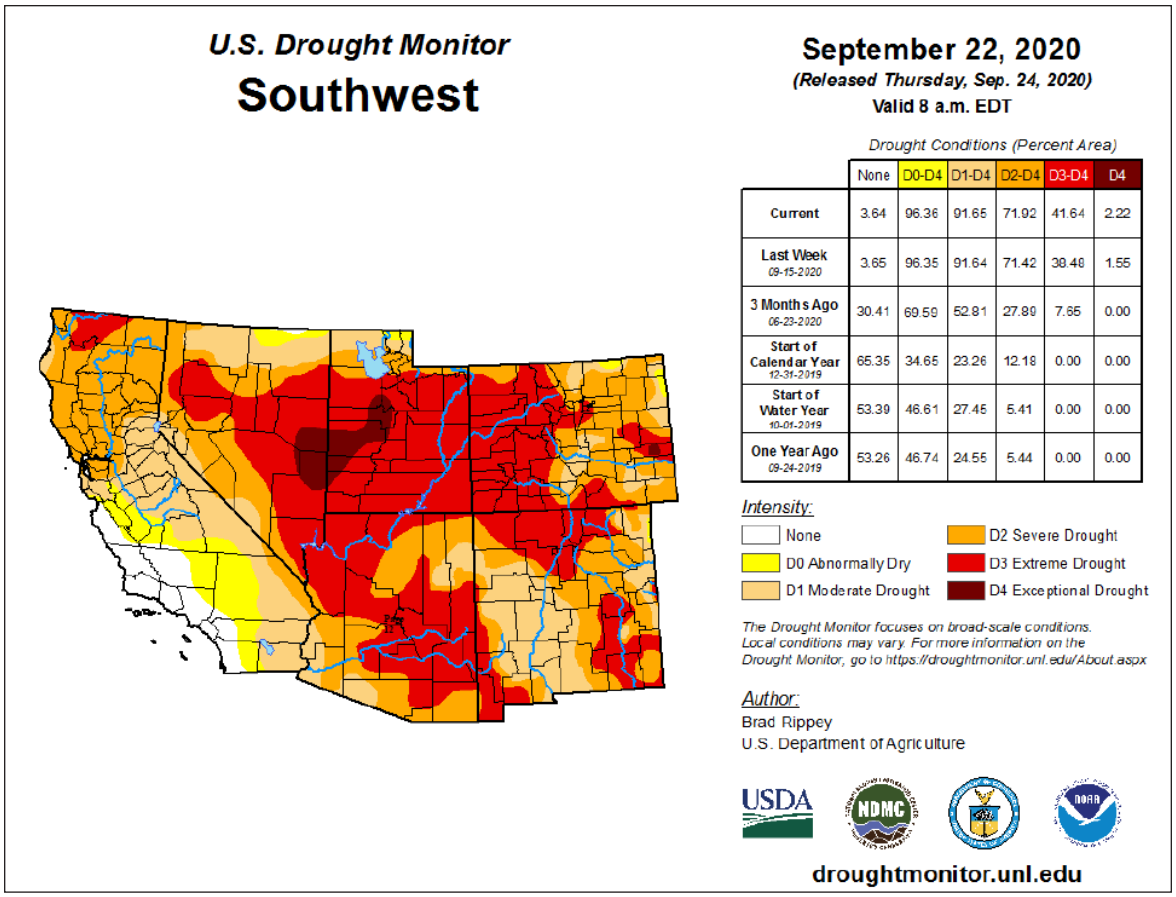


Figure 4. U.S. Drought Monitor for the Southwest, September 22, 2020.

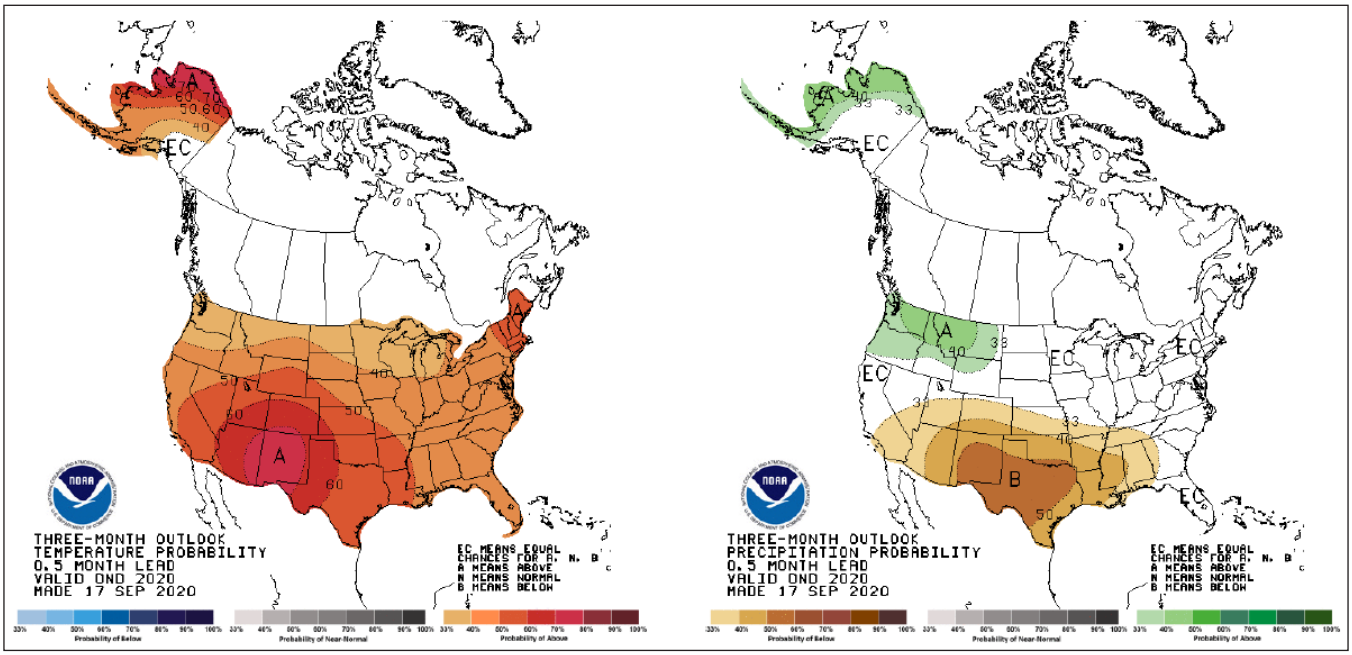


Figure 5. Three-month temperature (*left*) and precipitation (*right*) outlook.

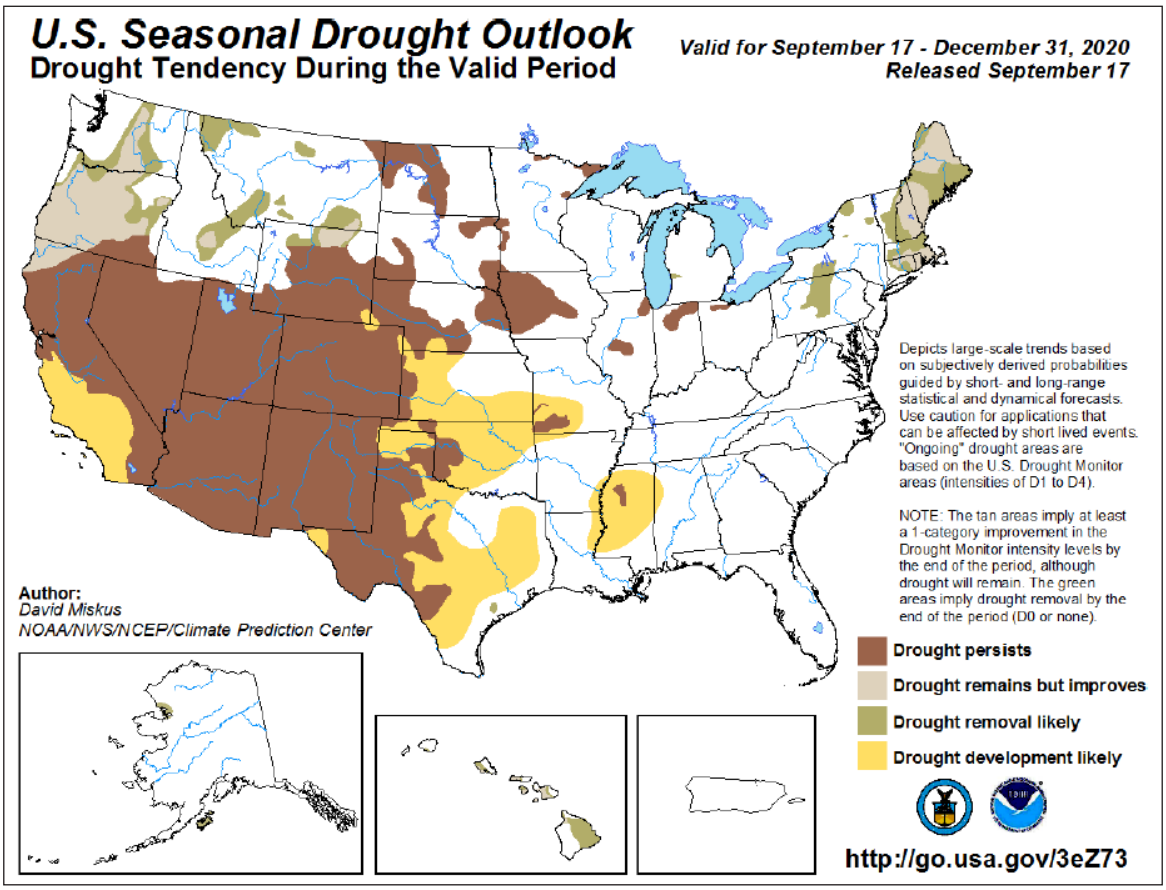


Figure 6. U.S. seasonal drought outlook for September 17-December 31, 2020.

entire area within the state of New Mexico. It also affects the Colorado water supply in our San Juan Basin.

Let me get into water planning. The governor has given us a directive on a 50-Year Water Plan. Last year, we asked the state legislature for $750,000, which included two additional staff positions to put the plan into effect. The response relayed to our office was that no funding or staffing was appropriate. Without this requested additional support, does that mean we can't accomplish effective water planning? It doesn't mean we can't, but we will have to look at other means. The funny reality (the hiring freeze notwithstanding) is that we're going to get about half that identified amount through our IWC Fund. This is a great resource, because those exact IWC funds that I highlighted earlier will be eliminated, so it's vital that we make good use of them now. We're using them for critical items like this, but they're not being replenished to the level that we need, which remains a problem for us.

New Mexico water planning challenges include:

- Drought
- Climate change
- Growing population
- Gaps between supply and demand
- Inadequate infrastructure
- Resource constraints on water administration
- Interstate and intrastate litigation

These items are critically important within the State of New Mexico. Often drought and climate change are combined, but we're showing them as two separate issues. With the growing population, gaps between supply and demand are a serious issue. New Mexico has a lot of inadequate infrastructure, including water infrastructure, dam safety, and water conveyance structures. We have 50-, 60-, 70-year-old infrastructure that needs to be updated, but we also need new infrastructure for new water resources. The resource constraints that have been placed on water administration make it really difficult to put in place the things that we need to do. We need to fund our staff and our initiatives so that we can accomplish important water related goals. Obviously, issues connected to interstate and intrastate litigation are not helpful. We have some cases with Texas that are constraining certain resources. The 50-Year Water Plan will provide an assessment of those challenges in various sectors of the state. The plan will describe how we'll bring all New Mexico stakeholders to the table. Again, OSE/ISC want to ensure inclusive water planning. The 50-Year Water Plan will include what New Mexicans can do to assist in

creating a sustainable plan for the next 50 years that is based on reality with respect to hydrologic parameters.

The major activities supporting the development of the 50-Year Water Plan include trying to incorporate Governor Lujan Grisham's water resilience vision into relevant portions of the 2018 State Water Plan. I want to give a shout out to Lucia Sanchez, OSE's water planner. She has done a great job at bringing all these actions together. Ongoing efforts include:

- Water Data Act implementation (per 2019 HB 651)
- Forest and Watershed Advisory Board (per 2019 HB 266)
- Climate Change Task Force
- Drought Task Force
- Tribal Water Summit

Stacy Timmons is doing well with the Water Data Act implementation, an initiative by Representative Melanie Stansbury and others. It's really important for us to incorporate the Forest and Watershed Advisory Board, Climate Change Task Force, Drought Task Force, and the Tribal Water Summit. All of these initiatives can feed into activities that support the 50-Year Water Plan effort.

We want to proactively engage all water-related climate work. Because OSE is somewhat resource challenged, we don't want to duplicate efforts. We do want to study and combine technical information. There are a significant number of studies, data, and informational resources available, including:

- Water Resources Research Institute statewide efforts
- New Mexico Water Dialogue
- Santa Fe Basin study and City of Santa Fe long-range planning
- Albuquerque 100-Year Plan
- Pecos River Basin study
- San Juan watershed climate change assessment
- Rio Grande Basin Study
- Regional water plans
- Previous state water planning documents

We are trying to bring everybody together so that we're not all doing our own stovepipe analysis and plan. We are bringing everybody together in order to come up with an all-inclusive state water plan that leverages efforts that are already taking place. Selecting the best and most relevant information from all of these other plans and incorporating them into our water plan will help reduce the cost of putting a plan in place.

We have a new initiative that we think will also be a major support for the water plan. We have titled the initiative "pivot and leap ahead." We will use the experience of selected New Mexico water and climate experts to look ahead 50 years and describe how water resources will change in various sections of the state and across the state as a whole. Up to eight New Mexico water resource and climate experts will be convened to make the leap ahead analysis. Both the current water resource situation and expected challenges in 2070 will be examined and assessed, while ensuring inclusive participation of all stakeholders from all New Mexico watersheds. Our preliminary approach has four phases over 18 months. Hopefully the plan will be in place by April or May of 2022. The phases are:

- Phase 1: Developing the Approach: Improving Resilience and Reducing the Risk
- Phase 2: Perform Leap Ahead Analysis: Assessment of Current and Future Water Resource Conditions at Risk
- Phase 3: Outreach and Creation of Strategies to Achieve Resilience
- Phase 4: Produce Draft, Review, and Finalize Plan

I will now quickly go through some basins. We have had such a dry water year in the Rio Grande Basin. Our office has had to curtail diversions by acequias with water rights dating back to 1600, if you can believe that. Those are the oldest water rights in the entire western United States. There was so little direct flow in the middle valley that the river would have dried naturally upstream of Albuquerque in July of 2020. The Rio Chama went into strict priority administration starting on July 16, 2020. There happens to be a shortage-sharing agreement in that area, but there were still ditches with very senior priorities that had to shut off. After the Middle Rio Grande Conservancy District (MRGCD) runs out of their water supply, the only water left for the Rio Chama is the available native flow. There are prior and paramount rights for the six middle Rio Grande pueblos that have to be accounted for that are taken off the top, a supplemental release of San Juan–Chama Project water by the Bureau of Reclamation for endangered species, and some of the San Juan–Chama Project water for the City of Santa Fe. That accounts for the only available water within the system.

Figure 7 is a graphic detailing the diversion rotation on the Rio Chama, with the Pueblo of Ohkay Owingeh taking water for three days and the other senior ditches, with 1600 priority dates, taking water the other three days. Therefore, only one day was available for these other acequia users that have priority dates as early as 1750. This day of usage was dependent on the availability of water.

These are highly problematic water conditions, so much so that an emergency storage release had to be done. I emphasize that it was necessary to do this release. New Mexico is in an accrued-debit status of almost 39,000 acre-feet in the Rio Grande. Under Article VI of the Rio Grande Compact, the state has to retain water in storage to the extent of that accrued debit. So, if we're going to store any water in El Vado or Santa Fe reservoirs, we need to store 38,800 acre-feet immediately to make sure that we have water in the bank for Texas downstream.

The Compact Commission by unanimous action could authorize the release of storage of any amount of water

RIO CHAMA

2020 RCAA ALTERNATIVE ADMINISTRATION ROTATION SCHEDULE

Available Flow=Average Daily Reading at USGS La Puente Gage - Set Transit Loss*+ Any Local Inflow Measured Above Abiquiu Reservoir

Ditch Name	Group	Priority	Schedule	Diversion (cfs)
CHAMITA (PUEBLO)	Senior		On @ Monday, 7 AM Off @ Thursday, 7 AM	Available Flow
HERNANDEZ	Senior	1600	On @ Thursday, 7 AM Off @ Monday, 7 AM	Available Flow
CHAMITA (NON PUEBLO)		1600		
SALAZAR		1600		
CHILI		1715	ON @ Monday, 7 AM OFF @ Tuesday, 7 AM	When water is available
RIO DE CHAMA		1724		
MARTINEZ Y DURANES		1724		
MANZANARES y MONTOYA		1724		
GONZALES		1724	ON @ Tuesday, 7 AM OFF @Wednesday, 7 AM	When water is available
LA PUENTE		1724		
QUINTANA		1724		
VALENTINE MARTINEZ		1724		
TIERRA AZUL		1724		
MARIANO		1724	ON @ Wednesday, 7 AM OFF @ Thursday, 7 AM	When water is available
FERRAN		1724		
JV MARTINEZ		1735		
JP GONZALES		1735		
ABEYTA TRUJILLO		1735		

* Set transit losses of 13.4 cfs for July, 12.5 cfs for August, 8.5 cfs for September, or 3.6 cfs for October.

Figure 7. 2020 Rio Chama alternative administration rotation schedule.

that is being held, which is a pretty bold action to take in these current conditions. Water was retained in storage in El Vado, Nichols, and McClure reservoirs, which are post-1929 reservoirs, to the extent that they had accrued debit. That is water in El Vado reservoir for MRGCD's use, and in Nichols and McClure reservoirs for the City of Santa Fe. When they started storing water last spring, they stored water in those amounts.

Figure 8 shows Rio Grande Compact (Article VI) cumulative departures from 1940 to 2019. Years are on the x-axis. Interestingly the red line on the y-axis is not at the zero demarcation line. The way the compact is written, above the -200,000 acre-foot line, New Mexico is following the compact. As you can see in 2020, there is an almost 39,000-acre-foot debit status. The state is projected to be in a debit status of somewhere between 80,000 and 100,000 acre-feet in 2021.

Due to extreme drought conditions, MRGCD requested through me as New Mexico's Compact Commissioner to allow an emergency release of debit water retained in El Vado. Earlier, I mentioned that we needed commissioners from Colorado and Texas to agree unanimously to that release. The goal for this release was to prevent significant economic harm to farmers that were in the middle of their irrigation season and to sustain habitat for endangered species. I was really surprised that with the *Texas v. New Mexico* litigation ongoing, the Texas commissioner was willing to allow us to go ahead and release that debit water. An agreement was made within a day and a half of the river going dry in mid-July. As soon as we had that agreement, I issued a State Engineer order, directing how the debit water would be used, for 38,000 acre-feet on the 17th of July. Water was released to try to get us through Labor Day in order to reduce economic harm to those farmers and to sustain the habitat for the endangered silvery minnow. The release would give the farmers in the middle Rio Grande and the endangered species another 60 days. The debit operations also preserved recreational and aesthetic benefits for the Rio Grande and assisted water users upstream of the middle valley on the Rio Chama and in the Rio Grande downstream of Ohkay Owingeh. We had to put conditions on the 38,000 acre-feet emergency debit release. The average of 300 cubic feet per second (CFS) released per day would satisfy area needs through Labor Day. We allowed for a maximum release of 400 CFS under certain circumstances. Overall, MRGCD did really well with those set conditions. The first couple of weeks didn't rain, so they asked for a variance to get them up to that 400 CFS.

The emergency release reduced the water that would reach Elephant Butte in 2020, and also reduced the Rio Grande Project supply for 2021, putting the state into a

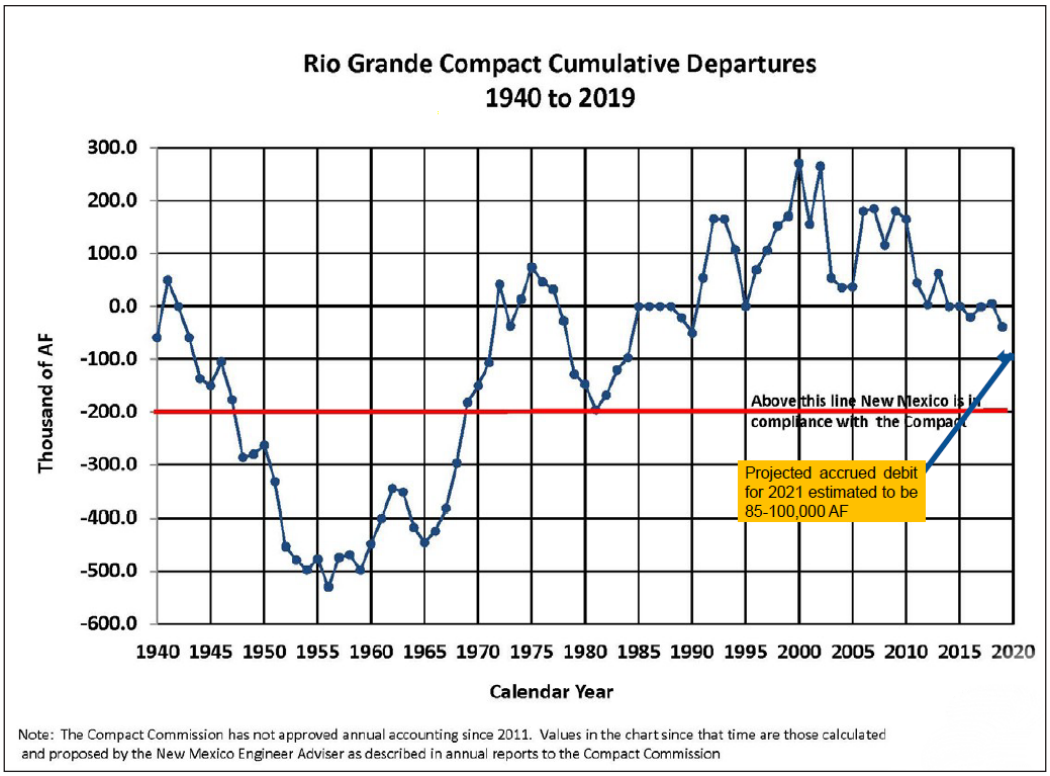
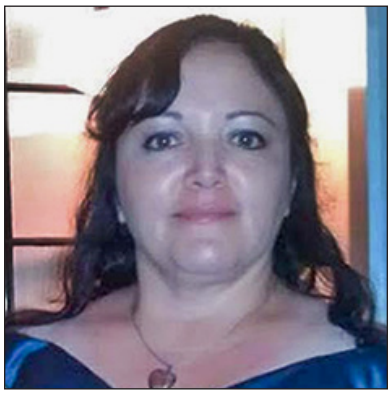


Figure 8. Rio Grande Compact cumulative departures, 1940–2019.

further accrued debit status. We're anticipating a very tough water year in 2021. There is the likelihood of very minimal runoff that could potentially end in May 2021. I spoke earlier about the projected compact debit for 2021. Currently, there are going to be storage restrictions in El Vado. Because of the structural issues there, about 120,000 acre-feet is all that can be stored. If better than anticipated runoff occurs, we're still going to have to require that most of the stored water be tied up for the prior and paramount reserve, which is necessary every year, as well as under Article VI, which means the water has to go down to Texas. We're going to be working closely with MRGCD on options, which will be evaluated based on hydrologic conditions and compact considerations.

I'm going to have to stop there, though there is much more that can be talked about. There are challenges all over the State of New Mexico. I highlighted just the pressing water-related issues that affect the middle Rio Grande.

Water Use and Conservation



Julie Valdez, New Mexico Office of the State Engineer

Julie Valdez is a water resource manager with the New Mexico Office of the State Engineer's (OSE) Water Use and Conservation Bureau (WUCB). Julie received a BS in environmental engineering from the New Mexico Institute of Mining and Technology. She has 18 years of experience working with the OSE. Julie began her career with the OSE administering water right applications and providing technical support for hydrographic surveys. For the past 15 years, she has worked in the OSE's WUCB, where she manages the water conservation outreach program, reviews subdivision proposals, reviews and prepares technical memoranda for water development and water conservation plans, and prepares technical reports regarding irrigation water requirements. Julie was a principal author of the 2005, 2010, and 2015 New Mexico Water Use by Categories Reports, which quantify all water use in the state.

The Office of the State Engineer (OSE), generally speaking, has a mandate to manage the use of water rather than to strictly preserve water. However, the OSE and the Interstate Stream Commission (ISC) have several programs and processes that serve to preserve New Mexico water supplies through better management:

- Water conservation programs
- Water use program
- Drought monitoring and planning
- Water rights administration
- Water planning (ISC)
- AWE scorecard

Each of the programs listed provide opportunities and challenges for preserving New Mexico's water, as it is a precious resource, especially in New Mexico's arid climate.

Water conservation is vital to every community throughout the state. To help preserve water, the New Mexico OSE has outreach material that we provide to the public on a variety of topics that range from xeriscaping to finding leaks. The Water Use and Conservation Bureau develops and publishes hands-on innovative education outreach material that is aligned with New Mexico public education standards for the classroom. We either provide the curriculum to the teachers or we present the material ourselves. Typically, our presentations are interactive, and they consist of a brief discussion that leads into breakout sessions with hands-on learning with the students. We also develop a list of outdoor tools that help preserve water. We have the New Mexico plant list and the plant app that include references for hundreds of plants to choose from when designing low-water-use landscapes that thrive on little or no supplemental water. In addition, the New Mexico landscape irrigation calculator works like a smart water controller by providing a personalized irrigation calendar. You can visit our website for more information and details about these tools (https://www.ose.nm.gov/WUC/wuc_conserve.php).

In 2013, our office prepared *New Mexico's Water Conservation Planning Guide for Public Water Suppliers* (https://www.ose.nm.gov/WUC/PDF/Planning%20Guide_Final_.pdf), also known as Technical Report 53. The purpose of creating Technical Report 53 was to provide a guidance document that all public water suppliers could use when preparing water conservation plans. Why should a public water supply system develop a conservation plan? First, to qualify for Water Trust Board funding, applicants who divert more than 500 acre-feet must have a water conservation plan written in accordance with our Technical Report 53. Second is to meet conditions of approval. Water right applications such as change of purpose and place of use, extension of times, or new appropriations typically require that a conservation plan be submitted. Lastly, it's essentially a good idea to write a conservation plan in order to be prepared and to manage a public water system effectively.

Water conservation plans are required to have the American Water Works Association audit and a gallons per capita per day (GPCD) calculator. The American Water audit provides a systematic method to organize water diversion status and track its path through the distribution system. The audit focuses on the supply side. The complete audit provides baseline data for a number of different system matrices. One of the primary benefits of the audit is that it allows a public water system to identify real losses. In 2009, the OSE developed a standard methodology for computing GPCD. The GPCD calculator methodology is used by the OSE to track municipal water use over time. It provides baseline data of historical and current water use. The calculator focuses on the demand side. It's a useful tool to help public water suppliers analyze the results of their water use and determine how to create appropriate

conservation measures and programs to specific end users based on their water conservation behaviors.

How are the OSE water use program and water preservation related? Drought is not the only circumstance in which water shortage occurs. Population growth or migration can also cause shortages by overburdening water supplies. Therefore, water preservation is an important consideration in water planning. Subdivision review and water development plans fall under the OSE's water use program. The Subdivision Act requires counties to develop rules for quantifying a subdivision's water needs, assessing the availability of water for those needs, and conserving water. The OSE conducts reviews of subdivision proposals at the request of the county to ensure compliance with the county code and the Subdivision Act. Reducing the water demand in subdivisions may add years of life to an aquifer. Indoor water use can be reduced by installing efficient plumbing fixtures and appliances. In any new construction, county regulations require that this happen. Outdoor water use can be kept to a minimum by installing low-water-use landscaping. Typically, hot tubs, swimming pools, and water gardens are not permitted in developments. Then in our review process, we ensure that subdivision proposals meet all the requirements of the codes and the Act. In some instances, we recommend that the developer consider more stringent outdoor water use requirements.

The OSE also has other rules related to land and water use. The Water Use and Conservation Bureau reviews water development plans, also known as 40-year water plans, which are written documents developed by public water suppliers to assess the amount of water needed to meet the current and future water demands in relation to the amount of water held by the permit. State statutes require that the water development plan be filed with an application to appropriate water or transfer water rights where the water right will be held or used or undeveloped. Our office requires at a minimum that a water development plan contain a summary of the current water rights, diversion for the past five years, a GPCD calculator, an audit, population projections, and water demand predictions. As part of the contribution component of the water development plan, we require that they provide a discussion of their conservation efforts, their goals, GPCD reduction, if any, and the staff they have devoted for the implementation of their conservation plans.

The Drought Task Force was established in 1988 and is chaired by the State Engineer, who oversees the implementation of drought preparedness activities in the state of New Mexico. Additionally, the Drought Task Force plays a major role in intergovernmental drought preparedness, response coordination, agency collaboration, and media information releases. The Drought Task Force is the singular official channel to the Governor for drought planning activities in the state. The Governor calls upon the Drought Task Force to provide drought updates and recommendations, and as a final authority in declaring drought emergencies. The Governor typically issues emergency drought declarations in the form of executive orders. In the past 20 years, there have been five executive orders issued by governors. The Drought Task Force receives their updates from the Drought Monitoring Work Group, chaired by the state climatologist and composed of these participating agencies:

- National Weather Service
- Natural Resources Conservation Service
- NM Department of Agriculture
- NM Energy, Minerals & Natural Resources Department
- NM Office of the State Engineer
- NM State Climate Office
- U.S. Army Corps of Engineers
- U.S. Bureau of Reclamation
- U.S. Department of Agriculture Farm Service Agency
- U.S. Drought Monitor
- U.S. Geological Survey

The Drought Monitoring Work Group meets monthly, and looks at different types of data to assess the drought, which is either hydrologic or climatic. It also makes recommendations to the Drought Task Force on potential executive orders. Figure 1 is a list of some of the triggers from the update to the 2018 Drought Plan. We went from having seven to having two. It was a big change. We've been using some of these triggers when we had our first Drought Task Force meeting back in September.

As for the Water Resource Allocation Program, the Water Rights Division administers water rights through New Mexico under the New Mexico constitution. All groundwater and surface water belongs to the public and is subject to appropriation under the doctrine of prior appropriation, which provides that earlier appropriations have higher priority over later appropriations. Anyone who wants to use either surface water or groundwater has to obtain a permit from the State Engineer. But before we grant that permit, we try to ensure that the application is not going to impair any existing rights, will not be contrary to conservation, and is not detrimental to public welfare. Active Water Resource Management (AWRM) is the State Engineer's critical water management initiative to address continuing drought, increasing variability in New Mexico water supplies, and increasing demand for water. The State Engineer has AWRM tools that help do this, which are to actively manage real-time distribution of water to prevent waste and to ensure that water rights owners do not exceed their legal right, implement priority administration of water rights in times of shortage, and ensure New Mexico's continued compliance with interstate obligations.

Drought Stage	Trigger	Drought Task Force Meeting Schedule	Responses
Watch		DTF convenes yearly	• DMWG meets monthly • Work groups meet as directed by the DTF to provide updates to SDC • SDC provides annual updates to the DTF, and as requested • DTF provides annual updates to the Governor, and as requested
Emergency	**50% or more of the state is at D2 levels or higher as documented by the USDM**	DTF convenes twice a year and receives updates on previous water year	• DMWG continues to meet monthly • Work groups continue to meet as directed by the DTF to provide updates to SDC • SDC provides quarterly updates to the DTF, and as requested • DTF considers making recommendation to Governor to issue an Executive Order o DMWG determines whether to make an Executive Order recommendation to DTF o factors considered: percent of state in D3, D4; duration; impacts
Exceptional	**20% or more of the state is at D4 levels as documented by the USDM**	DTF convenes at same interval as during Emergency Stage, with additional meetings as necessary	• DMWG continues to meet monthly • Work groups continue to meet as directed by the DTF to provide updates to SDC • SDC provides monthly updates to the DTF, and as requested • DTF strongly considers making recommendation to Governor to issue an Executive Order o DMWG determines whether to make an Executive Order recommendation to DTF o factors considered: percent of state in D3, D4; duration; impacts

Figure 1. Trigger-based drought responses.

These comprehensive tools allow the OSE to effectively manage water resources, protecting your water rights and the interstate delivery compacts.

Figure 2 shows what the real-time network looks like. It's essentially a network of streams, acequia ditches, and well monitoring sites that electronically transmit data values via radio and satellite telemetry and store the data in the database. You can obtain real-time data from our website (http://meas.ose.state.nm.us/).

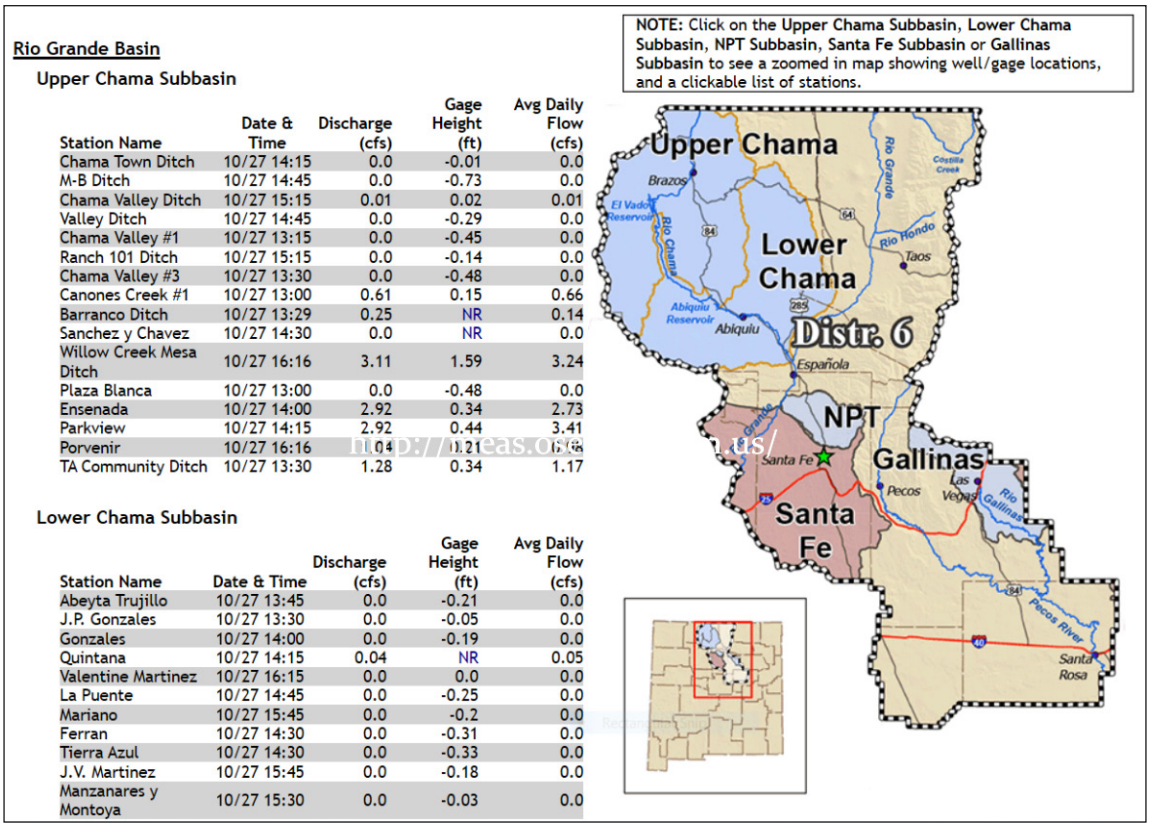
There are seven priority AWRM basins (Figure 3).

At this time, we have specific rules for the Nambé-Pojoaque-Tesuque water master district, and there are some other options available through AWRM, which include shortage agreements, voluntary rotation, and water banking. Due to the time constraints, I'm not going to discuss those.

This year's Annual New Mexico Water Conference theme was meeting New Mexico's pressing water needs, challenges, successes, and opportunities, which I think goes hand in hand with water planning, which is essential to the wise management of New Mexico's limited water supplies. The regional and state water plans are vital tools intended to guide water management in the state, now and into the future. By state statute, the ISC has the authority to implement the state regional water plans. Between 1999 and 2008, the ISC accepted 16 regional water plans. In 2016 through 2017, all 16 regional water plans were updated. The purpose of the update was to provide new information related to water planning and to evaluate future water planning and demand for each region using a common technical approach.

For the ISC to link the regional water plans to the state water plan, the ISC collaborated with the OSE to revise the method for calculating the region's future water supply and water demand gap in order to provide consistency among regions and across the state for the purpose of prioritizing investment in programs, policies, and projects addressing water infrastructure and management issues. The 2018 State Water Plan has three major components, which are a policy section, technical report section, and legal section. You can find all three sections on our website (https://www.ose.nm.gov/Planning/swp.php).

The Alliance for Water Efficiency is a nonprofit dedicated to the efficient and sustainable use of water across North America. AWE advocates for water efficient products and programs, and provides information and assistance on water conservation efforts. The water efficient and conservation state scorecard is an assessment of state laws. The assessment is based on survey results from all 50 states. Where are we compared to other states? In 2017, AWE surveyed all the states and identified efficiencies and conservation laws using a 20-prong



Rio Grande Basin

Upper Chama Subbasin

Station Name	Date & Time	Discharge (cfs)	Gage Height (ft)	Avg Daily Flow (cfs)
Chama Town Ditch	10/27 14:15	0.0	-0.01	0.0
M-B Ditch	10/27 14:45	0.0	-0.73	0.0
Chama Valley Ditch	10/27 15:15	0.01	0.02	0.01
Valley Ditch	10/27 14:45	0.0	-0.29	0.0
Chama Valley #1	10/27 13:15	0.0	-0.45	0.0
Ranch 101 Ditch	10/27 15:15	0.0	-0.14	0.0
Chama Valley #3	10/27 13:30	0.0	-0.48	0.0
Canones Creek #1	10/27 13:00	0.61	0.15	0.66
Barranco Ditch	10/27 13:29	0.25	NR	0.14
Sanchez y Chavez	10/27 14:30	0.0	NR	0.0
Willow Creek Mesa Ditch	10/27 16:16	3.11	1.59	3.24
Plaza Blanca	10/27 13:00	0.0	-0.48	0.0
Ensenada	10/27 14:00	2.92	0.34	2.73
Parkview	10/27 14:15	2.92	0.44	3.41
Porvenir	10/27 16:16	1.04	0.21	0.65
TA Community Ditch	10/27 13:30	1.28	0.34	1.17

Lower Chama Subbasin

Station Name	Date & Time	Discharge (cfs)	Gage Height (ft)	Avg Daily Flow (cfs)
Abeyta Trujillo	10/27 13:45	0.0	-0.21	0.0
J.P. Gonzales	10/27 13:30	0.0	-0.05	0.0
Gonzales	10/27 14:00	0.0	-0.19	0.0
Quintana	10/27 14:15	0.04	NR	0.05
Valentine Martinez	10/27 16:15	0.0	0.0	0.0
La Puente	10/27 14:45	0.0	-0.25	0.0
Mariano	10/27 15:45	0.0	-0.2	0.0
Ferran	10/27 14:30	0.0	-0.31	0.0
Tierra Azul	10/27 14:30	0.0	-0.33	0.0
J.V. Martinez	10/27 15:45	0.0	-0.18	0.0
Manzanares y Montoya	10/27 15:30	0.0	-0.03	0.0

Figure 2. Real-time AWRM data for the Rio Grande Basin.

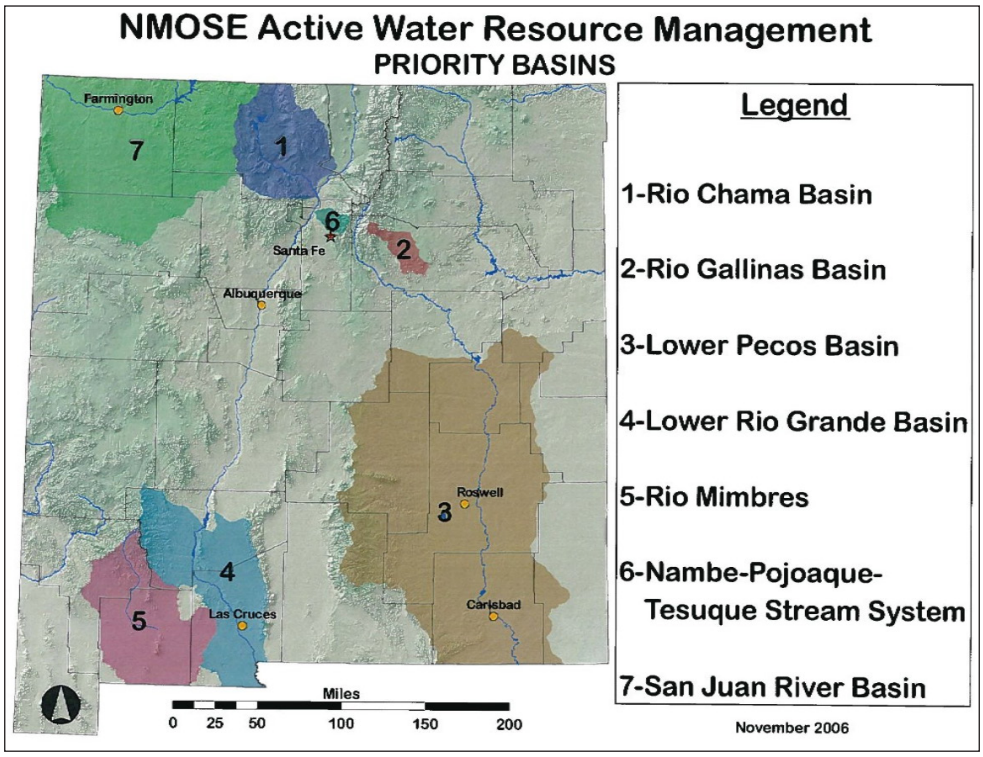
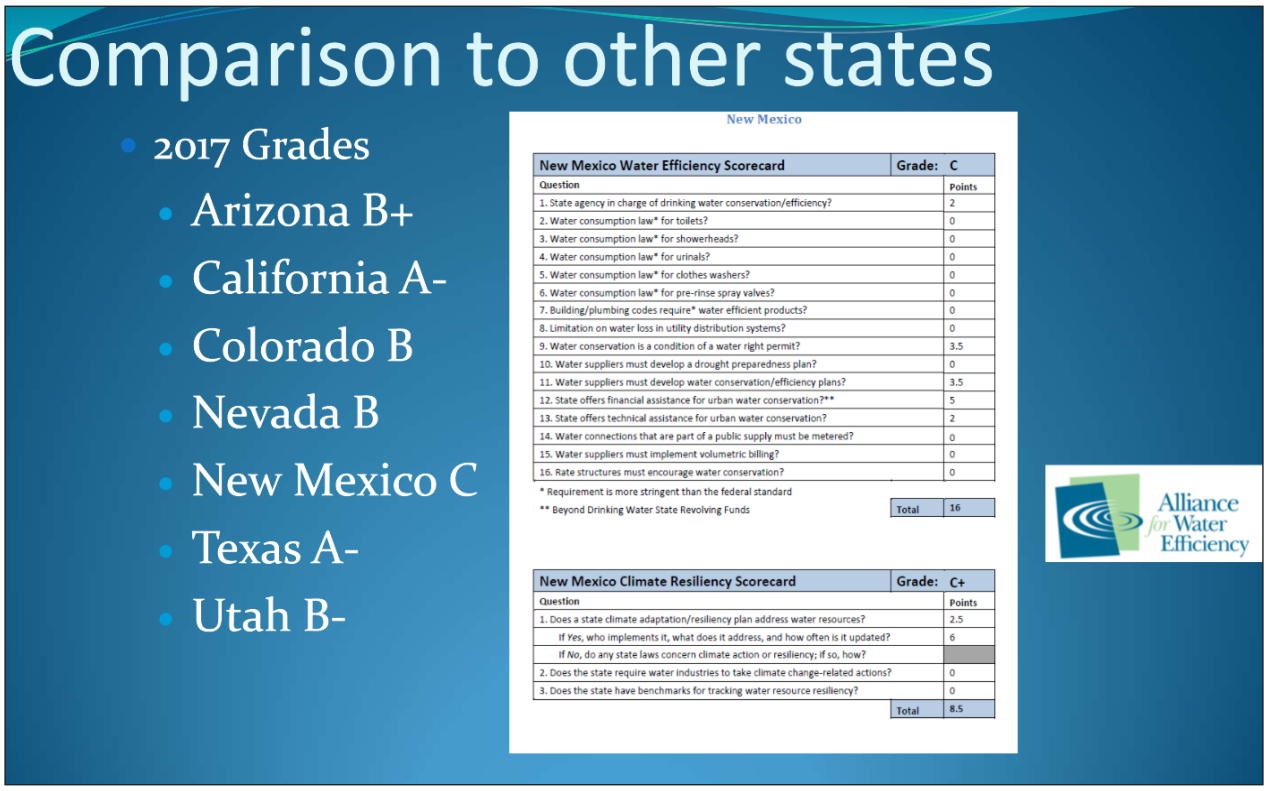


Figure 3. AWRM priority basins.

questionnaire, which broadly addressed the question, "What is the state's required or offered fundamental conservation planning?" One of the survey questions, just to give you an idea was, Does the state have a water consumption regulation for toilets? New Mexico doesn't have an official statute that states that we have to have that, but county regulations or public water utilities have that, so we didn't get points for those types of questions. Each state received a grade for efficiency and conservation and a separate grade for climate. The methodology used to score these states is described in their 2017 report. So, we received a grade of C, which means that we have room for improvement (Figure 4). However, there will have to be changes in legislation for our score to change.

In conclusion, New Mexico's water use continues to decrease even as population increases. The water use decreases can be attributed not only to the programs and processes the OSE has in place to preserve water but also to what the state is doing as a whole to conserve water.



New Mexico Water Efficiency Scorecard	Grade:	C
Question		Points
1. State agency in charge of drinking water conservation/efficiency?		2
2. Water consumption law* for toilets?		0
3. Water consumption law* for showerheads?		0
4. Water consumption law* for urinals?		0
5. Water consumption law* for clothes washers?		0
6. Water consumption law* for pre-rinse spray valves?		0
7. Building/plumbing codes require* water efficient products?		0
8. Limitation on water loss in utility distribution systems?		0
9. Water conservation is a condition of a water right permit?		3.5
10. Water suppliers must develop a drought preparedness plan?		0
11. Water suppliers must develop water conservation/efficiency plans?		3.5
12. State offers financial assistance for urban water conservation?**		5
13. State offers technical assistance for urban water conservation?		2
14. Water connections that are part of a public supply must be metered?		0
15. Water suppliers must implement volumetric billing?		0
16. Rate structures must encourage water conservation?		0
* Requirement is more stringent than the federal standard		
** Beyond Drinking Water State Revolving Funds	Total	16

New Mexico Climate Resiliency Scorecard	Grade:	C+
Question		Points
1. Does a state climate adaptation/resiliency plan address water resources?		2.5
If Yes, who implements it, what does it address, and how often is it updated?		6
If No, do any state laws concern climate action or resiliency; if so, how?		
2. Does the state require water industries to take climate change-related actions?		0
3. Does the state have benchmarks for tracking water resource resiliency?		0
	Total	8.5

Figure 4. Alliance for Water Efficiency state scorecard, 2017.

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High-Recovery Desalination to the Rescue: Making an Alternative Water Resource a Reality



Ronit Erlitzki, AdEdge Water Technologies

Ronit Erlitzki is Director of Business Development and Innovation with AdEdge Water Technologies, LLC. Ronit's career is based on strong scientific foundation and implementation of strategic and critical thinking. With more than 20 years of experience in biochemistry research and business development Ronit's main interest is water technology, and her goal is to accelerate the implementation of innovative and environmentally conscious technologies, focusing on improvement of high-recovery and low-waste sustainable solutions to environmental challenges. Ronit is a savvy water professional and has been successfully involved in the implementation of several technologies in the field of water quality analysis, biological water treatment for drinking water, and high recovery RO based on Flow-Reversal technology.

Ronit holds a BSc. in Biology from Tel Aviv University, and MSc and DSc degrees in Medical Sciences from Technion-Machon Technologi Le'Israel.

Editor's Note: This paper transcribes the speaker's remarks from the conference. No follow-up paper was submitted, and the remarks were edited for publication by the editor. The speaker did not review this version, and the editor assumes responsibility for any transcription or editing errors.

We're going to talk about high-recovery desalination and how we help rescue communities by helping them identify an alternative water source. After listening to some of the presentations yesterday, I decided to start with a thank-you slide because, first of all, New Mexico is one of my favorite states; I spend quite a lot of time there. Second, when I listened to the discussions, I realized that all these terms—desalination, climate change, alternative water source, high recovery, low waste, concentrate management—are topics that so many communities in the Southwest are dealing with, including, of course, New Mexico. This will be more of a technical discussion and I'm open to any questions.

We need to look at high-recovery desalination in the broader context of how we help communities find alternative water sources, and hopefully in the most cost-effective way. We're always seeking new water sources, but we know that new water needs to be safe. The treatment must be cost-effective and environmentally responsible if we want it to reach users. The way we see it, it's a call for innovation.

Figure 1 is one of my favorite slides. I use it a lot because implementing innovation is really, really hard. When we think about innovation, it doesn't always have to mean something brand new, straight from the lab bench. Sometimes, it's about taking existing technologies and improving them. Even bringing innovation into something existing can be just as important. In the cartoon you see here, it's the same old umbrella, but it's been repurposed to collect water.



Figure 1. Implementing innovation is hard.

One important piece of information I also like to share is that a study published in 2018 on existing water technologies concluded that it takes between 15 and 20 years for an idea to reach early commercial adoption. So, we need to be patient, creative, and persistent. We'll get there, but it takes time.

Now, just a few words about the work that AdEdge is doing. Figure 2 shows a treatment matrix. On the left side is an alphabetical list of contaminants. Across the

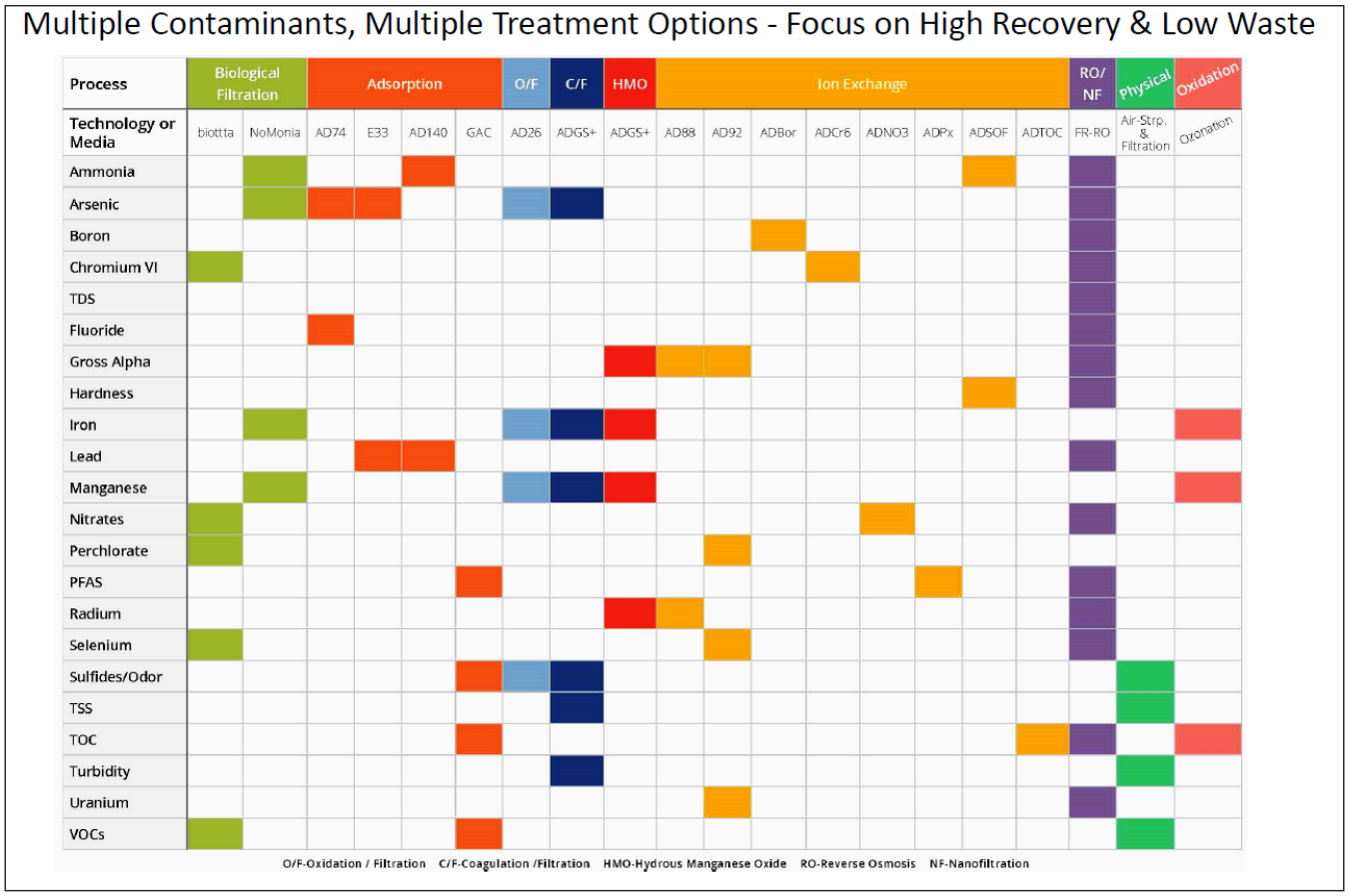


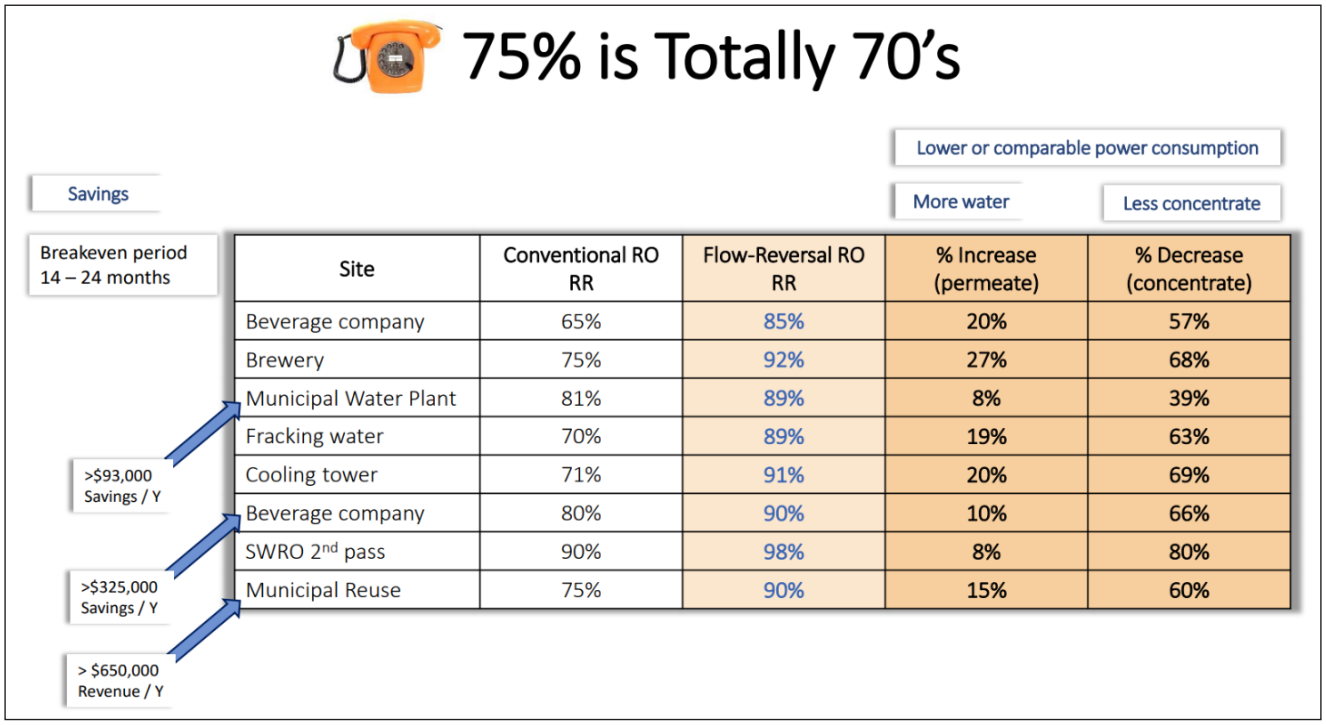
Figure 2. Treatment matrix.

top, color-coded, are different treatment approaches For example, green represents biological filtration from groundwater. I'm talking about treating groundwater, not wastewater. Orange shows adsorption technologies, yellow represents ion-exchange approaches, purple is reverse osmosis (RO), and so on. The idea, which many of us already know, is that there are multiple treatment options. Every water quality is different. We can craft the most cost-effective solution depending on specific water quality. Sometimes with one technology, we can treat multiple contaminants. Other times, we use a few methods in combination for a single contaminant. Multiple design considerations help us determine the best approach.

As a company, we know that innovation matters. AdEdge started by bringing to market Bayoxide E33 for arsenic removal. We completed multiple arsenic removal installations through a project with the Environmental Protection Agency involving 12 collaborative demonstration projects. Since then, a lot has happened. We developed H_2 Zero to recover backwash water, always important because there is never enough water. We created Biottta and NoMonia, biological treatments for groundwater, offering low-waste, high-recovery solutions without generating hazardous waste. A few years ago, we began collaborating with an Israeli company, Rotec, on high-recovery RO based on flow-reversal technology.

In Figure 3, please focus on the white columns for now. These show a list of sites that were initially designed for conventional RO installations. We redesigned them for high-recovery RO with flow-reversal, shown in the lighter orange column. You can see the expected recovery rate in blue is much higher. Looking at these recovery rates, we see that RO with flow-reversal generates more permeate and significantly less concentrate. I'm sure you all know, especially when it comes to brackish water and commissioning wells, concentrate management is always a problem. What do we do with this wastewater? Whether it's brine from ion exchange or concentrate from RO, reducing its volume by 50 percent, 60 percent, even 70 percent makes a huge difference. And it's not just about waste reduction. The examples in Figure 3 show actual annual savings that these sites achieved. These savings are significant for any community.

Flow-reversal is essentially conventional RO with a patented twist. It's innovative, but it's not brand new; there are already 30 to 40 installations worldwide. Flow-reversal



Site	Conventional RO RR	Flow-Reversal RO RR	% Increase (permeate)	% Decrease (concentrate)
Beverage company	65%	85%	20%	57%
Brewery	75%	92%	27%	68%
Municipal Water Plant	81%	89%	8%	39%
Fracking water	70%	89%	19%	63%
Cooling tower	71%	91%	20%	69%
Beverage company	80%	90%	10%	66%
SWRO 2nd pass	90%	98%	8%	80%
Municipal Reuse	75%	90%	15%	60%

Figure 3. Recovery rates of conventional RO versus flow-reversal RO.

helps prevent scaling. Scaling might look gorgeous under an electron microscope, but in reality, it's ugly and inconvenient. Reversing the flow inside the RO system prevents scaling. This method can be used for any new RO system, we can retrofit existing RO systems, and we can even use it as a concentrator to treat concentrate from a primary RO.

Let's talk about some examples in the United States (Figure 4). There is a full-scale flow-reversal system in Arizona. We retrofitted a beverage plant in California; they went from basically zero recovery to reaching 55 percent recovery, with silica concentrations of 260 mg/L, which is very high. We're also starting up a pilot system in a California municipality and finishing fabrication of a high-recovery RO system for a beverage company in Texas. In the top right of Figure 4, you'll see an orange container. That's ROxy, our pilot system. We tested it at the Bureau of Reclamation's Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, New Mexico. We demonstrated a 92 percent recovery rate, compared to 82 percent in conventional systems. We were also awarded a Bureau of Reclamation grant to demonstrate high-recovery RO for reuse, another way we can support local water supply resilience, instead of moving water between communities.

Many people ask: What does it take to convert to flow-reversal RO? Figure 5 shows that with a conventional two-stage RO system, by adding just a few valves and pipes, we can operate it with flow-reversal.

Flow-reversal RO is based on three principles. First, we reverse the flow inside the pressure vessels. The second is a process called block rotation. Third, this is a continuous process. You don't have to stop the operation like in a batch process, and you generate permeate at the same quality continuously.

If you look at Figure 6, the top half shows a conventional RO pressure vessel, where water flows from right to left. Normally, scaling builds up at specific points. With flow-reversal, we reverse the water flow in that pressure vessel from left to right, as seen in the bottom of the figure. Areas that would otherwise scale now get a rinsing effect because they are exposed to undersaturated water instead of oversaturated water. That is how we achieve higher recoveries without the scaling problem.

Another key principle is block rotation, shown in Figure 7. In a standard two-stage RO system, the first stage membranes experience less stress while the second stage sees higher concentrations, leading to scaling. With block rotation, the pressure vessel blocks switch between functioning at stage one and stage two. This spreads the load of potential scaling more evenly across all membranes in the system, thereby extending membrane life and improving recovery. You'll notice that when we rotate the blocks, we also reverse the flow direction.

What makes flow-reversal so unique and important? First, it is flexible, meaning it can be used in new or existing RO systems. We can take systems operating at 75 percent, 78 percent, or 82 percent recovery, add

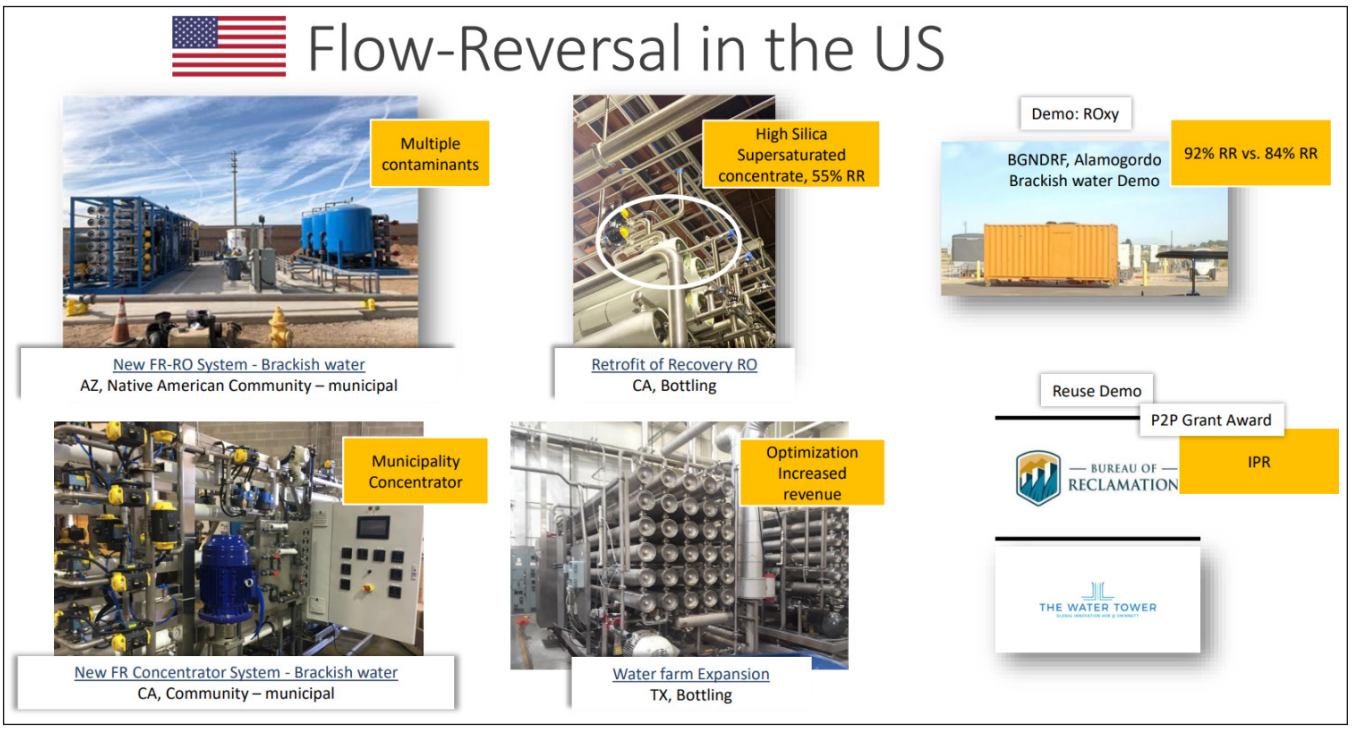


Figure 4. Flow-reversal RO projects in the United States.

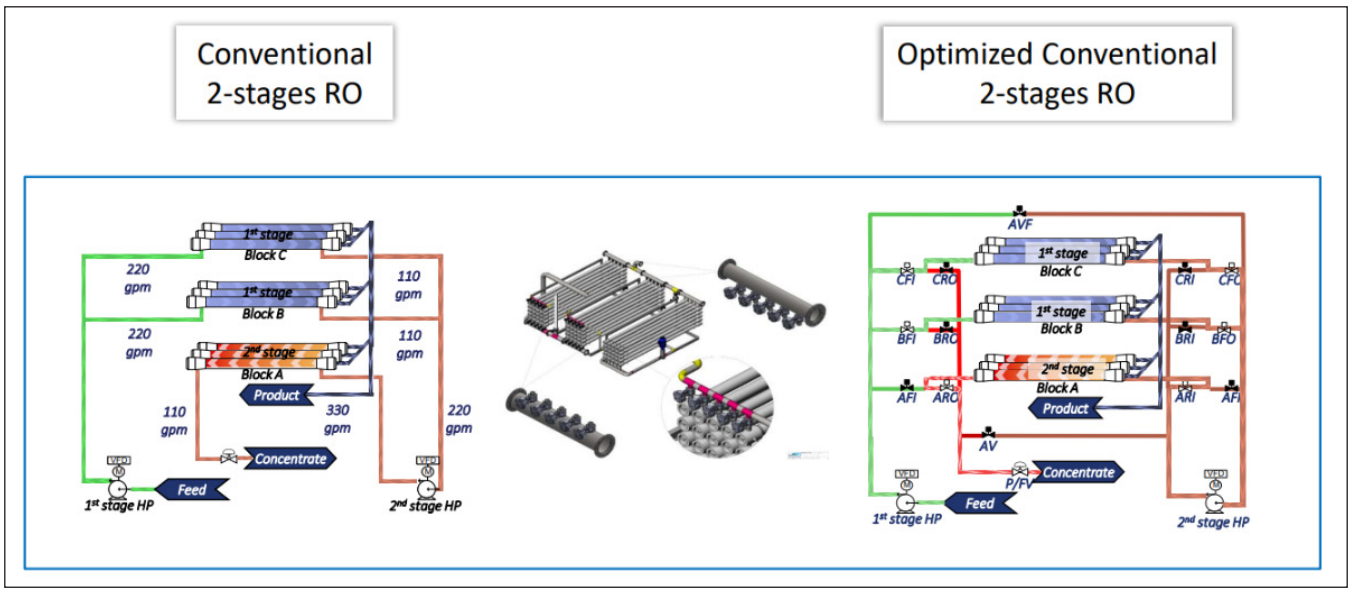


Figure 5. Flow-reversal RO technology.

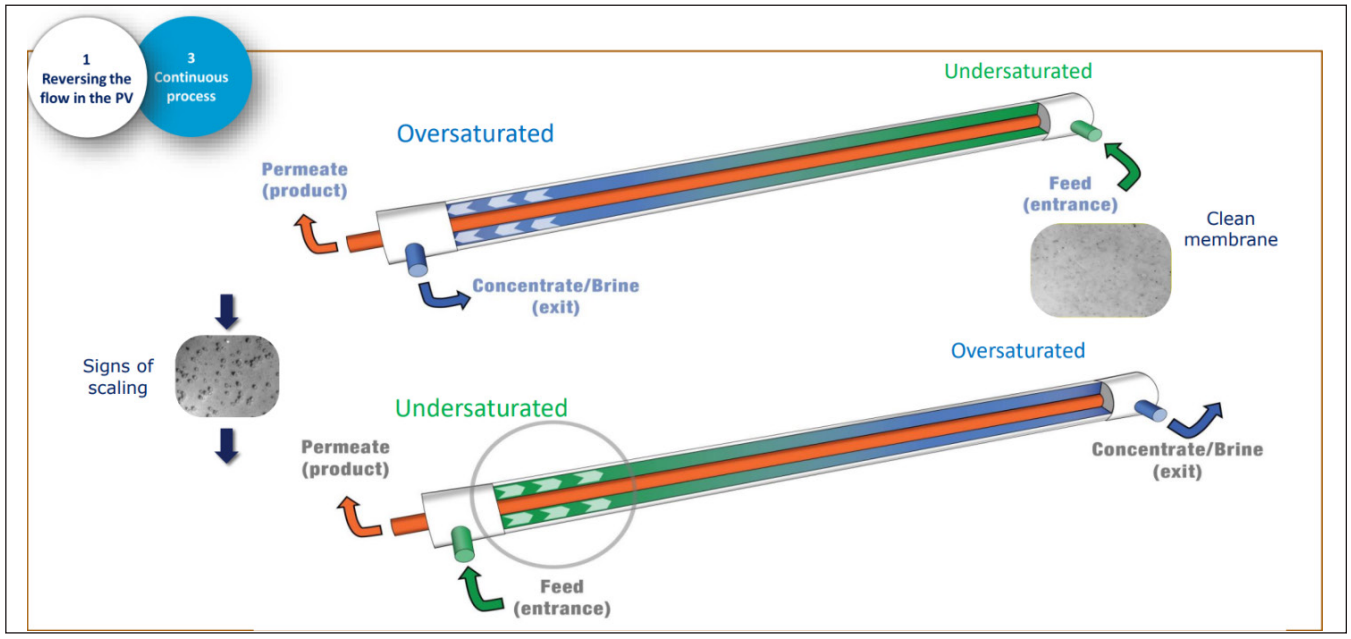


Figure 6. Flow reversal in the pressure vessel.

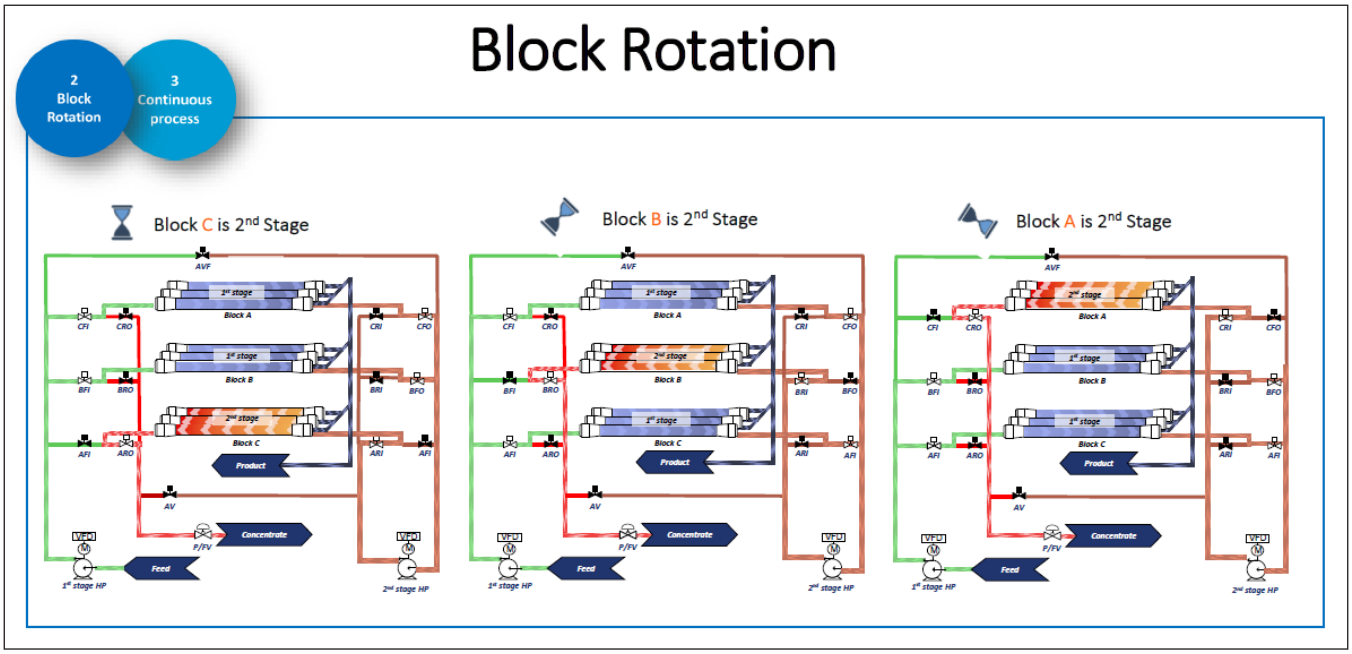


Figure 7. Block rotation.

flow-reversal, and then operate at 92 percent, 93 percent, 95 percent, even 98 percent recovery, depending on the water quality. Another advantage is that this process works with existing RO components available on the market. No proprietary equipment is used. Remember that cartoon with the umbrella? We're improving RO as an existing, proven technology. Also, operators don't need special training. It is easier to approach operators with a technology that is familiar to them. We believe that there is low operational risk because at any point the flow-reversal can be changed back to conventional operation, with the click of a button. We've also found that flow-reversal reduces biofouling. The shearing forces created by reversing the flow and changing osmotic pressures impact bacterial growth. By reducing scaling, we also save on chemicals and extend the life of membranes. But what matters most is how this helps real communities.

I'm going to present a case study from a community dealing with limited surface and groundwater resources, multiple water quality contaminants, cost effectiveness, innovation, and a very tight schedule. This community, the Ak-Chin community of the Maricopa Indian Reservation in Arizona, has a diverse economy, which includes agriculture, a casino, an airport, a golf course, and an entertainment complex. They're continually investing in improvements, so they have a new fire station, a water reclamation facility, and a surface water treatment plant built in 2012. Their primary water source is the Santa Rosa Canal, but in April 2019, they received notice that the canal would experience a temporary shutdown in November 2019, leaving them just six months to secure an alternative water source.

One possible solution was to recommission an existing idle well that could produce 800 gallons per minute. However, multiple contaminants were present in the groundwater, including nitrate, uranium, iron, and high total dissolved solids. All exceeded maximum contaminant levels (Figure 8).

Designing the treatment system meant balancing many factors: footprint, operational complexity, capital and operating expenses, and waste stream management. Working closely with the engineer and the community, we proposed a two-stage treatment: sorption-filtration for iron removal, followed by high-recovery RO using flow-reversal.

With high-recovery flow-reversal RO, they could achieve an 88 percent recovery rate, much better than the expected 75 percent for conventional RO. Plus, they reduced the concentrate volume by 50 percent. This meant they could manage the concentrate within their existing wastewater infrastructure until their planned evaporation pond expansion was complete. It also meant a smaller

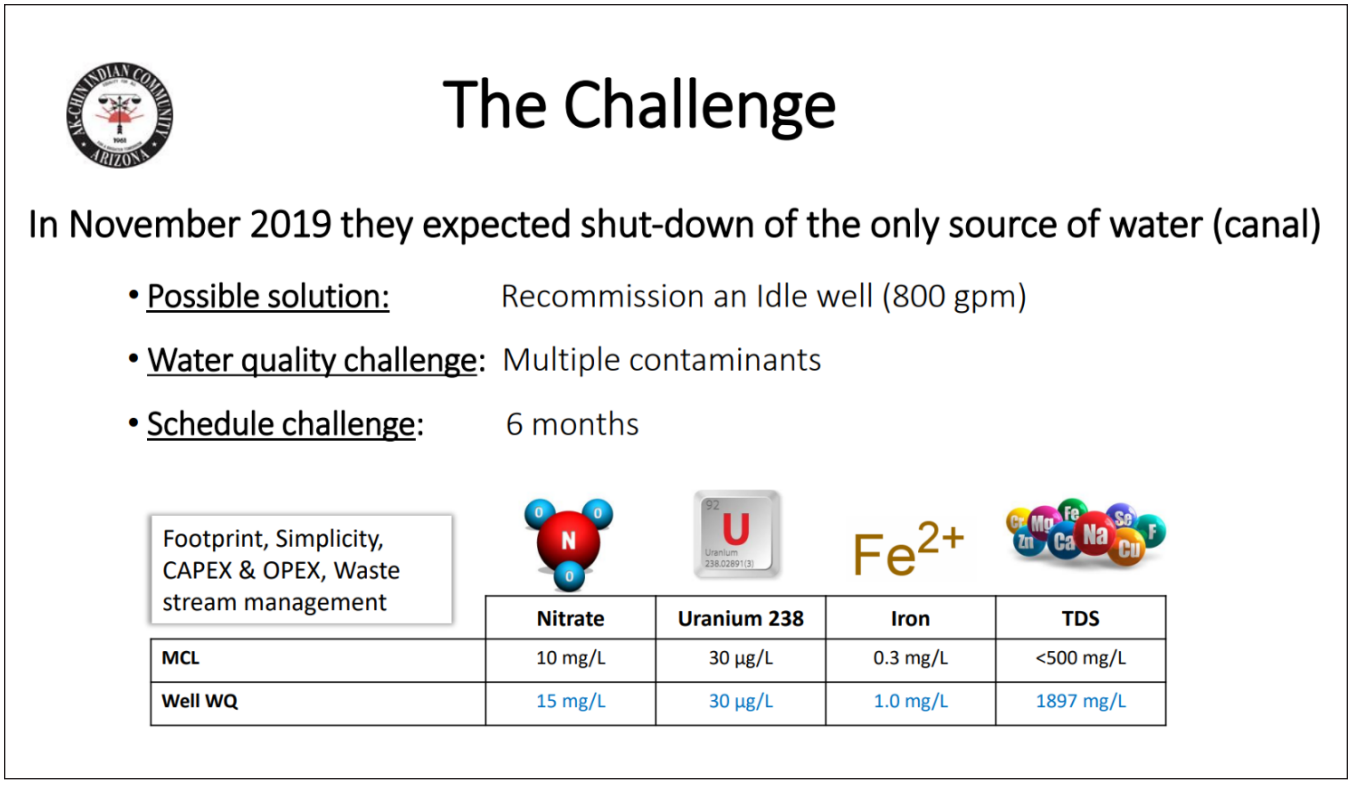


Figure 8. The challenge for the Ak-Chin community.

evaporation pond would be needed later. Additionally, of course, the system can handle three different contaminants plus the pre-treatment.

Fit-to-purpose design was key (Figure 9). Instead of treating all 800 gallons per minute through RO, we advised bypassing 250 gallons per minute and treating only 550 gallons per minute. With this plan, the plant reached a 91 percent recovery rate. At the bottom of Figure 9, you will see the progress we made from September through October 30, 2019, when the system was ready to provide water to the community. In mid-February, they also put a shed on the RO system, which is very critical because it did indeed cause problems later on, as I will explain.

Figure 10 shows a screenshot of the system in operation, with three blocks of stage one and a single block of stage three, rotating among themselves. Most exciting was the photo the operators and engineers sent us of them drinking the water produced by the system.

The flows and the recovery rate in the system are very stable. Still, remember that it's 2020. COVID-19 has caused us some delays and problems. One of the problems is that the community couldn't progress to the second phase, which is a permanent building. That meant the RO system remained exposed to Arizona's sun, which eventually caused some biofouling issues in the flush tank. Also, there was a reduced water demand, and RO needs to work and work. They had reduced revenue, which further delayed the progression to phase two. But overall, we can tell you that they have a great team, and we collaborate very beautifully in order to continue this process.

Another shutdown of the canal is scheduled at the end of October 2020. The great news is that the system is working and ready to supply an alternative water source. Also, the permanent building is expected to be completed in the first quarter of 2021.

There are a few important take-home messages. It's time to reverse the flow—the mental flow. There is innovation out there; it's proven and it's working. If it's a good fit, we need to adopt it. We must also continue securing alternative water sources for every community. I am a very big admirer of the decentralized approach. Especially for communities that are spread out, there are solutions available. Finally, we need to continue looking for creative treatment solutions. Thank you very much.

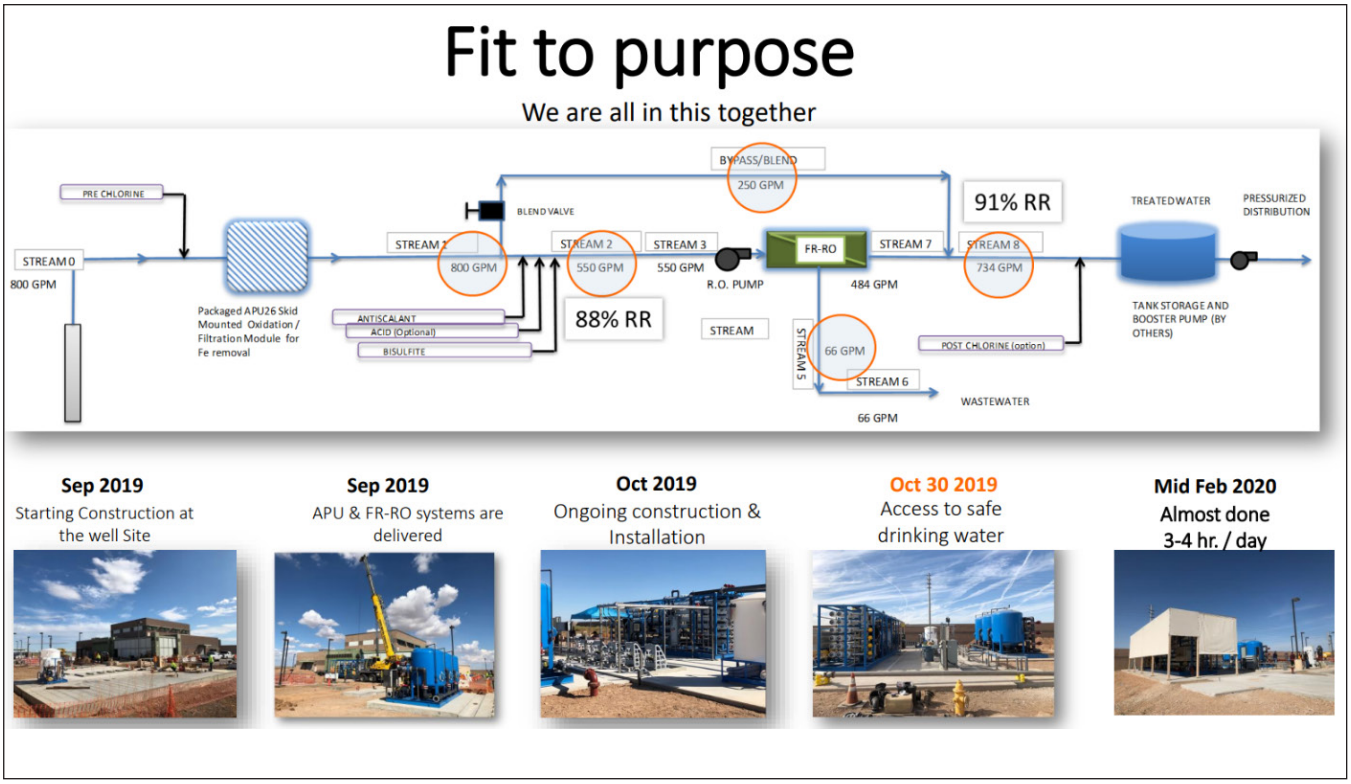


Figure 9. Fit to purpose and construction photos.

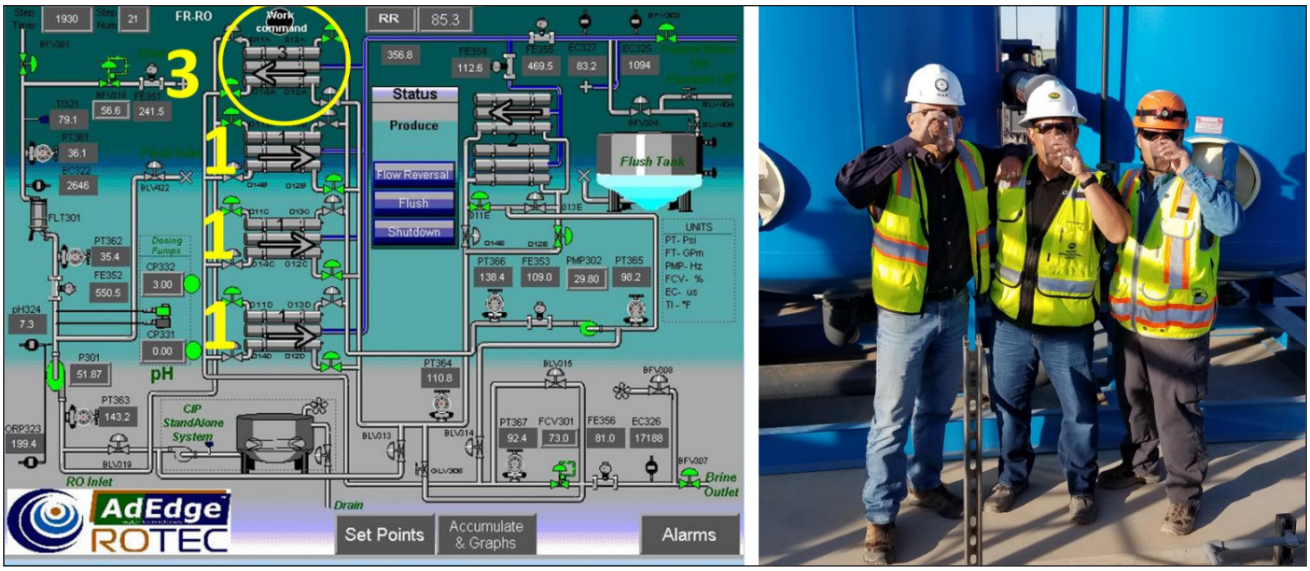


Figure 10. Fresh water supply starting on October 30, 2019.

Evaluating Water Policy in New Mexico

Editor's Note: The following papers represent a transcription of the panelists' remarks made at the conference; no follow-up papers were submitted by the speakers. Remarks were edited for publication by the editor. The speakers did not review this version of their presentation, and the editor is responsible for any transcription and editing errors.



Moderated by Aron Balok, Pecos Valley Artesian Conservancy District

Aron Balok grew up on a ranch in northwestern New Mexico, near the town of Fence Lake. He graduated from Ramah High School in 1991, and from New Mexico State University in 1997 with a BS in agriculture, extension, and education. Today, Balok is the superintendent of the Pecos Valley Artesian Conservancy District. He has been with the district for about 11 years. He also serves on the Interstate Stream Commission.

Balok has a passion for New Mexico's heritage and a deep appreciation for the complexity of the state's water issues. He has been professionally involved in water-related issues for the past 14 years. He and his wife, Hayly, and two of their three daughters live in Roswell, and their oldest daughter is a student at NMSU.

Rep. Derrick Lente, New Mexico House District 65



Derrick J. Lente is a member of the New Mexico House of Representatives, representing House District 65. He was recognized as a "Rising Star" by the Democratic Party of New Mexico and received the All Pueblo Governors Council's "Governor's Award." Lente serves on numerous local and national boards focused on agriculture, education, the environment, and health.

Previously, Lente was a professor and speaker at universities across the United States and has experience working on federal, state, and tribal issues. He was also an entrepreneur who earned returns on investments in offices he acquired in New Mexico and California, employing hundreds in the state and thousands more along the way.

Lente graduated from Bernalillo High School and holds two BA degrees in Intercultural Communications and English from The University of New Mexico, as well as a JD from The University of New Mexico School of Law.



Rep. Melanie Stansbury, New Mexico House District 28

Melanie Stansbury is proud to represent New Mexico's 28th House District in Albuquerque. A native New Mexican, born in Farmington and raised in Albuquerque, Stansbury has spent her career working in natural resources, science, and community development with a focus on water security. In addition to serving in the state legislature, Stansbury works as a policy consultant—advising philanthropic, nonprofit, research, and other organizations. Stansbury previously worked in Washington, D.C., as a staff member in the U.S. Senate Committee on Energy and Natural Resources and in the White House Office of Management and Budget. A sociologist with a background in the natural sciences, Stansbury has worked on land and water issues across New Mexico and the U.S., including projects on water policy, management, and conflict resolution, and as a science educator early in her career. She is currently working on a statewide effort to modernize New Mexico's water policies and practices.

Aron Balok: Good morning, Representative Lente. How are you?

Rep. Lente: Good afternoon. I'm well. How is everybody else?

Balok: Loving the snow.

Rep. Lente: It's such a blessing here. I'm calling in from Sandia Pueblo, where we probably got about a good nine inches here.

Balok: We comfortably got six inches here. That's a big storm for the greater Roswell area, so we're pleased with that. So, Representative, I would recommend that we just get started and allow you about five minutes, más o menos, to discuss an overview of your views on New Mexico water policy, some aspects that are near and dear to you, and some of the issues that you think will need to be addressed. Then, I hoped to move into a conversation about some specifics. I'd love to hear your thoughts on those. If you want to kick us off and get us started, that would be great.

Rep. Lente: Okay, I'd love to. Thank you for the opportunity to join all of you this afternoon. Once again, I am joining you from my home here on the Sandia Pueblo, which is a little bit north of Albuquerque, where just the past couple of days we received about nine inches of snow, which is an absolute blessing as parched as we've been for the past couple of months.

A little background on myself: I am from both the Sandia Pueblo and the Isleta Pueblo. I have families in both pueblos, and I come from an agricultural family. My father and my mother come from a large agricultural background, and I grew up with my father on the Isleta Pueblo, farming and ranching with him. I now make my home in Sandia Pueblo with my family, where I farm and ranch on a larger scale. My background, with respect to water, is that in the late 1990s to the early 2000s, I worked for Sandia Pueblo as a water resources technician, where I measured using piezometers, and I learned more about the technical aspects of water usage, water quality, surface water, groundwater, and all those other things that come along with the territory. From that experience, I was able to apply those different aspects to my own agricultural practice and how it could better serve my community and me. I also went to law school and learned a little bit more about water law. In the late 2000s, I won a seat on the Middle Rio Grande Conservancy District board of directors, representing Sandoval County. While on that board, I spent 10 years—8 of those years as their chairperson—really learning about developing policies related to agriculture and water delivery, flood control, drainage, the whole gamut in regard to agricultural, recreational, and major species matters, in the middle Rio Grande valley of New Mexico, which is basically from Cochiti Lake all the way down a little bit past Socorro to the Bosque del Apache refuge.

Springboarding from that, I ran for a seat in the New Mexico House of Representatives, where I am still a member running for a third term, now serving as the chairman of the House Committee on Agriculture and Water Resources. From those beginnings, I am now in that position, and I have a deep appreciation for water as it relates to our state. I know we are in either a feast-or-famine situation here. I am out on the farm daily with my own operation, so I respect the water from practical usage and agriculture. I can say this loud and proud: water is the lifeblood of our state. I can say without any hesitation that I will work and do whatever I can to protect and promote our water resources so that our future generations have access to the same luxury we have as New Mexicans.

Balok: Representative Stansbury, could you introduce yourself and give us an overview of where you're coming from with relation to New Mexico water policy? Then we will discuss New Mexico's prior appropriation doctrine.

Rep. Stansbury: Thank you, and thank you so much, commissioner. It's wonderful to see you all and to be able to join today. I am Melanie Stansbury, and I represent a state house district and Albuquerque on the east side of town, right here in the foothills. I'm looking at the snow melting out my window. My professional background is working on water issues. I cut my teeth in water during graduate school, studying the Aamodt case in the Pojoaque Valley of northern New Mexico. I went to Washington, D.C., to work as a policy and budget analyst for the Office of Management and Budget in the White House. I worked a lot on water conservation and climate issues there. Then I worked as the water policy person on the Senate Energy and Natural Resources Committee, which was chaired by Senators Domenici and Bingaman for many years. I moved back to New Mexico in 2017. I stepped up and ran for office, and now I'm a state legislator.

One of the things I've tried to do since serving in our statehouse is understand the opportunities to modernize New Mexico's water management. During my almost seven years working in Washington, D.C., I had the opportunity to work with states across the West, especially while on the Hill. My portfolio included the Bureau of Reclamation, the U.S. Geological Survey, and all the western water issues, including drought and irrigation systems. The thing that I was really struck by, especially on my return back home to my own community and working with many of you, was how much New Mexico has such a strong culture of water, a love for water, an understanding that water is life, water is culture, and water is key to the future of our communities. Yet, we have not been able to modernize all our systems to manage water with the precision needed. There are a lot of structural problems that stand in the way of doing that, including our water code, adopted in 1912, which was kind of a boilerplate water code in many ways. It has been modified

over the years to recognize many of our traditional systems, but frankly, it isn't serving us very well right now, especially as we're seeing severe drought this year and hydrologic changes. Overall, we're experiencing the need to upgrade all of our infrastructure to manage and meet our water requirements. Over the last two years, I've been holding listening sessions across the state with different stakeholders—everybody from the agricultural community to acequia mayordomos, from oil and gas representatives to water experts, lawyers, and others. I have been asking the question, "If you had a blank slate, if you could fix all the many challenges that we face in water, what would you do?" These sessions give people space to imagine and develop big ideas about what we would do if we could modernize our water systems. I learned a lot from these listening sessions. We had sessions in Santa Fe, Albuquerque, Socorro, and Las Cruces, and planned to hold them around the state this year, but the pandemic stopped us from doing things in person.

The three big takeaways I got from those listening sessions, which included hundreds of people, were: first, everyone—no matter where you live, no matter what your political ideology is, no matter what sector you work in—agrees that the system is not working well right now. We need to improve our governance structures, strengthen how our state interacts with all our water managers and sectors, and upgrade how we do business around water. We really need to fundamentally take a hard look at our water code and reboot it. The second thing I was surprised to learn is that everyone agreed we needed to do some challenging work on our water laws, because there is a keen sense that we know they are broken, but we cannot do better. I want to dispel that myth because we can do better. We have seen in other sectors here in New Mexico that we can implement comprehensive reform. For example, in criminal justice reform, we had a bipartisan commission that worked for over a decade and helped to pass a slew of bills to modernize our criminal code. Finally, our infrastructure is in the worst shape in the United States. We're rated at the bottom in terms of safety and need for maintenance, so we really need to figure out a comprehensive plan of how we're going to resiliently rebuild our infrastructure, and how we're going to accomplish it within the current hydrological regime that we're living in, since we are seeing the actual impacts. Thankfully, the snow is bringing us some moisture right now, but we are seeing the impacts of hydrologic change. If we want our communities to succeed, we need a real, serious, science-based plan for how to rebuild our water infrastructure in this state. Those are some of the big topical areas that we're working on.

I have a monthly work group that has been meeting to talk about the specifics, such as "How do we do this? How do we help communities?" I want to invite any of you to participate. I know I occupied more real-estate time during this call than Aron wanted me to, but I will stop talking, and you all can return to the discussion of prior appropriation. I will just say that I do not think it is realistic to expect that we can dismantle prior appropriation at this time, but I do think we can build more resilient governance structures focused on water sharing.

Balok: Thank you for that. I think you set the table for our conversation moving forward. Anybody who has worked in the industry for very long becomes familiar with the complexities of prior appropriation. We've had this system in place since before New Mexico was a state. I hear a lot of discussion about wanting to make major changes to move away from the prior appropriation doctrine. Of course, I have a very biased opinion on it. Here in the Pecos Valley, I think we're a little bit ahead of the curve as far as our water administration is concerned because the vast majority of the basin has already been adjudicated, which is a huge obstacle to applying the prior appropriation doctrine. Even so, I still am not a fan of abandoning the prior appropriation doctrine. One of the reasons I'm an advocate for it is because it is such a thorough system, and it contemplates a lot of different scenarios. A lot of times, we find ourselves asking, "How are we going to address this particular shortfall situation?" when the prior appropriation doctrine already tells us what happens.

It's important to point out that here in the Pecos Valley, the Pecos Valley Artesian Conservancy District sits upstream with a junior water right to downstream senior water rights holders. It would make sense for me to advocate doing away with the prior appropriation doctrine—my constituents would stand to benefit from that—but I don't. I think prior appropriation motivates water users to come up with alternative solutions if they don't want to curtail. I would like to ask Representative Lente to weigh in on the prior appropriation doctrine, and then I would like to direct the conversation based on the things that Representative Stansbury said and get to the heart of some of the questions that I have as it relates to water policy. So, Representative Lente.

Rep. Lente: Thank you, Aron. Representative Stansbury, it is good to see you. A little flashback to the past is that I met Representative Stansbury when she was working on the Hill. She was helpful with many of the measures the Middle Rio Grande Conservancy District was trying to take then. It was incredible that of all the people in Washington, D.C., the person we would go to see all the time to help us out on these important water issues was the woman from the North Valley of Albuquerque. It's good to have her on the team and helping us with these issues.

When I think about prior appropriation, it obviously depends on where you are on the system. That's going to decide how you feel about it. When I think about the

district I represent here in north-central and northwestern New Mexico, in an adjudicated area along the Rio Grande, many of the tribes rely on the prior appropriation doctrine to ensure they get their full drink of water, especially during times of crisis or climate change. I have seen where this federally protected water right has come into play and has helped protect tribal farmers, for instance, from going dry. When discussing the oldest water users along many of the systems in our state, the prior appropriation doctrine can, in certain cases, be applied to help protect and promote water for agricultural uses, but I have also seen it diminish and become very competitive as it relates to the interests of endangered species, recreation, and so on. In my former terms as a director for the Middle Rio Grande Conservancy District and in my work alongside the pueblos in the Six Middle Rio Grande Pueblos Water Coalition, I tried to promote and protect the prior appropriations doctrine. Having this doctrine protect the pueblos' water use was extremely important, and oftentimes it was a stretch to even implement it. To your point, Aron, and Representative, that has been my experience, and that is my take on prior appropriations.

Balok: Representative Stansbury.

Rep. Stansbury: I was just going to add one thing, based on a comment that was just posted in the Q&A about why we would hold on to prior appropriation. One thing that I would see is that oftentimes, when we talk about prior appropriation in New Mexico, we talk about it in a very binary way, either as good or as bad, rather than thinking of it as a tool for figuring out how to distribute water. There are also other systems and forms of distributing water that exist in the same space here in New Mexico. For example, we have pueblos that have been using water for centuries, millennia even. We have Spanish communities that have been using water for centuries, that use different forms of allocation within their own systems and then within the larger macrosystem. What we have seen in other states, like Washington state and, increasingly, in places like Montana, is that at the watershed level, people are coming up with innovative, collaborative water-sharing agreements. Prior appropriation is just one way to determine who should get water, especially in a water-scarce situation. You can have prior appropriation exist in a collaborative watershed agreement. For example, you can have an agreement that the pueblos, because of prior appropriation and their time immemorial water rights, get their water first. They may be willing—I'm not presupposing this—to share water in a time of shortage, or similarly, the acequias might be willing to share water for certain purposes if an agreement is reached. There are other benefits that come with them, like keeping the river wet and so on. One of the things I would really like to challenge our water community to do is to think outside the box, because I really think we tend to be very constrained in our box here in New Mexico, when there are so many creative ways we can solve water problems through collaborative agreements. You don't have to get rid of every aspect of our law in order to do that.

Balok: Representative, I think you bring up a good point. I kind of keyed in on your hand gesture there because of the blinders that we tend to put on when we discuss prior appropriation. Too many people perceive prior appropriation as a strict winners-and-losers kind of scenario, where senior appropriators get all the diversion while juniors get none. While technically that is probably the way the law reads, the reason I think it is so valuable to New Mexico is because it offers a bleak alternative. If we can't figure out how to come up with some of these agreements you were discussing, the hypothetical ones, that's the alternative. A junior user is going to have to do something to convince a senior user to let him continue using his water with that junior right. This opens the door, and I hate to be the one to say it out loud because Active Water Rights Management (AWRM) has such a terrible reputation among some people, but I really think a big part of what AWRM was intended to do was not to replace prior appropriation doctrine but to serve as an avenue to fulfill its requirements.

One of the problems I have with New Mexico is that it does not put in the hard work prior appropriation requires. A big part of that is the adjudication. I'm certainly not in favor of streamlining it, because if you do, you're going to have to make some sacrifices. I think the one thing that makes adjudication so time-consuming and expensive is that it is thorough. We're not jeopardizing the property rights that someone has invested in. Oftentimes, it's multigenerational. I once heard a quote that says something to the effect that 'quick and easy' is the kind of solution you want for baking a cake, not for big issues like the ones we're discussing. I wouldn't be a big advocate of taking away some of the securities that provide water rights owners with adjudication and protection under the prior appropriation system.

I would like to follow up with a question concerning your comments. Representative Stansbury, you said everyone agrees it is not working. I think it is probably more regional than statewide, and possibly even more a perception than a reality, but I'd love to hear your thoughts, and then we'll move back to Representative Lente.

Rep. Stanbury: In the four places that we went—and, of course, all of those were on the Rio Grande—that was the unanimous sentiment. It was not regional, but it was regional in the sense that those are the places where I held listening sessions. The answer to the question you're asking lies in a response I'd like to say to your earlier comments about prior appropriation.

I disagree with the idea that the state hasn't worked hard to adjudicate our stream systems. The reason why we have large numbers of stream systems that are not adjudicated is because it's not the right tool to solve our problems in some of the places where it has been tried to be used. In terms of the prior appropriation system, you have to think of it historically, right? It came to be in the late nineteenth century, as part of western expansion, to open up especially arid lands to settlement and commercial agricultural development. In places, for example, in the southern Pecos River, where that kind of homesteading and dryland development was happening, it made sense to figure out who should be able to use the water rights first. First in time, first in right; however, when you try to mash that up with thousands of years of occupation of these landscapes and stream systems, including other cultural ways of interacting with these rivers, other legal systems that were indigenous, came from Spain, or were embedded in Mexican law and later assimilated into U.S. law, the systems don't mash up in a nice, coherent manner. If you look, for example, at the history of adjudication, there were adjudications that were filed in the 1960s, and those cases are still not resolved today because the American legal system couldn't figure out what was a fair way for communities to share water. I fundamentally disagree that prior appropriation will solve our problems if we could just figure it out, because we have more than half a century of experience that shows it doesn't solve the problem. That is why, as a state and as a country, we have steadily moved toward collaborative water-sharing agreements. Increasingly, tribes have been willing to come to the table and work with states and the federal government to develop third solutions, such as settlements and related agreements. We value figuring out how we share water together, moving forward, having prosperity, and protecting our communities. It may work in some places, but I don't think it works for a lot of places.

With respect to the comment I made about people wishing for change, I'm sorry I made such a blanket statement. I have a whole list of things that we heard across the state that people would like to see changed in state law. First, our communities are struggling to build drinking water and wastewater systems, and the technical assistance and resources they're receiving for that are inadequate. We need to restructure how we finance, plan and build infrastructure, and provide technical assistance to communities. Second, we need a science and infrastructure plan for the State of New Mexico, and we need to prioritize how we fund assets to ensure we're funding what needs to be built. People are very frustrated working with the state agencies. State agencies are understaffed. They're difficult to navigate. Their IT systems are antiquated. They need to be upgraded, and we need to figure out how to streamline our state programs. There's a whole slew of things that people across the state feel like we really need to work on. That's more what I was referring to. Representative Lente, do you have thoughts on that comment?

Rep. Lente: I respect much of what Representative Stansbury talks about in terms of her perspective. Coming from a tribal perspective and representing a lot of Native American New Mexico that is unadjudicated along the Rio Grande, back in the late 1990s, early 2000s, I would be asked to go and sit in on meetings regarding water policy, water development, water planning for the future, adjudication discussions, etc. Preparing for those meetings, as a late teenager, I always thought adjudication, at least here at home, was imminent; that it was going to happen within the next 5 to 10 years. Here we are, 20, 25 years later, and nothing yet. Where I'm going with this is that the discussions I recall being part of and listening in to were always led by folks who wanted the best and have, without a doubt, the best in mind and in heart for New Mexico and for the scarce resource that is water. For many of the folks who were speaking up on behalf of that love, they had no skin in the game, so to speak, meaning that they were speaking out of a willingness to want to say, "Well, the pueblo should and the acequia should…," and so-and-so should do this, and share and share. All the while, the pueblos and the acequias, for the most part, were sitting on the sidelines, just listening in. I know dynamics have changed enough that there's more discussion, and I know that for many of the folks who are first in time, first in right, have much more capacity now to join those discussions and be a part of that table. Nonetheless, it just seems to me that we have to make sure that when we're talking about prior appropriations, we have those people who have the most senior water rights at the table and that they are a part of the discussion, if not leading the discussions, in terms of how they are going to be asked to share in the solution.

Balok: I agree 100 percent. As both of you are speaking, I'm contemplating some of the nuances of water. It is complicated and is not just a property right; it is also a public good, and that's really difficult to (a) get your head around and (b) balance, because there are owners that do own a property right in the form of a water right, and none of us can do without water, period. Our current system recognizes, to some extent, that when you take water and use it, you have the right to do so, but then it is returned to the public. It does complicate the issue.

I know we could spend the rest of the day just speaking about water law. Of course, it is the topic of our discussion, but I want to transition just a bit to another topic with roots here in the Pecos Valley. We use the term "conjunctive management." It is this notion that we have to manage groundwater because it is connected to the stream, and what you do to one affects the other. Just

a little factoid for the day: that concept of conjunctive management was born here in the Pecos Valley. It was used as justification to give the State Engineer authority to manage groundwater. It was intended to apply to limited parts of the state, but the way it was worded means that, when we have a deeper understanding of the resource, the State Engineer has the authority to manage it. As we have moved forward with this conjunctive management concept—19 western states have adopted the model New Mexico uses for conjunctive management—we have gone through some real growing pains over here in the Pecos Valley and have gotten in trouble with the State of Texas for underdelivery. That's what they pointed to as the cause for the underdelivery on the Pecos: groundwater pumping. Now we're seeing a similar situation play out on the lower Rio Grande, again with the State of Texas.

I would like to hear your thoughts, and we'll start with you, Representative Stansbury. What do you see as an opportunity to better manage or possibly to change policies to manage our groundwater? Remember that, unlike in the Pecos Valley, groundwater in many of these areas is fossil water. They're mining water; it is a finite resource.

Rep. Stansbury: I think we need two things. I think we need better science and a comprehensive groundwater policy for the state. First of all, a huge percentage of our state's aquifers and groundwater are not well understood. It's hard to manage something you don't understand well, especially the hydrologic connectivity between surface water and groundwater. I would like to see the state and federal government make a sustained investment and really try to understand that hydrology. Second, I don't know what it would look like in terms of a comprehensive groundwater policy, but a number of other states have moved in that direction, including California, which passed the Sustainable Groundwater Management Act a couple of years ago to help facilitate and improve the way that groundwater is managed. We should look at what different states are experimenting with and figure out how we can improve conjoined management, because it's just one water and we've got to manage it well.

Balok: Representative Lente.

Rep. Lente: Aron, if I may, I agree 100 percent with the sentiments of Representative Stansbury. Those two things are extremely important, but I know the State Engineer is in the meeting and that we've had really frank and honest discussions about his department's lack of a strong budget. We can't do much in this state if we can't even fund our own State Engineer's office appropriately. It is incumbent upon folks like Representative Stansbury and me to really step up to the plate and fight on behalf of departments like Mr. D'Antonio's, because those are the departments that will make these things happen and really help us help ourselves. If we continue to kick the can down the road, unfortunately, we'll just keep creating battles between folks along certain river areas and also just before us, with the tough decisions about what Mother Nature has given us.

Balok: I certainly appreciate that. I've got something of a parting shot for both of you. You can address it if you'd like in your closing comments. One of the things we see here in the Pecos Valley is the financial value of water and how it impacts our efforts to manage it. A good example of that are wells used for construction. They're filing permits to divert water from domestic or livestock wells. They can divert three acre-feet from that and then file for two more extensions and take a total of nine acre-feet from oil that doesn't have a water right associated with it, which, in and of itself, is a good idea. You must have a water source in these areas where you're doing construction projects and gas and oil development. That really shines a spotlight on some of the solutions we discuss for our future water needs.

We just heard a discussion on desalinization, and there has been a lot of discussion about how we can use produced water from the oil field to meet some of those needs. I did just some quick math here. I'm sure you all know that there are 44 gallons to a barrel. That's 7,405 barrels in an acre-foot. Over here, right now, water is selling anywhere from 50 to 75 cents per barrel. That equates to a range between 3,700 and 5,500 dollars per acre-foot. That's expensive water. When you're talking about a rate of one dollar a barrel to clean up water to the point where we can use it for fracking, it really becomes difficult to see how our producers are going to lean toward produced water instead of buying fresh water and using it for that. If you all would like to include that in your closing comments, Representative Lente, I would ask that you go first and wrap things up. I certainly appreciate you taking the time to be here with us.

Rep. Lente: Aron, folks, and Representative Stansbury, it's an honor and a pleasure to join all of you this afternoon. I know this is a minimal amount of time we can apply to this type of situation and this discussion, but there is more conversation to be had. As it relates to the legislature and the work we're doing there, most folks can rest assured that we are in full support of departments like our State Engineer and other folks to make sure that they are fully staffed and that their budgets are adequate. Obviously, we're not there yet, but we are looking forward to getting there. If we don't plan adequately today for water resources in the State of New Mexico—again, it's a feast-or-famine situation—we're going to continue to kick the can down the road, as discussed previously. If we can prioritize our ability to begin those discussions and bring the important parties to the table when we're making these plans, that's going to help the planning process immensely. I am aware of discussions of prior appropriations and other emerging concepts, and I grant that many of the

systems in our state are, in fact, old and dilapidated. We have a lot of work to do, and our state's failure, in terms of water planning and water investments for infrastructure, is expensive. The fact is, we have to do something about it because water is becoming increasingly scarce. To that point, Aron and folks on the call, I appreciate the opportunity to join all of you this afternoon.

Balok: Representative Stansbury.

Rep. Stansbury: Thank you, Aron, and thank you also for this great conversation. I love these conversations. I think produced water generates a lot of heated discussion. To me, produced water is a chemistry and an economics question. At the end of the day, can you clean that water at a cheap enough and fast enough rate to make it reusable, certainly in the oil field, which we should be doing, and then make it safe enough for consumption uses? There are still some question marks around how it is regulated, how we desalinate it, all these things, and whether, near term, there is technology that makes it economical. There's already a research consortium of New Mexico's greatest minds at New Mexico State University and around the state, probably including many of you on this call, working on those technical questions. There's no doubt in my mind that if anyone can figure out those technical questions, it's the scientists of New Mexico's universities and national labs. I hate to opine on a technical matter before we hear from our technical experts.

In summary, I just want to repeat and say thank you to Chairman Lente. I really appreciate everything he said and agree with it wholeheartedly. We need to invest in it as a state and support our state agencies that manage water. We need to work on modernizing everything we do in this state, including investing in infrastructure and streamlining processes, all to care for our most precious resource, which is water, and which is life. I look forward to working with all of you. If you have any questions or follow-ups, please feel free to be in touch. Thank you.

Balok: I've been seeing all these questions pop up, and I wish I could go through and answer all of them. I love the fact that it has generated some thoughts. As an instructor once told me, at least we're getting some neurons to fire there, and people are thinking about this. I think Representative Stansbury hit the nail on the head that there's a ton of technical work that we still need to do. We rely heavily on models, but they are only as good as the information we put into them. That's why so many people love to cuss the models that we use. Yes, they're inaccurate, and they don't do all the things we'd love them to do, but that's because we can only make them as good as the information we put in. There are a lot of data gaps there.

I want to thank both of you for taking the time to visit with us. Hopefully, we got people thinking about the realities and complications of addressing our New Mexico water policy. Thank you to the audience for participating and listening to us.

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Albert E. Utton Memorial Water Lecture



Michael L. Connor, former U.S. Deputy Secretary of the Interior, Wilmer Hale LLP

Michael L. Connor is a partner in the law firm of Wilmer Cutler Pickering Hale and Dorr LLP. His practice focuses on strategic advice and legal services to clients in matters involving water resources, public lands, energy development, environmental compliance, and Native American law. Previously, he held several leadership positions at the federal level. The most recent was deputy secretary of the U.S. Department of the Interior from 2014 until 2017, where he was the department's second-highest ranking official and a key leader in implementing the Obama-Biden administration's priorities related to climate change, water resources, science-based landscape-level management of public lands, expanding renewable energy development, and improving the federal government's fulfillment of its trust responsibility to Native Americans. Prior to this position, Connor served as the commissioner of the Bureau of Reclamation from 2009 to 2014, where he led efforts to address challenges associated with water supply and hydropower generation in the West. Connor received his JD from the University of Colorado and a BS in chemical engineering from New Mexico State University. A native of New Mexico, he is an enrolled member of the Taos Pueblo.

Editor's Note: This paper transcribes the speaker's remarks from the conference. No follow-up paper was submitted, and the remarks were edited for publication by the editor. The speaker did not review this version, and the editor assumes responsibility for any transcription or editing errors.

Sam Fernald: Before I introduce Michael Connor, I have a brief note on the Albert E. Utton Memorial Water Lecture. Albert E. Utton served New Mexico as a member of The University of New Mexico (UNM) School of Law and the Interstate Stream Commission, while advising the New Mexico Water Resources Research Institute (NM WRRI) on water issues. Teaching administrative law, environmental law, and international law, he was heavily vested in water issues. Having served on NM WRRI's Water Conference Advisory Committee for twenty years, and in recognition of his service to the New Mexico water community, the NM WRRI established the Albert E. Utton Memorial Water Lecture Fund, which provides support to speakers who are selected to give this lecture.

This year, we have Mike Connor, who has quite an impressive resume himself. He's now a partner in the law firm of Wilmer Cutler Pickering Hale and Dorr, and, as he put it, knows a thing or two about water. Mike was Deputy Secretary of the Department of the Interior from 2014 until 2017, responsible for many water-related issues and managing public lands and resources in the nation. He was also Commissioner of the Bureau of Reclamation and has been heavily involved in water in the western U.S. and is a native of New Mexico. I learned at our 2012 New Mexico Water Conference that he went to the same junior high as my kids. He is also an Aggie, and we really respect him for his water expertise.

Michael Connor: Thanks, Sam. I appreciate the introduction, and particularly you making sure that folks know that I have some New Mexico bona fides, which makes it doubly a pleasure to be part of this conference. As you mentioned, I don't think I've spoken at the conference since 2012. At that point in time, I believe the State of New Mexico was initiating an action that soon became known as New Mexico v. Connor, regarding operations of the Rio Grande Project, but let bygones be bygones. It all got usurped by Texas v. New Mexico anyway, so I appreciate the opportunity. It would only be better if we were all together in New Mexico.

I haven't been able to tune in for as much of the conference as I would have liked, given the agenda that you've put together, which is terrific. But I did get a chance to take in Senator Udall's comments on Tuesday, and my comments today will be an extension of his comments delivered about climate change in particular and the urgency of the moment that exists.

New Mexico has, needless to say, been blessed with wonderful, visionary political leadership in recent years, as demonstrated by Senator Udall. I think everybody saw the short clips from Senator Heinrich and the rest of the delegation on Tuesday. It has been terrific to watch the leadership and the focus on these issues of concern. I had a chance to work for Jeff Bingaman for eight years when he was leading the Senate Energy and Natural Resources Committee. Jeff always had a laser-like focus on water issues in particular. We moved a lot of water resource legislation through the committee, everything from Indian water rights settlements to programmatic initiatives for New Mexico, as well as the country overall, science-

related bills, aquifer studies, and building rural water projects in New Mexico.

Particularly for today, given the subject I'm going to talk about, the one that stands out the most is the SECURE Water Act, which I believe was the first climate-focused legislation that was enacted by Congress. It was enacted back in 2009 right after Barack Obama took office in March of that year. I remember Jeff calling me into his office the day after we held the first ever climate change water hearing in the Water and Power Subcommittee. Based on what he had heard and what he was seeing on the ground, he wanted to introduce and move forward with a piece of legislation that addressed the implications of climate change on water. This was the start of the SECURE Water Act, introduced in October 2007 and finally getting enacted a little less than two years later, which is pretty good for moving legislation through Congress. This is just a long-winded way to say that I've been involved in climate and water issues for many years now.

I've given lots and lots of speeches, especially during my years in the Obama administration running Reclamation and as Deputy Secretary of the Interior, but never have I felt the urgency and the need to act as I do today. I want to focus my discussion on the implications of climate change, and therefore, the title of my presentation is simply "Drastic Times…"

Figure 1 was put together by NOAA and identifies the climate- and weather-related disasters that have occurred in the country with losses in excess of $1 billion as a result of those activities. At a very high level it talks about the nature and breadth of the far-reaching effects of climate change across the country as a whole. Climate change manifests itself in many different ways. There are 16 different weather and climate disasters that are identified on this chart, as of October 7, 2020: one drought across the West; 11 severe storms, derechos, and other tornado events that have occurred; three hurricanes and one wildfire event or series of events in Northern California and Oregon that occurred. That ties the record of $1 billion of disasters that have occurred and have been attributed to weather- and climate-related activities. There were also 16 events in 2011 and 2017. In Colorado, this last week wildfires really took off. The East Troublesome Fire grew from a small 10,000-acre fire to almost 100,000 acres within a couple of days. I just heard on the radio this morning that it took out at least 100 homes in the area of Grand Lake, Colorado. When you combine this with the other Colorado wildfires in the area, it's likely to be added as a billion-dollar weather and climate event. Furthermore, Hurricane Zeta hit the Louisiana and Mississippi coast late yesterday afternoon. We'll have to see what the implications of that event are, but more likely than not, we're headed toward a record year with respect to weather and climate disasters, and the financial impacts of those are very significant, as you can see.

Of course, the western United States is acutely sensitive to climate change and its implications overall. Some years more than others but this is one of those years that certainly makes clear the related nature of climate change, drought, and wildfire, as they do go hand in hand. But this year in particular is downright scary for a lot of different

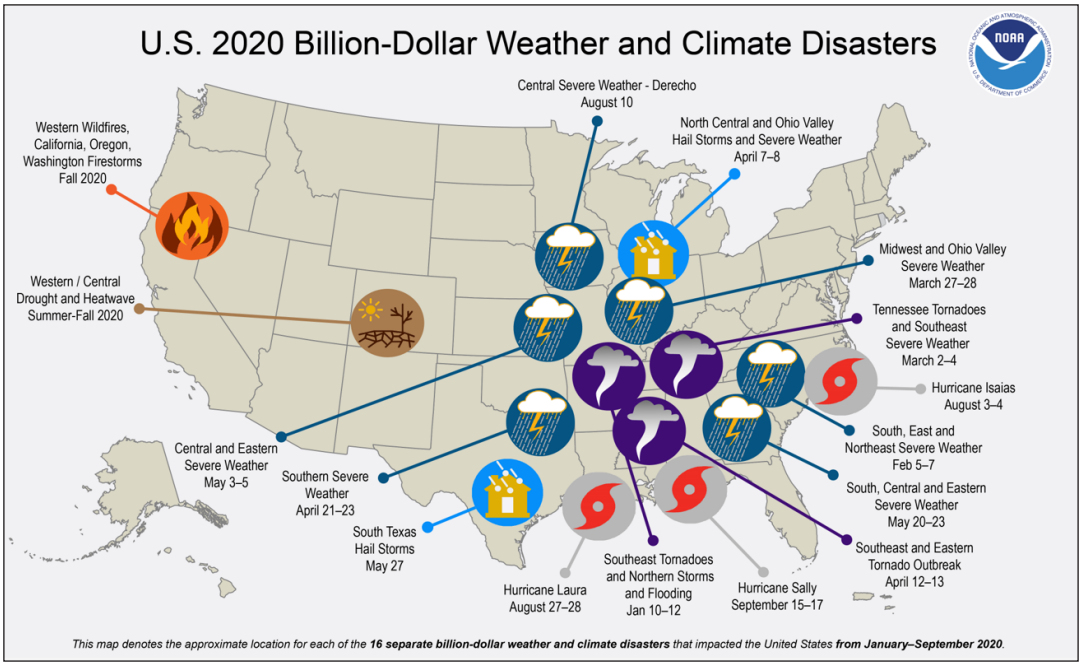


Figure 1. Billion-dollar weather and climate disasters in the United States, 2020.

reasons. The map on the left of Figure 2 is an identification of all the current wildfires that are moving through the West. Of course, California has been severely impacted by a record number of fires and a record size of fires this year. Colorado has had three record fires this year each exceeding 200,000 acres, which had never occurred before within the state. Overall, from a fire perspective, as of October 2020 there have been about 8.5 million acres that have burned across the nation this year. The 25-year average, year-to-date, is 6.2 million acres, and the 10-year average is 6.85 million acres. This means we're way ahead of the pace for an average year, and we still have several months to go. California itself has had 4.15 million acres burnt this year and it is still wildfire season for the state. However, these days the wildfire season is year-round.

Historically, fire seasons of more than 10 million acres across the landscape were unheard of prior to the last decade, and we had two of them when I was at the Department of the Interior during the Obama administration. I believe there has been one in the last four years, and we'll see where this year ends up. Interestingly, I would note that the actual number of fires is significantly reduced from what it has been historically. The increased acreage indicates that the fires are larger on the ground and they're more unpredictable. Overall, I would say that with respect to the West-wide drought and wildfires, I don't think scientists are really focused these days on the issue of whether climate change is occurring. I think there's so much overwhelming evidence that it's not really being discussed, except in the U.S. Congress at times, but that is simply politicizing an issue that has no factual basis. I think scientists are more focused these days on connecting warming temperatures to activity and actions on the ground. There are more and more reports and analyses highlighting the connection of climate change to the increased nature of wildfires and to extreme drought situations. Interestingly enough, I just read about some scientists no longer calling it drought. Rather, they're calling it the advancement of aridification of our western United States.

The last thing I'll say about this, particularly from a western U.S. perspective, is that these impacts and these effects of climate change as they manifest in drought or aridification and wildfires really take their toll on rural communities as opposed to cities. They take their toll from the standpoint of simply the lack of water available for agriculture in the West and the implications of that. From a municipal supply perspective, rural communities do not typically have as diverse a number of supplies as larger municipalities that conjunctively use groundwater and several surface water sources. Obviously, cities experience impacts from wildfires, particularly health impacts from smoke. We certainly experienced that all along the Front Range this year, but it's the communities closest to these wildfires that experience it worse. There were evacuations, home loss, all sorts of devastation that wildfires can bring, which seriously impact rural communities as opposed to those of us who reside in cities.

Focusing on little old New Mexico, the headline of Figure 3 says it all. This was from an Albuquerque Journal story during the first week of October 2020. You can see the extent of drought: 100 percent of the state is in at least moderate drought, greater than 85 percent of the state is in extreme drought, and 2.1 million people, the entire population of the state, are affected by drought in 2020. Unfortunately, if the climatologists and meteorologists are accurate in their predictions, of which I have no doubt, a La Niña pattern is developing in the oceans, and the expectation for winter is that there will be above-normal temperatures and continued below-normal precipitation at least for the next several months and into early 2021.

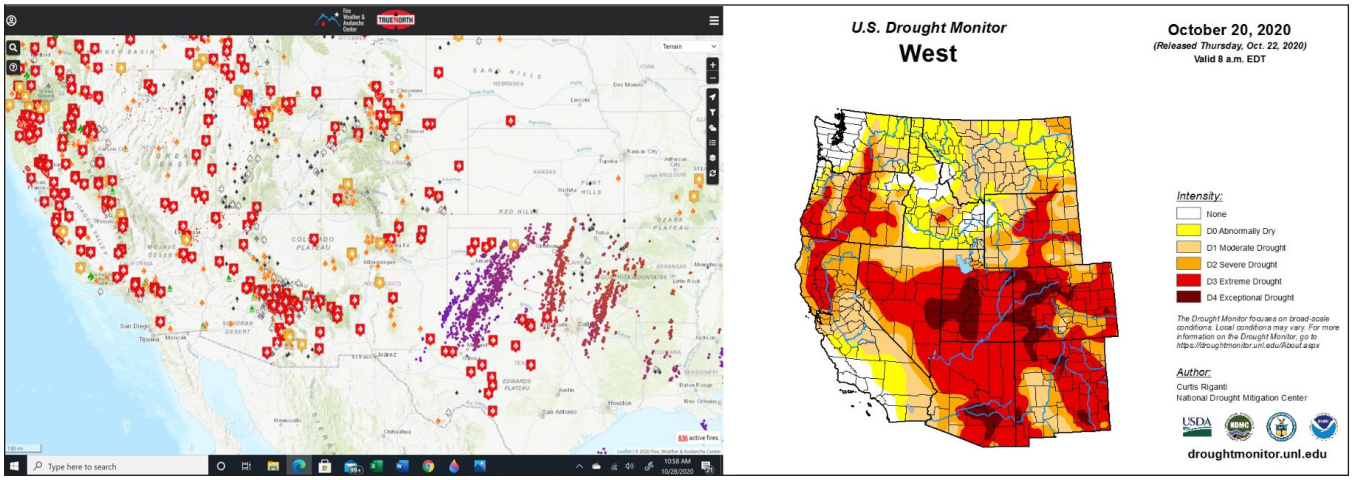


Figure 2. Fires in the western United States as of October 2020.

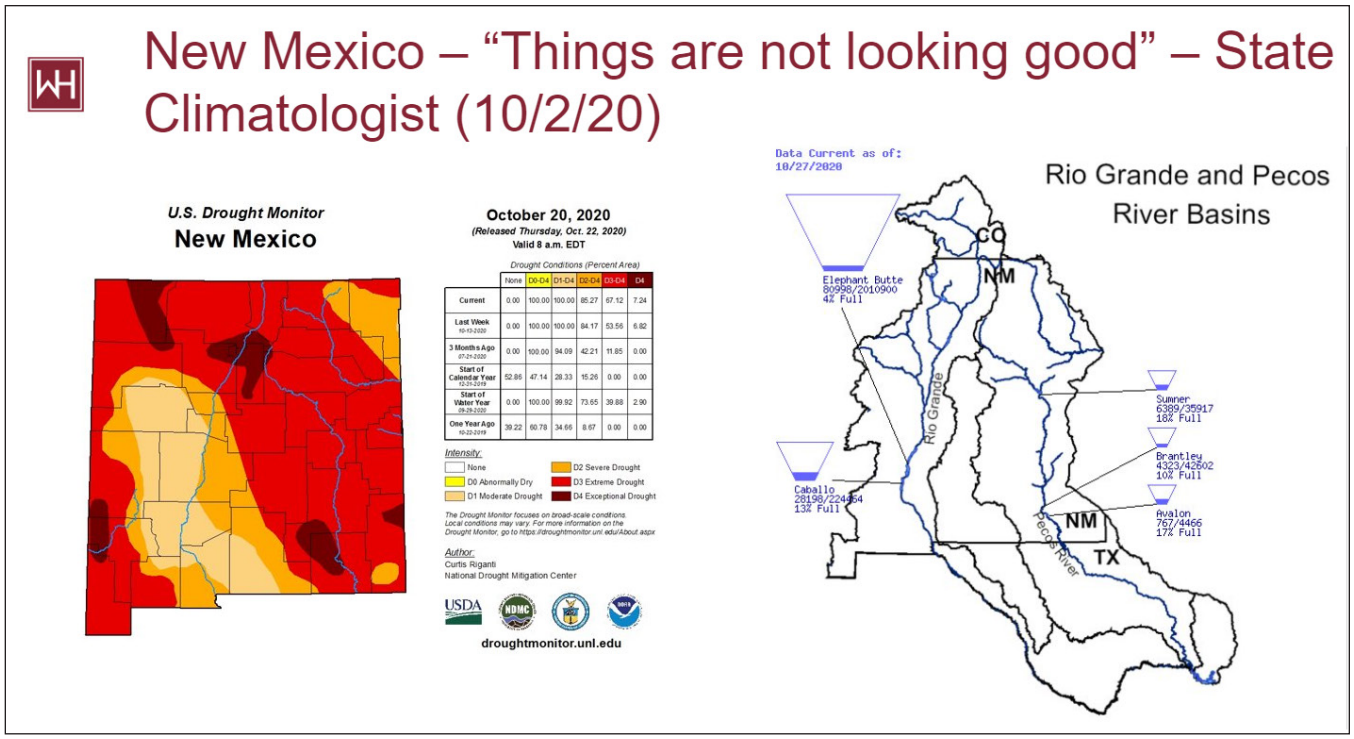


Figure 3. New Mexico drought status and reservoir capacities.

The reservoir capacities that exist in the Rio Grande and the Pecos River Basins are shown on the right of Figure 3. It's not hard to see that those reservoir levels are not going to sustain water use in New Mexico's river systems going forward through 2021 unless there is a dramatic change in precipitation levels. Of course, the implication is that groundwater mining will continue. Access to groundwater will be hit hard in 2021. There is no doubt that this will heighten tensions in the lower Rio Grande situation, which has been the primary issue between Texas and New Mexico, and has resulted in the ongoing Supreme Court case. We'll talk more about that in a minute. In addition to the water supply impacts, this will have extreme implications for fish and wildlife in the state, as well as recreational resources, and each of these have economic impacts on communities. So, it's serious from all kinds of stakeholder perspectives.

Looking more long-term, I just read a summary of a presentation given by Dave Gutzler, a well-known UNM professor and climate scientist in the state. Looking ahead, we can expect average temperatures will continue to increase. To date, New Mexico has had an increase—I think Senator Udall mentioned this—of 2.7°F, which is equivalent to 1.5°C. Interestingly, it was the objective of the Paris Agreement to keep temperatures from exceeding that 1.5°C increase worldwide. We're not quite there yet worldwide, but we are well on the way. In New Mexico, we're already there. The significant implications of this for water supplies include snowpack decline, increased evapotranspiration, reduced streamflow, and reduced groundwater recharge. There are two other long-term implications, according to Gutzler. One is that the atmosphere will continue to have more energy in it and there will be more variability with respect to weather events and precipitation, which most likely means more extreme events. The other conclusion is that the winter storm track will move permanently north, adding another adverse effect to New Mexico. Drastic times indeed.

What do we do about that? Apparently, some think that the best thing to do is to fight about that, through litigation such as the following:

- Texas v. New Mexico, No. 65 Original (S.Ct) – Pecos River
- Texas v. New Mexico, No. 141 Original (S.Ct) – Rio Grande
- United States v. Abousleman, 2020 WL 5792100 (10th Cir.)

If you look at the top two bullets, there are good friends in Texas who have taken that approach with respect to our state. There are currently four active interstate water disputes that are pending before the U.S. Supreme Court. There are obviously the two cases that had a significant amount of activity over the last year or two. There was also Florida v. Georgia, which is an equitable apportionment case on the Apalachicola, Chattahoochee, and Flint River systems, involving not just Florida and Georgia but also the state of Alabama. The other case is an interstate allocation case between Mississippi and Tennessee, which

is a first-of-its-kind groundwater pumping case involving a shared aquifer along the border of those two states.

To give you context with respect to this litigation, Florida v. Georgia has been 30 years of litigation in various forms. A little bit like Texas v. New Mexico and the Rio Grande, it has not all been in the Supreme Court. It's been in other court systems. But Florida v. Georgia has been 30 years without any kind of decision that has nailed down the allocation issues. In 2018, there was a decision by the Supreme Court that got into resolving the standard of proof involved in seeking a remedy for equitable apportionment. A tiny fraction of the issues at play, but that was the nature of the 2018 decision. So, stay tuned. There's probably a lot of litigation left in that particular case. Mississippi v. Tennessee has been before a special master for over five years now. It's unclear when this might lend itself to being elevated to the Supreme Court, but it's probably going to take some time. Florida v. Georgia is likely to have a decision that's teed up for argument in the next term of the Supreme Court.

Getting back to our neck of the woods with Texas v. New Mexico. The original action identified as number 65, the Pecos River case, was the first case to be heard in the Supreme Court term. It was argued on October 4, 2020, after being dormant for a while. Apparently, an extreme weather or flooding event back in 2018 yielded a dispute over the river master's decision. The Pecos River is one of two river systems that has a river master appointed under the Supreme Court's original jurisdiction. The river master is in charge of determining the counting under the compact. There was an issue associated with flood flows and the evaporation from Brantley Reservoir. The State of Texas has disputed the river master's decision in that particular situation, and that was the nature of the argument that occurred the first week of October. It's an arcane issue that came up before the court. It has no precedential value for anyone else in trying to determine how to resolve disputes among the states. From my perspective, it has been mostly a waste of judicial resources to bring this before the Supreme Court. Given the reports that were written in the aftermath about the proceedings, I think the justices also may have been a little irked to have this case before them, but we'll see what happens with the decision. It is a complex accounting case, and it wasn't one that was easily addressed, as noted by some of the justices during the hearing.

Texas v. New Mexico on the Rio Grande, number 141, has a lot more at stake regarding the effect on groundwater and surface water use in the lower Rio Grande. Nonetheless, this case was filed by Texas in 2013. I think it's unfortunate that it has gone on this long. I believe the case has always had a framework in place that could be the basis for a negotiated resolution. One that is based on a better, more thorough, and joint understanding of the interaction of surface water and groundwater below Elephant Butte through the State Line into Texas. If there had been that joint work done, better technical analysis could have led to a better model and a better negotiated resolution of how surface water should be allocated in light of groundwater use in New Mexico. There are other accounting issues associated with the Rio Grande Compact, but if you can get to that fundamental issue from a technical standpoint, I think the other issues could have been negotiated. But that has not been the case, and that has not been the parties' choice.

Here we are now in 2020. Hopefully, there is still the prospect of a negotiated resolution. The parties are going to begin mediation in mid-December 2020 with an appointed mediator. We'll see if Judge Wanger, a retired judge from California, can work some magic with the parties and bring them together. If not, I think the trial phase before the special master, not before the court itself, is scheduled to begin in July or August of 2021. The last count I saw was that the parties had identified 130 witnesses between them. Therefore, the special master will essentially be watching a lot of paint dry in July and August of next year if there is no negotiated resolution. We'll see what happens in Texas v. New Mexico (the Rio Grande case) and whether the wars will ultimately give way for the scientists and engineers to design a sustainable approach to conjunctive water use that can be the foundation for a negotiated resolution. As noted by our good friend Honest Abe, "lawyers should take heart in the fact that even in negotiated resolutions, there will still be business enough to keep them employed for the long term." And that's of interest to me, too.

Finally, I would just quickly highlight the United States v. Abousleman case. This is the Jemez River adjudication. In September 2020, the 10th Circuit Court decided on a very specific, narrow issue focused on whether the Pueblos and the Jemez River system possessed aboriginal water rights and whether those rights have been modified or were extinguished by Spain, prior to the lands being taken under United States control. The District Court had decided that they had been extinguished under Spain's rule; the 10th Circuit Court reversed that decision. It's a very arcane, specific issue that will not resolve the allocation issues in the Jemez River system. Maybe the decision will be a springboard to negotiations, which have been ongoing for some 20 years. We'll see what happens there.

These are novel cases that have novel legal issues, which are interesting from a lawyer's perspective, but they do not appear at this point to be leading to novel solutions for difficult water resource and management issues. From that standpoint, I think my takeaway is that litigation, if that is the approach, does not reflect the urgency needed to resolve the critical issues that we just talked about, which are all exacerbated by a warming climate. I would point to

the words of Justice Oliver Wendell Holmes, who in 1931 first introduced the doctrine of equitable apportionment, in New Jersey v. New York. In introducing this concept, his words were: "A river is more than an amenity, it is a treasure. It offers the necessity of life that must be rationed among those who have power over it." Those are words that all water managers should consider when deciding how to move forward in resolving issues among different water users or different states.

If it's not litigation, what are the better measures to take to address the water resource challenges facing every state, particularly in the West, and every set of water users? These are drastic measures not in the sense that they are individually drastic, but in the sense that these measures, which have been ongoing in New Mexico, need to be amped up. We need to be doing these same types of strategies exponentially all across the state and all across the West. These strategies are to invest in water resources, study, plan, and design long-term solutions even while we implement actions in the short term; to engage the different stakeholders in the system in ways that we haven't before, to be part of the problem-solving mechanisms that we need to have in place; and then finally to negotiate and resolve these disputes, rather than resorting to 30-plus years of litigation.

With respect to investing, I just identified a few recent examples of things that are ongoing that reflect good strategies that need to be highlighted and that seem to be gaining traction. Although they've been pending for quite a while, we need to continue similar actions as we move forward. The Water Resources Development Act, which is currently pending on Capitol Hill, includes the Bernalillo to Belen flood control project. The Middle Rio Grande Conservancy District (MRGCD) has been the local sponsor for that $300 million project, which is long overdue in the basin. It encompasses 48 miles of engineered levees and 266 acres of riparian habitat restoration. Within the engineered levees portion, hopefully there is room for natural infrastructure solutions, which are increasingly a high priority for a lot of folks in water management and the public policy arena in DC. There is also the Rio Grande ecosystem restoration project for the Sandia Pueblo to Isleta Pueblo reach of the river. This is $25 million focused on river conductivity between the mainstem Rio Grande and the floodplain that exists, as well as a lot of restoration of native habitat. Lastly, MRGCD is working with a number of partners in the system to make use of the Regional Conservation Partnership Program at the U.S. Department of Agriculture. This is to take a whole lot of tools from Farm Bill programs—the Environmental Quality Incentives Program water conservation activities, the Wetlands Improvement Program, and the Conservation Reserve Program—and apply them in different ways to conserve water in order to more efficiently restore certain critical areas of habitat. This is an ongoing program that has had success in a lot of different areas. We need to bring that to New Mexico, not just in the middle Rio Grande, but elsewhere.

I'm sure you're all aware of the Bureau of Reclamation's Middle Rio Grande Basin Study. A memorandum of understanding was established between Reclamation and other parties in September 2020. This study program is an outgrowth of the SECURE Water Act that Senator Bingaman and Congressman Udall sponsored in 2007. It has led, in many situations, to a very aggressive set of actions in other river basins like the Colorado River Basin, which had finalized a study in 2012. Also, the Yakima River Basin, which has an integrated plan that has been implemented for several years now, and was the subject of congressional authorization just in the last year. Part of the basin study will be to look at how the existing infrastructure will perform over time and whether it should be modified in any way, shape, or form. This is a model for another provision that is in the Water Resources Development Act in the House, which is the reauthorization for Abiquiu Reservoir to increase storage capacity, to add the flexibility of storing native Rio Grande flows there, and to do so in a way that protects landowners around Abiquiu while providing much needed flexibility from an existing reservoir at little or no cost to the government. There may be costs obtaining additional easements around the reservoir, but that is the subject of the water users. So, what we really need there is authority. Revisiting these existing risk scores is key. We also need to engage in different ways; the legislature just funded a Lower Rio Grande Groundwater Conservation Pilot Program that is hopefully moving forward quickly in implementation. I think this pilot program can be part of the solution that is necessary in the lower Rio Grande. I'm not quite sure if that's exactly why it was designed and moved forward, but I sense that it was. We need to bring in stakeholders different from the traditional ones and bring resources to the party to address ongoing issues. Audubon New Mexico has done two things. They have acquired a water right in the tributary to the Rio Chama and applied to change that right's use from an agricultural one to an instream flow—the first one in New Mexico that was just in the last year approved and recognized. That's one tool Audubon has brought to the table and moved forward through the process. They also acquired storage on their own and added themselves as well as other folks like MRGCD, Bureau of Reclamation, and the Interstate Stream Commission, who have long been supplementing flows in the middle Rio Grande to address endangered species and other fish and wildlife needs in the basin. This is a great sign that we've got more stakeholders and new players coming in bringing resources and solutions.

Finally, negotiate, negotiate. I talked at length about the lower Rio Grande and the need for resolution of those issues outside of litigation. There are also the Indian water rights settlements. New Mexico has four settlements, involving Navajo Nation in the San Juan Basin, Jicarilla Apache Nation in the San Juan and Rio Grande Basins, Taos Pueblo, and the four Pueblos in the Aamodt litigation settlement along the Rio Grande. At this point in time, The Nature Conservancy is working with Jicarilla Apache Nation to see if they might strike an arrangement to create the first strategic water reserve application in the San Juan River Basin, and if they can be part of that demand management program or analysis ongoing in the Colorado River Basin. Some of the other Pueblos and Jicarilla have also been involved historically in supplementing flows in the Rio Grande system to avoid Endangered Species Act conflicts. Negotiated settlements about the rights of Indian Tribes and Pueblos not only address their needs, from an equitable standpoint, but also bring Tribes and Pueblos to the table as players who can be part of the aggressive set of solutions that we need in the future.

I'll end on the note that in addition to taking these actions at the state and local level, we need a strong federal partner. The question is, where is the federal government going to be in the coming years when climate change is becoming such an urgent and pressing issue? We have drastically different options before us coming up in the November 2020 election. The question is, are we going to be governing on climate change, or are we going to be reacting to climate change? I'll start with the good news in Congress. At least since the first SECURE Water Act legislation, Congress has shown more willingness on both sides of the aisle to address climate adaptation and the development of technologies to reduce emissions, and to create options to help begin to address the emissions aspect of climate change for adaptation and resilience. The two Senate bills, a Senate water bill and a Senate energy bill, from a water perspective have strong bipartisan support and have provisions that are specifically related to climate change. So, Congress is moving, though not rapidly. HR2 moves on the House side to address climate change, and it's still indicative of tension with respect to mitigating greenhouse gas emissions and the source of climate change. We are much more likely to build larger support in Congress as it is made up today by focusing on adaptation. In the executive branch, we'll see. On the Democratic side, Vice President Biden got a commitment for $2 trillion of investment over four years for clean energy, infrastructure resilience, and a goal of net-zero emissions by 2050. There's much more to the plan than that, but the bottom line is that Vice President Biden is running on climate change. It threads through every piece of his agenda, whether it's jobs, economy, public health, foreign relations. You name it, it has a climate element in it. If he's elected, he intends to govern from that perspective. If President Trump is re-elected, we'll have more of the same with respect to regulatory reform and an energy-dominance agenda that exacerbates the root cause of climate change. Perhaps there will be infrastructure investments. They've long been promised but have yet to manifest themselves. So, stay tuned for the role of the federal government in helping us address the urgency of climate change.

I think I've left at least a couple of minutes, but I'll defer to Sam on whether I actually have time for questions.

Fernald: You do have three minutes for questions. There are three questions in the Q&A.

Connor: Katherine Ottmers asked, "Can you speak to any pre-disaster mitigation planning or funding?" My sense is that pre-disaster mitigation planning or funding is all about the planning in the studies being conducted, for example, under the basin studies programs. I think looking at supply and demand and the implications of climate and extreme events is all part of that planning process that is really intended to mitigate disasters. Once you're in a disaster, you're completely reacting unless you've analyzed and put in place the resources and strategies beforehand either to react immediately or to avoid some of the implications. With that being said, I think that planning is incredibly important. I know that FEMA is doing more and more in the area of pre-disaster mitigation, but I don't have the specifics.

Mark Murphy asks, "Back when we were all working on funding the Ute pipeline project, the Rural Water Projects Completion Act was introduced in the Senate and would have applied to Ute. Whatever happened to that commitment?" Well, the Rural Water Completion Act bill was a reauthorization of the Rural Water Program, if I remember right, for Reclamation, which never got fully done. But quite frankly, it hasn't stopped Congress from continuing to appropriate dollars for rural water projects. In fact, I think they've gotten pretty good support, but not from a budget standpoint. They're never very well-funded in the Reclamation budget. Congress has written in additional funding to continue to construct those projects. Unfortunately, the Ute pipeline (the Eastern New Mexico Water Supply Project) has been in the queue behind other larger projects that were funded or authorized earlier. Hopefully, it is in line to get increasing funds to continue moving forward.

Finally, Norm Gaume has a question: "The State Engineer is urged by MRGCD. We waste and consume water that the Rio Grande Compact requires to be stored in post-compact reservoirs in the amount of the current 39,000 acre-feet of accrued debit. The State Engineer noted yesterday that the forecasted accrued debit through the middle Rio Grande to Elephant Butte will reach 85,000 to 100,000 acre-feet this year, making a compact

violation too close. New Mexico does not have a plan to avoid a compact violation. What would you advise regarding our duty to ration water in the middle Rio Grande in 2021 to avoid violation of the explicit water delivery requirements?"

Well, I would say a couple of things. In addition to a conservation pilot project, it's time to see, not just from an economic standpoint, but also from a compact-compliance and long-term perspective, whether we should act aggressively in asking whether farmers have interest in forgoing more water use this year to address compact delivery, if it works from their economic perspective. Do we have the infrastructure in place to effectively marshal that water down the river, even while we try and take care of some of the real environmental needs? I don't know the specifics to the question, Norm. I do know that it sounds like the type of urgent water issue that needs immediate attention and an approach that throws many options out there. But at the end of the day, it requires significant investment if we're going to work through these issues and avoid a crisis.

Bridgette asked, "When water is transferred from agricultural use to instream flow use, are the agricultural lands more susceptible to wildfire?" That's a great question. Unless there are conditions or parameters that formerly irrigated land needs to adhere to or that the entity doing the transferring needs to provide, there is a chance that they would be more susceptible to wildfires. The reality is that even being followed they could still result in water consumption. I know that was something looked at very closely in the system conservation pilot project that the Bureau of Reclamation initiated in the Colorado River Basin. Particularly in the upper basin to identify the conditions necessary on any land that was fallowed in order to ensure full credit could be attained. There's not a credit system right now, but they wanted to ensure that you were maximizing the conservation of water from the system and addressing the issues, such as whether there would be invasive plants or other issues on those fallowed lands that can affect neighboring landowners. So, it's a great question that needs to be worked through.

Fernald: Unfortunately, we are going to have to stop there. I want to thank you for a great talk, Mike. Hopefully we'll see you back here in the future to hear more about the great things you're doing for water resources.

Connor: I appreciate it, and this was a lot of fun. Thank you for having me.

New Perspectives on Water Data



Moderated by Stacy Timmons, New Mexico Bureau of Geology and Mineral Resources

Stacy Timmons directs the hydrogeology division and the Aquifer Mapping Program, with the state geologic survey, the New Mexico Bureau of Geology and Mineral Resources, at New Mexico Tech. Working with the Aquifer Mapping Program for the last 15 years, Stacy has worked around the state on hydrologic and geologic research topics and a variety of water data collection and integration endeavors. In 2019, Stacy began serving on both the Water Quality Control Commission and the Interstate Stream Commission and leading the implementation of the Water Data Act legislation.

Stacy Timmons: I'm going to first say that it is hard to follow the previous panel. What a great discussion. I'm not only going to moderate, but I'll also provide an update on how we're handling water data in New Mexico. Thank you all for joining us, and a special thanks to NM WRRI for hosting this conference in this new online format. It's a huge shift from the previous 64 years of conferences, and I am truly impressed with this year's conference. For those of you online here today, engaging with us on this panel, I hope you will send your questions in the comment box. We will try to address them, and you can also reach out to me directly if you would like to discuss New Mexico's water data further.

So, to introduce myself, I'm a hydrogeologist, and I've been working at the state's geologic survey for 16 years. When I think back on how my career in hydrogeology began in the early 2000s, I realize that the first step in building a new research project is to gather data. Of course, in my world, I envisioned going out and collecting field data, making measurements, collecting samples, but really, it often starts with going through existing data on work that has already been done. It surprised me how much time was needed to hunt down that data and make use of it. The difficulty of accessing water data in New Mexico is one of those topics that no one wants to talk about. We seldom acknowledge it; it's like that spooky skeleton in the closet. There were certainly no panels at water conferences that I was aware of that discussed water data. So, I'm excited to have this opportunity.

Fortunately, since the early 2000s, we've made some improvements. We have a wide variety of websites and tools available where we can access data in a variety of forms. These include the Office of the State Engineer's water rights reporting system, the Bureau of Geology's interactive map, where you can obtain information about geology or groundwater data, NM WRRI's statewide water assessment application, and the New Mexico Environment Department's various portals, including the drinking water portal and the interactive map where there is a ton of water and environmental data. While these websites are handy, I think a lot of us have difficulty trying to answer some of our basic questions: "Is our water safe to drink? Are we running out where I live?" To me, it seems that finding the data you need to answer those basic questions and knowing how to use it requires a bit of training or expertise.

In 2019, New Mexico made a big move to begin facing that challenge, to stare down that skeleton in the closet, and start addressing our water data challenges. We adopted a new statute, the New Mexico Water Data Act, which originated from legislation led by Representative Melanie Stansbury, who we just heard from, and Representative Gail Armstrong, along with numerous other supporters in the legislature and those outside of it (Figure 1). The Water Data Act is a big step toward opening up our state's water data. Essentially, it aims to make water data more accessible and interoperable, and I've been helping to lead this effort with a solid implementation team and extensive collaboration from various state agencies, as well as numerous other water-related data organizations in New Mexico.

For this panel, I am not going to go into the technical details of how this all comes together. What I want to be clear about is that we're not trying to build another database. What we're really trying to do is push a more fundamental paradigm shift in how we share our data. We're not asking people to say, "Stacy, here's my data. Put it in your data portal." Instead, what we're trying to do is help data providers expose their data—data that has been quality checked and that they're comfortable sharing—and provide it in a machine-readable format (Figure 2). Basically, we're asking people to make



Figure 1. 2019: Water Data Act becomes law (NMSA 1978, § 72-4B).

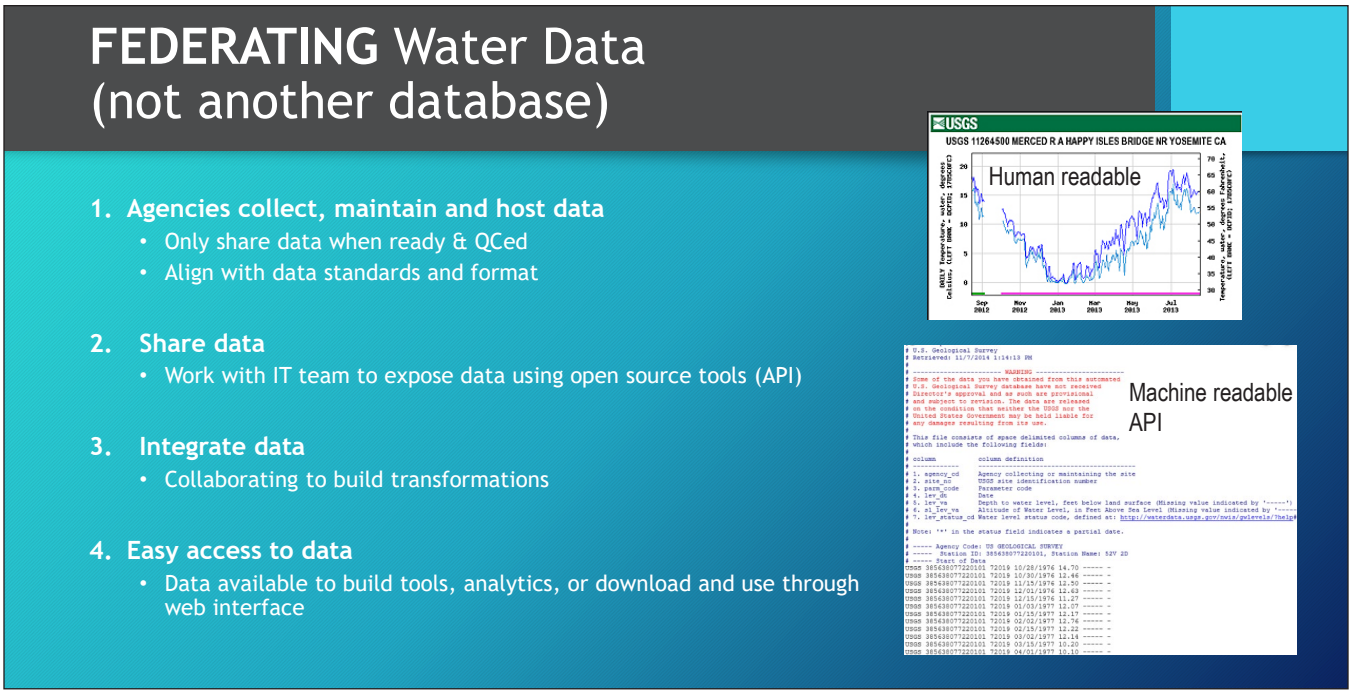


Figure 2. Steps detailing machine-readable actionable programming interface (API).

their data machine-readable and available through an application programming interface (API). From there, we can aggregate the data with other datasets and integrate it with similar data from other agencies. Then it can be used to answer some of those basic questions that people are thinking about. It can also be more readily accessed to improve water models, to aid in water planning, and to help us build a resilient future here in New Mexico in the face of climate change. Additionally, it may help build consensus around some of the big water issues and heated debates. This is a multiyear effort that's well underway now. I acknowledge that a lot of our data is already online in some form, but we're working to make that data even more accessible, particularly in a machine-readable format.

The benefit of this is that it significantly opens our data for use in various tools and applications. A mental picture for that concept is Google Maps, but centered around water themes. The website is newmexicowaterdata.org. Feel free to check it out and provide us with some feedback; we'd love to hear about the type of data you're looking for and how you plan to find it, so we can develop the right tools to help address some of those common questions. We also have a data catalog, where we've started to put together our electronic data inventory. I would like to note that the inventory originated from the State Water Plan, and a significant amount of work went into developing that technical report.

I would like to acknowledge that it has been a great honor to have the opportunity to work on water data for New Mexico. You have to collaborate with various state agency partners and our different working groups (Figure 3). I've also been impressed with the outreach and engagement we have received in New Mexico to address our water challenges from outside the state, especially from some of the folks on the panel with me today.

I'm going to give a quick intro to the other panelists, and then I'll ask them to begin their presentations. First of all, the Internet of Water has been an absolute pleasure to work with on state water data challenges. New Mexico is one of their first pilots. For those who are unfamiliar, we are greatly benefiting from their team's expertise and knowledge in water data and data architecture. Ashley Ward is going to talk about that here today. The West Big Data Innovation Hub, specifically Meredith Lee, has been a significant supporter of New Mexico's efforts in water data. I'm glad that they've even included New Mexico in their water data challenge hackathon event this year. I am thrilled to be working on this effort with New Mexico Environment Department staff, particularly Gunnar Johnson. We have a data challenge team that's building a tool to help us think about how the changes in the definitions of the waters of the United States are going to affect people on the ground in New Mexico. Then we'll hear from Adel Abdallah, who's here from the Western States Water Council. That group uses a lot of New Mexico's water use data in their Water Data Exchange Program, which I'm sure we'll hear about.

So, first, if you wouldn't mind, Ashley, could you give us a quick introduction to yourself and tell us about the Internet of Water's work on state data?



Figure 3. Collaboration partners.



Ashley Ward, Internet of Water

Ashley Ward's career has focused on engaging communities to identify and address issues, and helping communities develop long-term, sustainable strategies relevant to their particular community needs. Her previous work with NOAA's Carolinas RISA team connected rural and urban communities and policy decision-makers with relevant climate and health data, particularly related to vulnerabilities and impacts. Engagement with communities across the Carolinas revealed a knowledge and access gap in climate data, wherein many communities did not have the necessary data and expertise to inform decision-making, planning, and preparedness. Ashley and her colleagues at CISA worked with community stakeholders to develop a suite of open-access, web-based tools to address these issues.

Before her work with CISA, Ashley completed her PhD in geography and worked with communities throughout North Carolina on a host of issues, such as local food availability and asset-based economic development strategies. Ashley's passion is building coalitions to advance scientific understanding and communicate information in a way that is relevant for use by decision-makers. Having worked in a broad range of communities with varying levels of capacity, Ashley is particularly thoughtful about meeting communities where they are and working from there to achieve community goals.

Editor's Note: This paper transcribes the panelist's remarks from the conference. No follow-up paper was submitted, and the remarks were edited for publication by the editor. The speaker did not review this version, and the editor assumes responsibility for any transcription or editing errors.

Thanks, Stacy. I am Ashley Ward. I am the engagement and outreach associate with the Internet of Water. The Internet of Water is a project located at Duke University's Nicholas Institute for Environmental Policy Solutions. Our mission is to facilitate a modern water data infrastructure across the United States. No big deal, right? We achieve this through close partnerships with public agencies, like we have in New Mexico, but also through partnerships with nongovernmental organizations, utilities, private industry, and universities. The activities within these partnerships vary and are directly responsive to partner needs. At times, this means that we're developing technical solutions to support the development of a modern water data infrastructure. At other times, it means addressing the cultural aspects of a modernized water data infrastructure, such as concerns over capacity and security, the need to think differently about water data management, as Stacy was just talking about, and the need to demonstrate why investments should be made in improving water data infrastructure.

For today, one of the questions Stacy asked me to think about was how this effort supports research. I've come up with a quick, short list of examples to share with you, and I'm happy to answer any additional questions you may have about these. The first step is improving discoverability of water data. A lot of water data is collected, but little of it is integrated with other data, in part because it is unclear where it is or what's available, or it requires a particular technical expertise to find it. If you want to think about it this way—something completely removed—say you wanted to look up movies playing in theaters in Albuquerque, New Mexico. You could google "movies Albuquerque," and you would get a list of the movie theaters around Albuquerque. But what if you were in a situation in which you googled "movies in Albuquerque" and what you received instead was an extensive list of random theaters across New Mexico or a broader region, movie reviews, even from old movies, and some interviews from actresses and actors. That would make it a lot more difficult to find the information you need in a timely manner. Before this conference, I googled "Navajo Lake," and I received 9.9 million hits on Google and found all kinds of interesting information about the state park, about camping there, and a Wikipedia article, but no links, at least in the immediate search, to organizations and data sets about Navajo Lake.

Geoconnex is a product being developed by the Internet of Water in collaboration with the U.S. Geological Survey. It is a search index for water data, and operates a lot like a Google search engine for water data. By linking water data to its location, Geoconnex enables the discovery of that data. Currently, when a person googles a specific body of water, relevant data sources may be returned. What Geoconnex hopes to accomplish is that by connecting data with real-world geography, when you google, say, data on Navajo Lake, you would receive a list of any relevant data sources collected about Navajo Lake and surrounding areas, in some cases upstream and downstream (Figure 1). This easing of discovery saves time and facilitates more efficient data acquisition, all without requiring additional technical expertise.

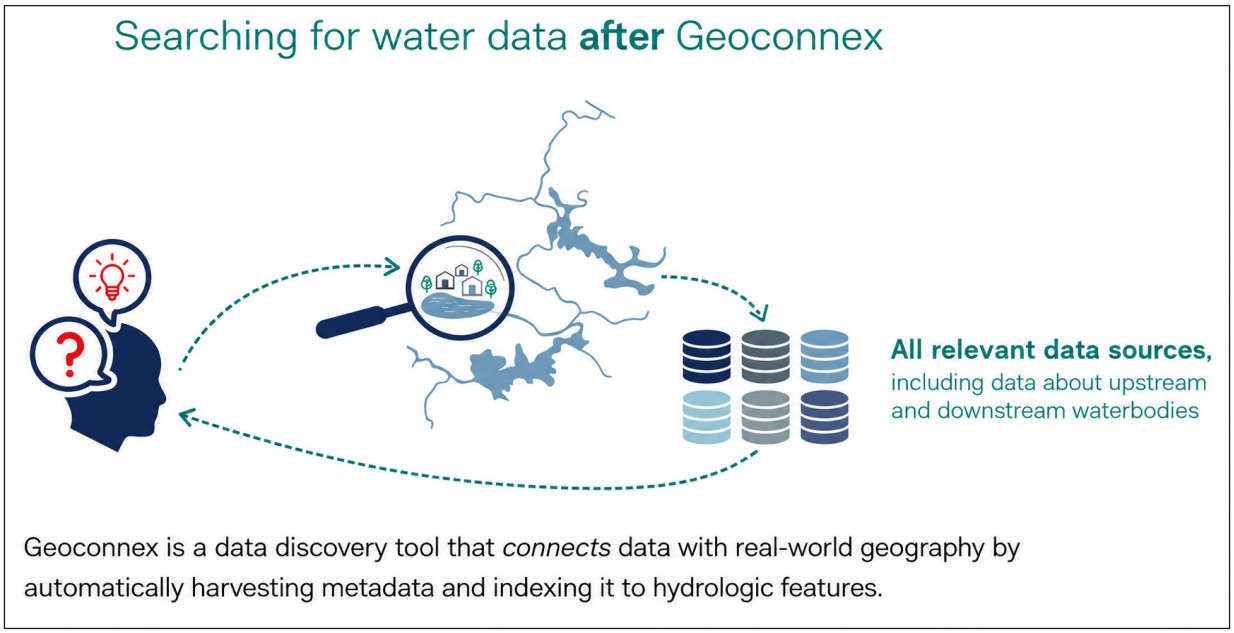


Figure 1. Geoconnex: A search index for water data.

A second issue is fragmentation. Data fragmentation remains a significant issue that not only makes data difficult to find but also very costly to process. HubKit is a data-integration software kit that will be open source, enabling organizations to create their own water data hubs (Figure 2). This is very similar to what Stacy is talking about, which New Mexico is currently doing. The idea behind HubKit is that instead of having to go to multiple locations to get a complete data set, you go to one location, a data hub, that would then connect you to all of those other data sets. This reduces time, saves money, and makes for more efficient data acquisition. Because most of the time water data hubs require certain data standards and metadata standards, it also makes the data-processing end of it much easier for researchers.

I also want to talk a little bit more directly about how modern water data infrastructure can expand and enhance research. For example, one of the tools that we're creating is this ABOUT-US tool (A Boundary Update Tool for Utility Services) for public service boundary areas (Figure 3). The idea behind this tool is to create smart, interactive tools that allow utility managers to edit and update the digital boundaries of their service areas. Now, why is this important? Having access to these digital boundary areas greatly improves the ability to conduct research and support policy efforts. For example, epidemiological research on water contaminant exposure and social science research on infrastructure access disparities are all greatly improved by an accurate delineation between areas served by one water utility or another, or a water utility and those served by groundwater wells. In North Carolina, up to this point, these studies have relied on outdated pipe location data; however, having digitized service boundaries means that researchers can overlay them on top of other data, potentially opening up a whole new set of questions while also clarifying the questions they're already asking. This is an important area where modern water data infrastructure can be beneficial.

So quickly, to wrap it up, when we think about how a modern water data infrastructure can improve research, we think about not only improving discoverability with more efficient data acquisition, but also improving data processing through data standards and metadata standards and the ability to ask new questions or illuminate more the questions currently being asked because we now have access to integrate data sets with each other in ways that we couldn't before. All of this means that there's an increase in transparency. Also, the emphasis on standards means that there's an increase in trust in data. It's clear through the metadata how the data is collected and managed. It's also clear what the different standards are, and in some cases—if you're thinking about, for example, nongovernmental organization data—the tier for quality assurance/quality control for different data would be obvious and easy for people to find out. So, those are some significant ways in which the Internet of Water project and the promotion of a modern water data infrastructure support research in New Mexico, as well as nationwide, and help researchers in New Mexico connect with others in the region or to broader national efforts. Thanks, Stacy.

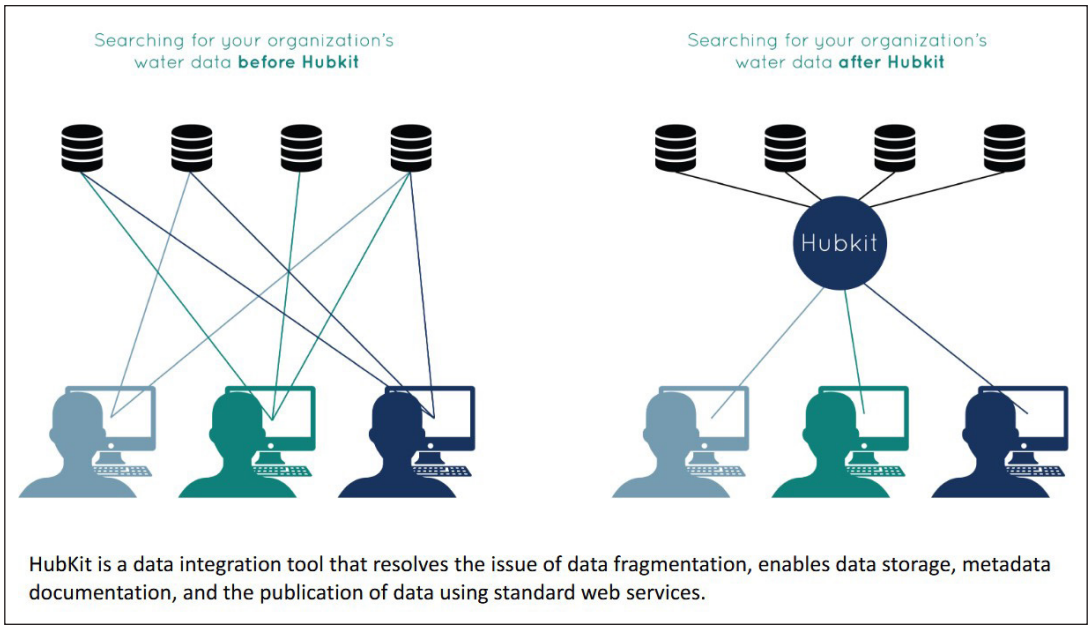


Figure 2. HubKit: Data integration software.

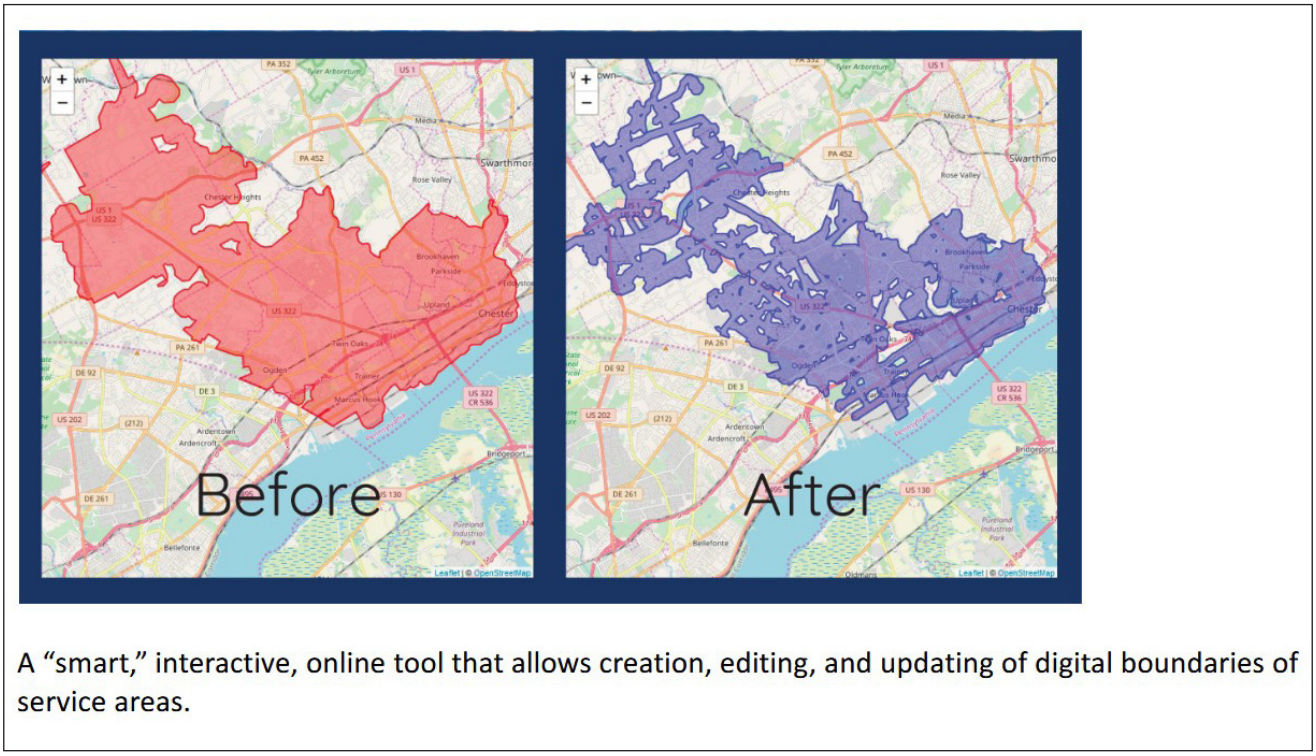


Figure 3. ABOUT-US: A Boundary Update Tool for Utility Services.



Meredith Lee, West Big Data Innovation Hub

Meredith is the Founding Executive Director of the West Big Data Innovation Hub, a venture launched with support from the National Science Foundation to build and strengthen partnerships across industry, academia, nonprofits, and government. Based at the University of California – Berkeley, Dr. Lee collaborates globally as part of a national network of Big Data Innovation Hubs to address scientific and societal challenges. Her work focuses on translational data science, including initiatives in Smart and Connected Communities, Water, Disaster Recovery, Health, and Education.

Meredith was previously an AAAS Science & Technology Policy Fellow at the Homeland Security Advanced Research Projects Agency, guiding strategic programs in graph analytics, risk assessment, machine learning, data visualization, and distributed computing. Under the Obama Administration, she led the White House Innovation for Disaster Response & Recovery Initiative and contributed to several science, technology, and open data / open government initiatives.

Meredith completed her BS, MS, and PhD in Electrical Engineering at Stanford University, developing real-time biomedical diagnostics. She has taught Human-Centered Design and Innovation at Stanford and in government, and continues to advise organizations with efforts in technology, data science, and multi-stakeholder collaboration. Dr. Lee serves on the Advisory Committee for NASA DIRECT-STEM and the inaugural National Leadership Council for the Society for Science and the Public. Her work has been featured by whitehouse.gov, ArsTechnica, The Washington Post, Forbes, WIRED, Bloomberg, and Nature.

Editor's Note: This paper transcribes the panelist's remarks from the conference. No follow-up paper was submitted, and the remarks were edited for publication by the editor. The speaker did not review this version, and the editor assumes responsibility for any transcription or editing errors.

Thanks so much, Stacy, and to all of the organizers for having me here. I'm always so impressed by the breadth of community perspectives that are convened year after year. I haven't been to all 65 of the New Mexico water conferences, but the ones I have participated in, and really any workshop that this team pulls together, are always super productive. The legislative representatives we just heard from, alongside researchers and community leaders, and the hundreds who are tuning in or watching this, are a prime example of the breadth of collaboration needed. Since my colleague Ashley covered some of the topics of discoverability, data acquisition and processing, research questions, transparency, and trust so nicely, I will take a slightly more meta perspective, but I'm happy to connect offline if folks want more specific details.

The West Big Data Innovation Hub is one of four National Science Foundation Big Data Innovation Hubs in the United States, bridging research, education, and a community of practice. When we launched almost five years ago, we very quickly noted that water physically connects our states in the region. The topic of natural resources and hazards was a compelling area to build activities and initiatives that would allow us to raise awareness of regional opportunities, inspiring new commitments and contributions, like the ones through the water data challenge that Stacy mentioned. The topic allows us to catalyze team formation from a number of different sectors. That's where the accessibility of water data and the consistent emphasis on bringing in diverse perspectives—centering and valuing different perspectives—is so aligned with the topic of the session and the conference overall. Increasingly, we're digging deeper to develop and enable more translational or applied pilot projects in our thematic areas. This is all held together by this foundational support for data science education, training, and workforce development that is not only incredibly motivating in its own right but also feeds the ecosystem that we build, our capacity to be able to reach all these other goals.

Specifically looking at natural resources and hazards and water efforts, I wanted to reflect that the California Water Data Challenge we've been running now for three-plus years was a unique opportunity, given the timing of the first-in-the-nation legislation in California, the Open and Transparent Water Data Act in 2016 (AB-1755), much like the Water Data Act that Stacy just mentioned (NMSA 1978, §72-4B). The fact that I can rattle those numbers off shows how much we have dived in—pun intended—to the water arena. It's worth noting that state data stewards and communities in California, New Mexico, and other states are considering this broader perspective beyond what's required by the legislation. We see this palpable spirit of collaboration, where we roll up our sleeves to build, test, share, and improve iteratively. I think that enthusiasm and opportunity coming out of the initiative and the Open Data projects can often be quite colorful.

I've been told by some folks that Figure 1 looks nothing like a data policy legislation memo. What's the deal with this? I often refer back to something that Connie Maxwell, who is in the audience and is based at NMSU, said when we were discussing ways to connect with students, particularly underrepresented groups that haven't historically had a seat at the table or had their voices heard. Connie said, "You know, it really boils down to framing this as 'plan your future with data.'" It's a simple concept. We've found that it translates across languages, across disciplinary boundaries. It's incredibly powerful in implementation because it intentionally puts people first, underscoring the sense of agency and recognizing that data is a way for us to assess our current situation as a community, as individuals, and as neighbors, and to prepare for a more resilient future.

That shift, to Stacy's point, in how we share data—I look at it as a bridge toward understanding—has led to all sorts of great results that we've been able to pursue both nationally and globally. I'm sure you all have seen the 10-year fund for safe and affordable drinking water. We're so excited to have New Mexico's data challenge be part of the 2020 summer and fall tranche. If you know anyone with open data projects, we are offering $16,000 in different prizes to recognize the teams working toward this challenge this year. In the interest of time, I'll direct you to the Let's Make It Count website (https://www.letsmakeitcount.org), noting that it has been a banner year for engagement at all levels, including high school students. We love connecting with New Mexico educators from all different backgrounds. And whether it's around water data or focused on training more community members in data science education as part of this larger network, it has been great to partner with all the New Mexico stakeholders. I'll turn it back to Stacy and Adel now.



Figure 1. California Water Data Challenge illustration.



Adel Abdallah, Western States Water Council

Adel Abdallah served as the Program Manager for the Water Data Exchange (WaDE) program at the Western States Water Council. In this role, he was responsible for overseeing the development and implementation of WaDE 2.0, which aimed to facilitate the sharing of water data among western states, federal partners, and the public. Adel played a key role in enhancing data interoperability and accessibility, collaborating with various stakeholders to improve water management and decision-making processes.

Editor's Note: The Western States Water Data Access and Analysis Tool (WestDAAT) was released publicly in the spring of 2023. More details can be found here: https://internetofwater.org/blog/unveiling-westdaat-a-breakthrough-for-water-rights-data-management-in-the-western-united-states/

Thank you. My name is Adel Abdallah, and I manage the Water Data Exchange Program (WaDE) at the Western States Water Council. I have enjoyed the conference so far, listening to the local conversations about water rights. That's really fun for me, coming from a big-picture, regional water perspective. Listening to the local discussions enriches my perspective

My presentation will still be relevant to the discussions that Meredith and Ashley presented about the regional perspective here. It's amazing to see 150 folks here on the call, and if we were in person, I would ask how many of you are familiar with the Western States Water Council. For those unfamiliar, the Western States Water Council is a voice for water in the West. Its mission is to ensure that the West has an adequate, secure, and sustainable water supply of suitable quality for both the present and the future, meeting diverse water needs. We adopt policy positions on behalf of the western states for Capitol Hill, including voting and other matters. Part of the Western States Water Council's activities is the Water Data Exchange Program that I manage, which was established in 2012 to formulate a strategy or to have a platform to enable western states to share water data with each other and with federal agencies and the public. Many of you probably know that the U.S. Geological Survey (USGS) has a lot of data on surface water discharge. There's the National Ground-Water Monitoring Network, the Bureau of Reclamation water information system, and there's the Environmental Protection Agency's (EPA) water quality data system. The unique part that WaDE brings is water rights data, aggregated water use and budget estimates, site-specific uses and withdrawals from states themselves, and regulatory overlays. None of this data is being, or has been before, provided on a regional scale, so WaDE is coming here to fill the gap.

So, I'll quickly talk about what we do here. We work with every single state agency in the West to bring their data into a centralized database that we built for WaDE, and then we enable centralized access and data portals. We're working with the Internet of Water group to integrate that data with USGS, EPA, and Bureau of Reclamation data services, so you can hopefully accomplish the vision that Ashley laid out, to have Google for water data. Besides the technical aspects, we also attempt to translate water terminology across different states to map data effectively. We have 32 metadata terms that are common across the West. Among these, five are particularly important: beneficial use category, water source type, site type, legal status, and water allocation type. For the beneficial use of water rights, we have approximately 350 unique state terms for beneficial uses, and we have attempted to map them to 22 WaDE terms to facilitate data filtering. For water source types, we mapped 34 state terms to five WaDE terms. These were relatively easy, but the most difficult ones, such as the legal status of a water right or the type of water right, are really challenging because they have legal implications, and we have our legal committee trying to review and come up with these terms. For example, the meaning of the term adjudicated water rights in Wyoming is different from that term in New Mexico, so we're trying to be careful as we provide that data across the West.

Figure 1 is a snapshot of our local dashboard, which is not publicly released yet. It shows water rights across the West. These colors represent the 22 beneficial uses we have identified so far. This is so beautiful to me that what keeps me up at night or gets me up in the morning is enabling regional access to water rights.

We enable research by answering specific questions, such as: What were the water rights for agriculture and

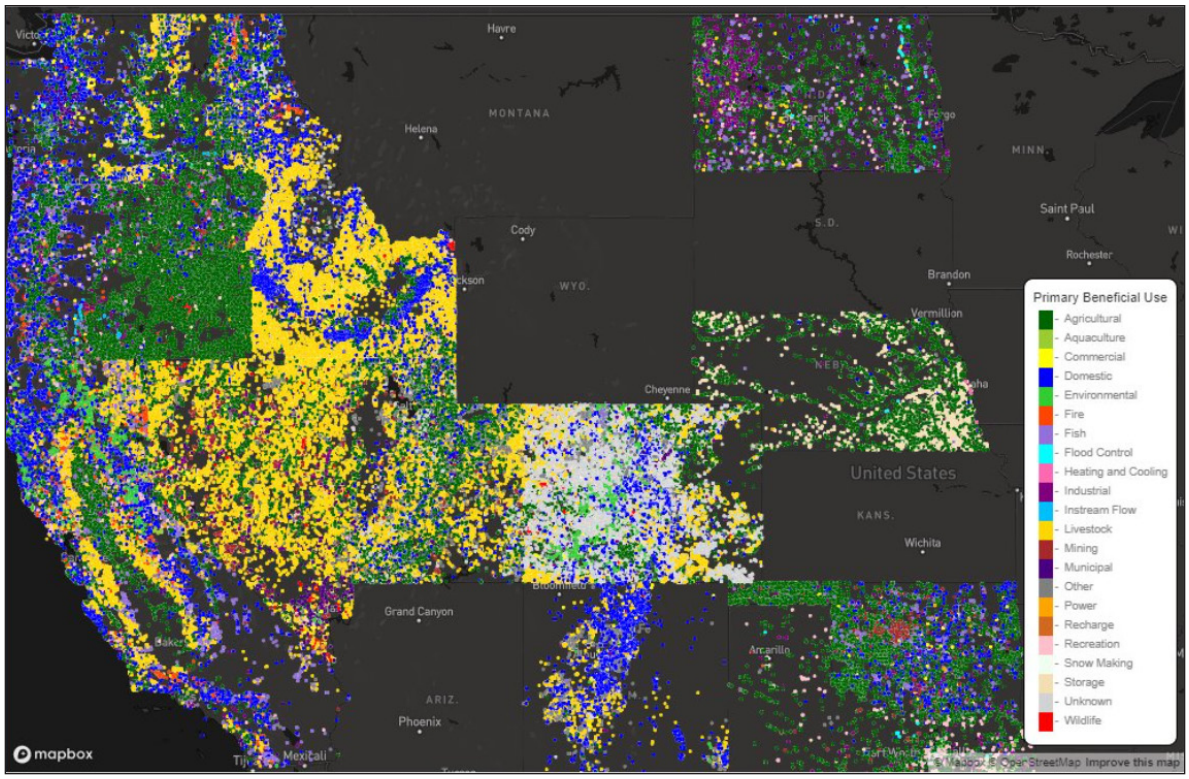


Figure 1. Primary beneficial water use map.

municipal use prior to 1922, the compact date, in the Colorado River Basin? We can clip all these water rights to the Colorado River Basin, and we have a slider bar that allows you to go back in time (Figure 2). The dashboard shows those water rights that are immune if there were to be a call on the river because they are senior to the compact. So, these are some of the policy decisions that such data on a regional scale can inform.

Another type of data I'm discussing today is the aggregate and county water use map, which encompasses nearly all the watersheds in the states (Figure 3). So, New Mexico, for example, estimates watershed data per county, and we report that consistently across the West. Figure 3 shows three states—Texas, Utah, and New Mexico. There are other tabs, including HUCB level or custom watersheds. We have three more states as well. We're trying to fill them out with water use on a regional scale.

Figure 4 shows another example for the Bureau of Reclamation's watersheds, consumptive use for the Colorado. If you click on one of them, it shows a pie chart of where the water is being used, what percentage, and the time series.

The first phase of the WaDE program, spanning the first five years, aimed to establish the program and develop the data system. We're now in the second phase, where we're redesigning a system to focus on use cases to support research questions like the one I showed about the Colorado River Basin. We're looking to release, in the third phase, a public portal that will allow anyone to answer questions about water use and water rights across the West.

We're thankful for all the funders, collaborators, and partners, which include philanthropic groups, federal government funding, the western states water agencies like the New Mexico Office of the State Engineer, the Internet of Water, CUAHSI, Don't Panic Labs (our IT contractor), and USGS. All of them have been wonderful in helping us. I'll leave you with this question for discussion if we have time. Would this water data for other western states be helpful to you in New Mexico? If yes, I would love to hear how, so we can better design the system to answer such questions for you. Thank you, Stacy.

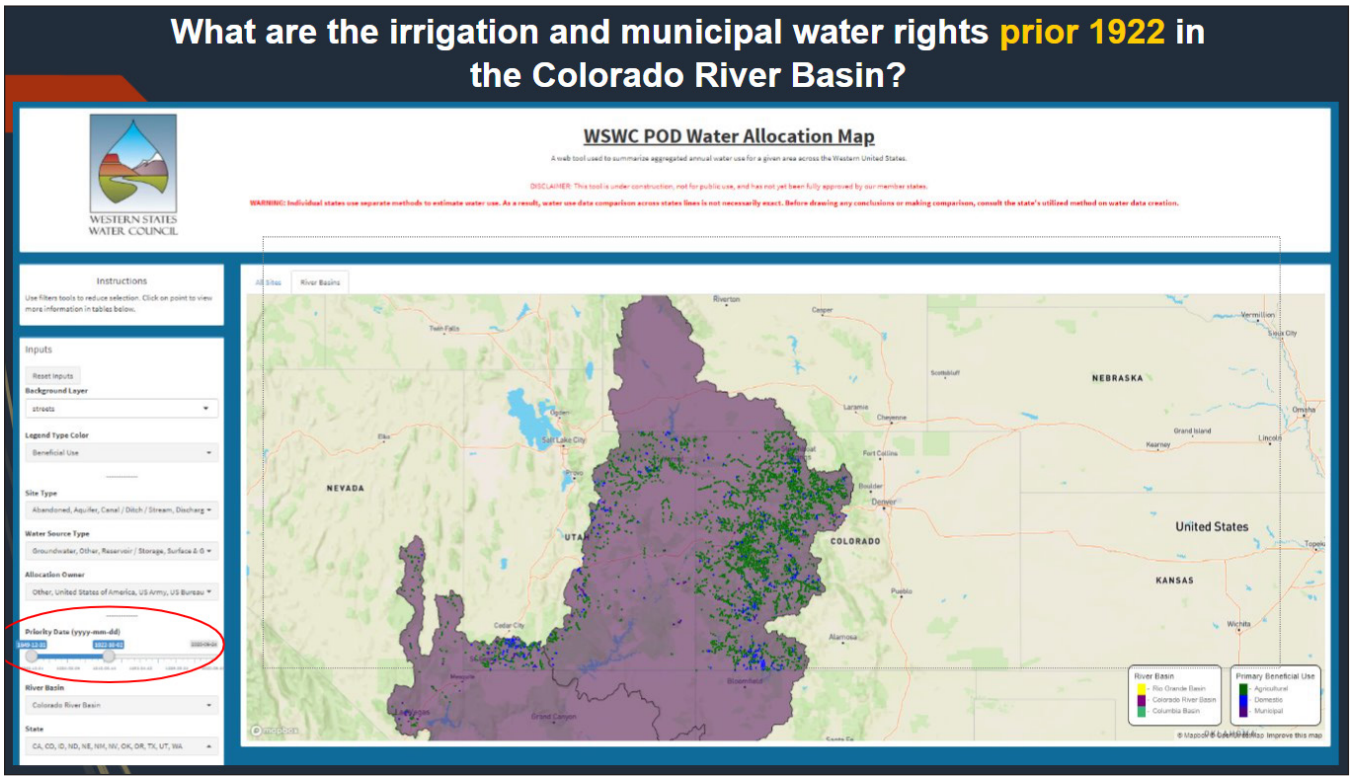


Figure 2. Irrigation and municipal water rights prior to 1922 example.

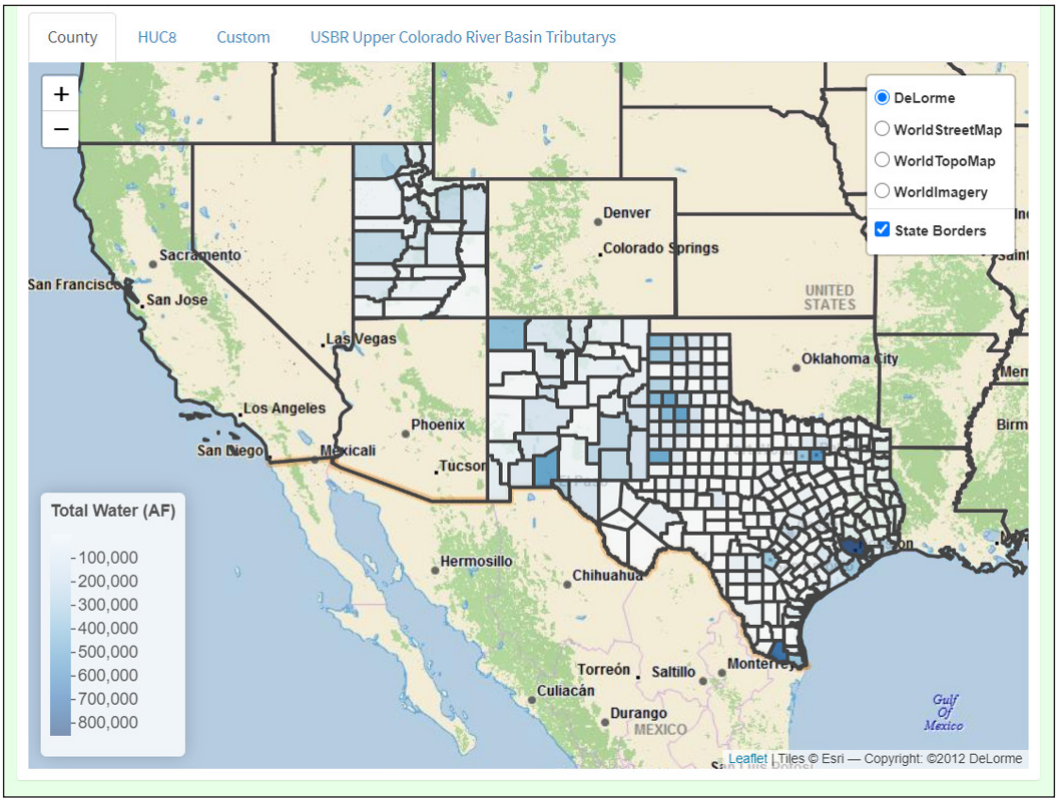


Figure 3. Aggregate county water use map.

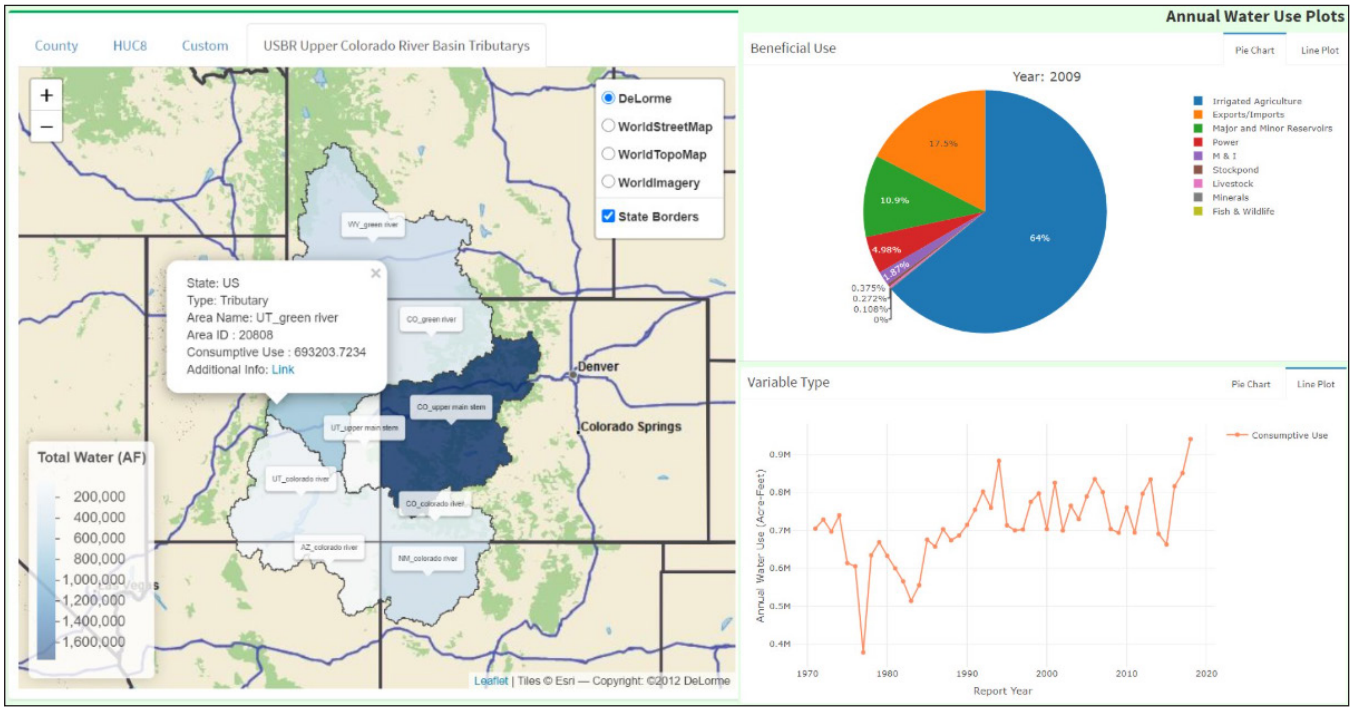


Figure 4. Aggregate county water uses map example.

Timmons: Thank you. I love the idea of having a little bit more feedback. Adel asked a great question, and I would also love to hear what kind of water data is exciting or interesting for you all. If you have any comments, please feel free to post them in the Q&A chat window. For right now, I wanted to quickly mention to Ashley that there are a lot of folks in this meeting who are working for state agencies, and I wanted to know if you had any comments or ideas on how they can engage in learning more about water data.

Ward: Thank you so much. I'm so glad you brought it up, Stacy; I should have raised this in my presentation. One of the efforts of the Internet of Water is the Peer-to-Peer (P2P) Network (https://internetofwater.org/peer-to-peer-network/). The P2P Network now has over 100 members from more than 30 states. The membership of the P2P Network is for state, local, and tribal government agency employees. It's also for utilities and river basin commission employees. The purpose of the P2P Network is to connect folks from all across the country who are working on different data-modernization efforts. They can share what they're doing, successes, and lessons learned. We host a forum where people can interact and ask questions, such as, "What do you do with all this legacy data?" We also host a webinar series. We have one workshop on metadata scheduled for November 17-18, 2020, in which Adel is one of the presenters. We've had a lot of success with our webinars and have been very happy with the participation in those. If you have a good topic that you would like to see addressed, please let us know. We've talked about a water budgeting handbook. We've had an 'Ask the Data Architect' session, where people sent questions to our data architect, and he answered them during the webinar. Following the workshop on metadata, we will present some that highlight the work being done in other states. We would love to have you join us, and we hope you will.

Timmons: Thank you. Meredith, I would love to get your take on the various data that the West Big Data Innovation Hub works with and the community of folks you work with on these data challenges. Do you see water as being particularly challenging to work with relative to some other sectors of data that you're engaged with?

Lee: That's a great question, Stacy. I initially thought, given that wars have been fought over water and movies have been made about wars fought over water, that it would be pretty contentious. With the water rights that have been mentioned and the vulnerable community lens, we are shaping our first water data challenge and trying to gather all these voices and inputs. As we've regionally and nationally gone deeper in areas like health care, transportation, mobility, and access, all of these areas of social impact have lots of very complex issues around how to navigate the intersection of data, science, and people

responsibly and in a way that matches the pace—or lack thereof—of policy changes or legacy systems. It's not just the IT systems that are legacy and in need of rejuvenation. That was our initial take, that the water area would be more challenging compared to the others. There's a lot of difficulty all the way around, but the opportunity lies in trying to compare what has succeeded and is thriving in one particular area—resonating with Representative Melanie Stansbury's point—and how you can learn from that, even if it's in an area that's not water, or maybe it's not data, and translate that over to this realm.

Timmons: That's great. I love the idea of taking something that worked in a completely different sector and translating it to address the challenges we're working with.

There are a few comments asking about some of New Mexico's specific challenges that we're facing. I'll address that, and then perhaps we can talk briefly about some of the other states' perspectives. For New Mexico's challenges, I think we're seeing a lot of our state agencies have real struggles. I think it was alluded to in the panel just before but staffing availability and their budget restrictions or constraints make it very difficult for them to scale up, to build their skills to engage in this water data challenge. What we need to do is change the culture around how we handle data. Everybody has their way of doing it right now, and it's hard to envision something new and different when we're just busy keeping up with the day-to-day and trying to make ends meet with the time that we have available. The comment I would have to some of the biggest challenges here in New Mexico seems to come back to funding these agencies in order to support an engaged effort on this.

In looking at the chat, other questions I'm seeing are, "What are some of the most exciting and interesting water data efforts that are coming up across the country? Where are they succeeding, and what can we learn from others?" I don't know who wants to start that. Ashley, you're smiling.

Ward: One of the things I think is very interesting is the effort that we are undertaking. It's still ongoing, but we finished the first phase in California. Harmful algal blooms are a significant concern, and the California State Water Boards sought to develop a more robust reporting and notification system for these blooms. However, it is cost-prohibitive for the state to monitor water bodies throughout California. It's not something that the state can take on itself. So, we worked with the Internet of Water, with the California State Water Boards, a group of non-governmental organizations, and two tribal governments in California to develop a data-ingestion model so that nongovernment entities can easily ingest their monitoring data into the state system, expanding the state's capacity around monitoring and notification for harmful algal blooms. We've just finished this process where we put together the implementation plan, and now, at the beginning of the year, we will work to implement what was laid out through that stakeholder-engagement process. What is important there is that when we talk about a time in which state capacity is limited, and probably going to grow more limited, this is one way in which we can get more data, how to address those issues about quality assurance and quality control, and how to expand state capacity for those types of questions, not just on harmful algal blooms. I can see that being used for a variety of other topics as well. I think that's something that's really exciting and may be of interest to the folks on this call.

Lee: There's another unique effort, a governance and consortium structure in California that I wanted people to be aware of called the California Water Data Consortium (https://cawaterdata.org). I could say I'm biased because I'm on the board of directors, but I'm an unpaid member. So, I feel confident in sharing that this is quite unique. The chief data officer and the head of the State Water Resources Control Board, and so many other key data stewards and leaders, are engaged in an official 501(c)(3). We announced a steering committee in November 2020, and that's something to stay tuned for, as it will provide lessons learned, best practices, and insights from friends on the other side of the border who are working to establish a sustainable partnership around data and data-enabled decision-making.

Timmons: I do have one question for Adel, and then I'll jump back over to the chat if we have time. Adel, I'm curious about the different states you've been able to engage with in the West, particularly in relation to part of WaDE's process. Speaking from my own perspective, the engagement with WaDE and being able to share data has been eye-opening for both the states and you. Can you discuss any comments you're hearing from some of your collaborating states and what they've learned through the process of engaging and sharing data with WaDE? Are there any thoughts that come to mind on that?

Abdallah: Thanks, Stacy. The general sense is that since we're trying to generalize how we share and represent data across state lines, we ask questions of our states about things like metadata or methods that normally they don't think about because the data is being used locally. There was no purpose to look at the data in the bigger picture, so I think it opened their eyes: "Oh, we should add these metadata columns in our data to better describe our own data." That has been the common theme that we have heard from our member states. Thinking in that way has been helpful to them. Data is usually collected for a single purpose, based on my personal experience and the findings from the Internet of Water. You can't collect data for all the purposes in the world. Sometimes, the metadata that is documented with the data is limited. However, when we start asking questions for a purpose other than the one for which the data was collected, states begin to think about

additional metadata or a different way to represent the data. I hope that helps.

Timmons: From our perspective, in working with New Mexico agencies, when we start saying, "Hey, but where's the metadata? Where's the instructions for how to use this?" people start saying, "Oh, okay, let me get back to you." I think that's a really important point regarding all our data practices: we have to remember to have some documentation about it.

Abdallah: And that costs time and money. That can be annoying too, say, if I want to finish this data collection, share the data, and then move on, but I have to go back and try to add that metadata. It's a process, but I think in the long term, the more we add that metadata, the more value we can get out of that data with minimal additional expense.

Timmons: Right. And making that part of the common practice of how we manage our data now, and going forward, and not just shoving it out in an Excel file and saying, "There we go. Deal with it."

Abdallah: Exactly, and it takes some training. I'm glad to see all those folks on the call today, because it takes some training sometimes to get the bigger picture of what we want to do with this data. There's an insight gained from working with others.

Timmons: Are there any other burning comments? I'm seeing the time limit. Do you want to make any last remarks on water data or water data in New Mexico at this point before we end this session?

Ward: Stacy, Lily Conrad brought up a good point about how we're connecting with communities that have less capacity to engage in this way, and I think it's a great point. Meredith, I see you've put a link to some information. I would also like to add a couple of comments to directly address Lily's comment. There are many components of this question. One way the Internet of Water is addressing these issues is by creating all our tools as open source. Most of the information is available. There are no proprietary software packages, and therefore, there is no cost associated with them. Many of the tools, such as the Geoconnex tool we're developing, are designed to enable people with limited technical expertise to access the data. How does this impact different communities? We're more in the background, less upfront. We play a more indirect role in the sense that we work with organizations that work in these communities. We are not only enabling these organizations to have access to data but also thinking about how that data is delivered with regard to dashboards, making sure that it's communicated in a way that is clear and understandable, and supporting these organizations who work regularly within communities so that they can then deliver information and support the community with this data and information that they have. That's how the Internet of Water has been engaging with different communities that find themselves perhaps on the outside, without the capability to engage otherwise.

Timmons: Meredith, is there a link you'd like to share with the broader community?

Lee: Yes, I have some links that I would love to share. Lily's question pointed to efforts to help connect communities that may not have internet access—broadband, let alone any internet—and how to, importantly, address inherent disparities in privilege or access. One link I added was to some video recordings from early June (https://www.waterboards.ca.gov/resources/data_databases/wq_science_symposium.html). Day one of the California State Water Boards' Water Data Science Symposium had some great panelist discussion, if you look up the environmental justice community discussion on some of these issues.

I see many parallels with the disaster response and recovery community. There's a great five-minute lightning talk that I can share at another time from a colleague on the FEMA National Advisory Council, Dr. Nicolette Louissaint, who is thinking about existing infrastructure and what it would look like to ease the burden. Making people aware that not everyone can simply hop on a Zoom is definitely something that I think deserves greater emphasis and advocacy, along with how we can mitigate the inherent systemic inequities in the shift that we're all experiencing right now.

Timmons: I would like to add that we're currently working on outreach efforts through the New Mexico Water Data Act to engage with communities across the state, not just via Zoom. It'll be printed material for a little while until we can feel safe going out and meeting in person. I would welcome ideas about how we can connect with some of these various communities. In our more rural parts of the state, we would love to hear from them about how and what type of water data they would like to find.

I just want to quickly say a huge thank you to Ashley, Meredith, and Adel. This panel has been totally awesome considering all our time commitments around this, and I appreciate all of your support for our work here in New Mexico on water data. Thanks, everybody.

Impacts in New Mexico of Revised Clean Water Act Jurisdiction

Editor's Note: The following papers represent a transcription of the speakers' remarks made at the conference; no follow-up papers were submitted by the speakers. Remarks were edited for publication by the editor. The speakers did not review this version of their presentation, and the editor is responsible for any transcription and editing errors.



Shelly Lemon, New Mexico Environment Department

Shelly Lemon has worked for the Surface Water Quality Bureau (SWQB) of the New Mexico Environment Department for over 15 years, serving many distinct roles. The mission of the SWQB is to preserve, protect, and improve New Mexico's surface water quality for present and future generations. As bureau chief, Lemon currently manages and oversees three technical teams that fulfill the state's responsibilities under both the federal Clean Water Act and state Water Quality Act, such as developing and revising water quality standards, and implementing surface water protection regulations. Lemon earned a bachelor's degree in biology and a master's degree in hydrology from the University of Arizona. As a graduate student, Lemon worked for the Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA) and completed her thesis research on spatial and temporal variability in water chemistry associated with land use and hydrologic flow paths in the San Pedro River watershed, Arizona.

I was asked today to talk about different regulatory changes that have been happening. As Mike Connor pointed out in his previous talk, numerous regulatory changes have occurred over the past four years, with some having significant impacts. I'm going to give information about the scope and jurisdiction of the Clean Water Act and provide a brief history of the waters of the United States. Then I'll move on to the new Navigable Waters Protection Rule and discuss the actions the Environment Department is taking now to partially fill the gaps created by these new rules.

Over time, Supreme Court decisions have clarified that the jurisdictional scope of the Clean Water Act encompasses more than traditional navigable waters, but less than all waters. I would like to remind people that the purpose of the Clean Water Act is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. It does not grant federal jurisdiction over all waters found within the boundaries of the United States. As we know, many waters are hydrologically connected, and there are temporary or permanent upstream waters that have the potential to change downstream waters over a variety of spatial and temporal scales. Currently, the challenge is to reconcile the Twenty-First Century ecological and hydrological science's core concept of connectivity with the Clean Water Act's Nineteenth Century paradigm of navigability, and Congress has thus far declined to resolve this tension. I will also discuss how the Supreme Court has contributed to the confusion.

So, a brief history of Clean Water Act jurisdiction: we had a definition of waters of the United States for quite a while, until relatively recently. The definition followed the 1986 WOTUS definition, which included traditional navigable waters, interstate waters, all other waters that could affect interstate or foreign commerce, impoundments of waters of the United States, tributaries, territorial seas, and adjacent wetlands. Then, in 2001 and 2006, the Supreme Court issued decisions that clarified that the scope of navigable waters must be more closely tied to protecting the integrity of waters used for navigation. In 2006, the Rapanos Court attempted to establish clear jurisdictional boundaries but was unable to reach a majority opinion, resulting in two opinions being formed from that decision. The Scalia opinion said that federal protection only extends to "relatively permanent" waters and wetlands with a continuous surface connection to larger rivers and streams. The Scalia opinion was the official plurality opinion of the court, in that although the majority did not join, it had the highest level of support with four justices. The Kennedy opinion relied on the "significant nexus" test, which requires a connection between waters that is more than speculative or insubstantial to establish jurisdiction. Despite being a concurrence, the Kennedy concurring opinion is the one that's most often cited in significant water jurisdiction cases since Rapanos. Essentially, the Kennedy concurrence was the law as far as courts were concerned until 2015.

After Rapanos, the Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers were left to formulate a rule that would modify the 1986 efforts to define the scope of waters protected under the Clean Water Act, based on the guidance in these three court cases:

United States v. Riverside Bayview (1985), SWANCC v. Corps (2001), and Rapanos v. United States (2006).

In 2015, a new definition of "waters of the United States" was developed, proposed, and issued, sparking significant litigation. The 2015 Clean Water Rule emphasized Kennedy's significant nexus test, and it included traditional navigable waters, interstate waters and territorial seas, tributaries and adjacent waters due to their presumed significant nexus, impoundments of jurisdictional waters, certain regional waters within a floodplain, and looking at things on a case-by-case analysis for significant nexus. It depended on chemical, physical, and biological data to evaluate the jurisdiction of the waters, either individually or in combination.

Then, in 2020, a new rule was proposed and became effective on June 22, and that is the Navigable Waters Protection Rule, which emphasizes Scalia's "relatively permanent" opinion. The new rule interprets the term "waters of the United States" to encompass these four categories of waters that are federally regulated under the Clean Water Act: territorial seas and traditional navigable waters; perennial and intermittent tributaries; certain lakes, ponds, and impoundments of jurisdictional waters; and wetlands next to other jurisdictional waters.

The Navigable Waters Protection Rule shows 12 categories of waters that are not considered waters of the United States and therefore are not federally regulated under the Clean Water Act, including ephemeral features, which is significant for the state of New Mexico. Most of our surface waters in the state are ephemeral waters. We also have groundwater, which wasn't a change from the earlier waters of the United States definition, but the Supreme Court recently held in County of Maui v. The Hawaii Wildlife Fund that groundwater connectivity does not sever jurisdiction where discharges are the functional equivalent of a direct discharge. So groundwaters could be regulated if there is a functional equivalent to a direct discharge. We also have certain artificial lakes, ponds, and impoundments; ditches; prior converted cropland; and stormwater control features. Those were excluded, as well as wetlands that do not meet jurisdictional conditions, even if the surface connection is artificially broken, which is a key consideration. So, if there is a wetland divided by a road, it may no longer be jurisdictional if there is no surface water connection between the two to another jurisdictional water.

There are critical impacts to the State of New Mexico from this new rule. As I said before, most of our surface waters are ephemeral. Less than seven percent of New Mexico's streams are perennial, leaving most of the state's waters subject to pollution threats under this new rule, including important interstate streams such as the Rio Costilla in the Valle Vidal and the Gila River in the southwestern part of the state. In addition, many of our perennial streams and intermittent streams are interrupted and therefore may not be subject to Clean Water Act protections because the surface water connection is broken. We also have ephemeral water bodies that serve as drinking water sources, which puts those sources under threat. Figure 1 shows the important estimates that the Environment Department has looked at: 89 percent or more of stream miles are non-jurisdictional because 89 percent of our waters are ephemeral. Up to 50 percent of perennial and intermittent streams may be non-jurisdictional due to these interruptions. Of course, 100 percent of our ephemeral streams are not jurisdictional, and 70 percent or more of our wetlands may not be jurisdictional because of the clause that if an artificial divide prevents surface connection, then the wetland is no longer jurisdictional. As a result, a large majority of National Pollutant Discharge Elimination System (NPDES) permits may no longer be needed (60 percent or more of individual permits; ~80 percent of general permits) because the location where they are discharged is no longer considered jurisdictional.

Over the past year, we've seen a trifecta of new Clean Water Act rules come into effect. As I mentioned earlier, the Navigable Waters Protection Rule, which took effect on June 22, 2020, has significant implications for ephemeral deregulation. We've already received complaints from the public about the impact of ephemeral alterations. The Clean Water Act Section 401 Certification Rule was also revised. That rule takes effect on September 11, 2020, and we're still trying to determine its implications for the state and the department. We're concerned about state conditions that may no longer apply under the new rule. Recently, the Corps of Engineers issued nationwide permits for Clean Water Act Section 404 dredge and fill activities. The last permits were issued in 2017 and are usually effective for five years, but the Corps decided to issue early and publish the revised nationwide permits on September 15. I will point out that the public comment period is still open, and the public can provide comments to the docket until November 16, 2020.

So, what is the Environment Department doing to help at least learn more about the impacts or help fill the gaps? We entered multistate litigation over the Navigable Waters Protection Rule. We also entered multistate litigation over the changes to the Section 401 state certification rule. We hired a contractor to conduct an NPDES gap analysis, evaluating where the state is deficient, where existing rules and regulations are already in place, and what funding and resources will be required to assume authority over the NPDES program in New Mexico. We are certainly commenting on and going to certify the proposed nationwide permits. We're involved in the

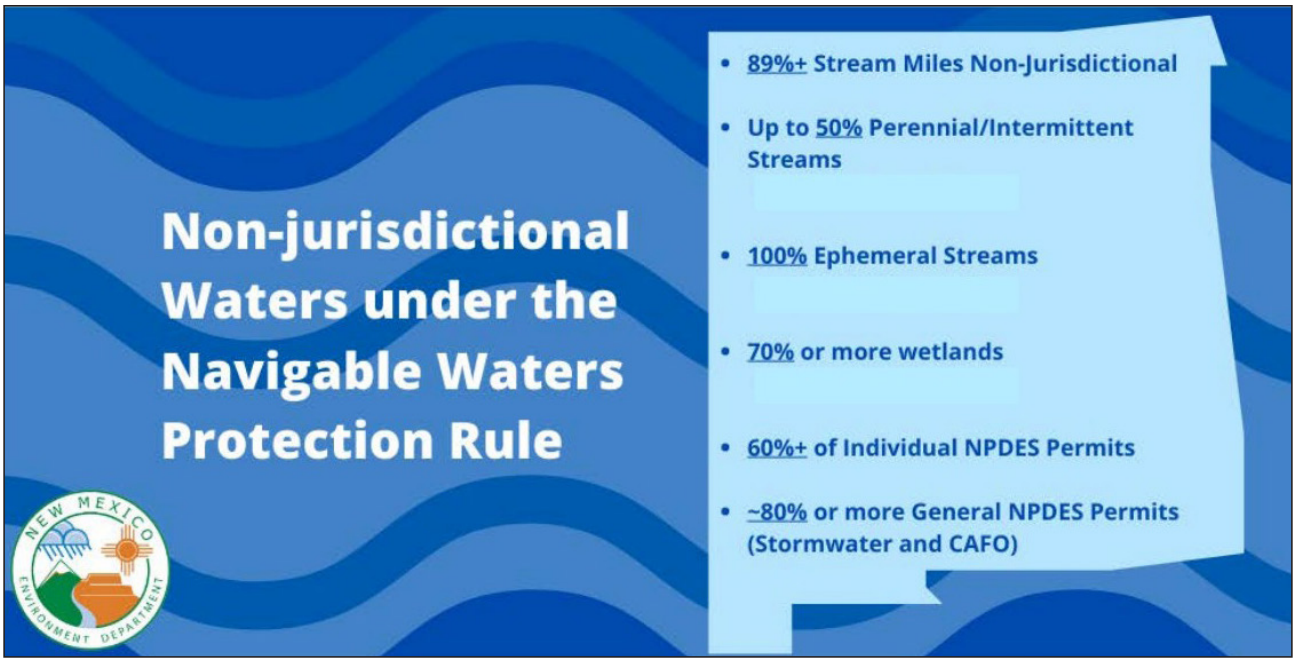


Figure 1. Critical impacts of NWPR in New Mexico.

water data initiative and a data challenge, which you may have heard Stacy Timmons talk about yesterday. We are involved in the national stream flow duration study, which is helping to implement the Navigable Waters Protection Rule. The Surface Water Quality Bureau also has a hydrology protocol that shares a similar concept. It basically helps to decide whether the stream is ephemeral, intermittent, or perennial. We're investigating the potential to enter into memoranda of understanding with the Corps and EPA regarding 401 certifications, so that both federal and state agencies understand the process and timelines that we agree upon. We're also coordinating with a variety of stakeholders to discuss water challenges and potential actions. The Navigable Waters Protection Rule is not rebalancing the relationship between states and the federal government, which the Clean Water Act does envision. It's essentially punting environmental protection to the states, and some states, like New Mexico, do not have the infrastructure right now. We're not equipped to adjust for those immediate gaps. We're working on it, but it won't be an immediate solution.

I believe I have a couple of minutes for questions. I provided my contact information (shelly.lemon@state.nm.us, 505-470-5018), along with that of my boss, Rebecca Roose (rebecca.roose@state.nm.us, 505-670-6852), who is the Director of the Water Protection Division, and John Verheul, our Assistant General Counsel (john.verheul@state.nm.us, 505-469-8862). If you have any legal questions, you should contact John to discuss them.

It looks like the first question is, "Can you say more about the number and kind of complaints from the public regarding the impact of ephemeral alterations?" We receive complaint calls about people filling in arroyos with dirt and other debris. With storm events, people are reporting that their roads are getting flooded and that clogged culverts have gone awry. If they're damaged in any way, there's no regulation to work on that. We haven't had many problems. We've just gotten a few complaints about ephemeral filling when it rains. We've also talked with the Department of Transportation, and they're very worried about the ephemeral exclusion.

The second question asks, "Is the Rio Grande, especially below Caballo, considered an ephemeral stream? It is bone dry most of the year." It is not considered ephemeral. I would consider something like that to be interrupted. The Rio Grande at the Texas border is traditionally navigable water. Therefore, if there is a surface connection to the traditionally navigable water at the Texas border in any given year, it would be considered jurisdictional. So, the Rio Grande is still jurisdictional in that area. Justin Riggs, who will be speaking after me, may have some additional comments on that.

The last question is, "Can the New Mexico legislature provide the Environment Department with the ability to replace the diluted rules? If yes, what action is being taken?" We cannot replace the federal rule. What we can do is establish state regulations and statutes to help protect the state's surface waters, and the state has a more stringent or protective definition of surface waters.

However, we do not have a regulatory program to regulate discharges to surface waters of the state. Right now, the federal government regulates those discharges. There are federal permits under the Clean Water Act, not under the state Water Quality Act. We are investigating the gaps in regulations and statutes that may require changes or implementation, as well as the resources needed to transfer these programs from the federal government to the state level. Obviously, implementing it will require people, resources, and time, which we are looking into.



Justin Riggs, U.S. Army Corps of Engineers

Justin Riggs is a regulatory project manager with the U.S. Army Corps of Engineers Albuquerque District. He has been with the district for eight years. Justin's area of responsibility is southern New Mexico and west Texas. He evaluates projects under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. Justin has a bachelor's degree in soil science and a master's degree in plant and environmental sciences, both from New Mexico State University. Before working for the Corps, Justin was a soil scientist for the Natural Resources Conservation Service. He was responsible for mapping soils on White Sands Missile Range as well as parts of Doña Ana, Sierra, and Luna Counties in New Mexico.

As mentioned in the previous presentation, I will delve into the Navigable Waters Protection Rule in a bit more depth.

We're going to talk about the key changes from the 2019 rule. Under the new rule, we have only four categories, which were previously discussed. However, in the Obama Administration's 2015 rule and the 1986 rule, there were originally eight jurisdictional waters. Today, we have four categories: territorial seas and traditionally navigable waters; tributaries; lakes, ponds, and impoundments of jurisdictional waters (the new category); and adjacent wetlands. Regarding the key changes, I mentioned earlier that there were eight categories of jurisdictional waters; now we have four, with the addition of twelve categories of excluded waters that are not jurisdictional. Under the categories of jurisdictional waters, the new rule has combined traditionally navigable waters with territorial seas. Those were both jurisdictional. Under the other two rules, they were categorized separately, and currently, they are combined into one. The other significant issue is the absence of a stand-alone category for interstate waters. In the 2015 rule, or the 2019 rule, as it was renamed, and the 1986 rule, waters across state boundaries were considered interstate waters and thus jurisdictional. Today we don't have that. We also no longer conduct case-specific significant nexus analyses, where we had to examine and determine if water was chemically, physically, or biologically connected to the downstream water that is no longer at our disposal. Another key change is the new category of lakes, ponds, and impoundments.

We'll start with (a)(1) territorial seas and traditional navigable waters (TNW). There are no major changes aside from the new rule that combines the categories of navigable waters and territorial seas. As mentioned, the Rio Grande is traditionally navigable water after the State Line, right at the American Diversion Dam. Under the Clean Water Act, the Rio Grande is considered perennial even though it is shut off and dry most of the year. According to the Corps of Engineers, we consider it perennial and thus jurisdictional, and it becomes a TNW in Texas.

The major changes came in (a)(2) tributaries. Again, we don't have a significant nexus test, and we no longer have ephemeral streams. Now, one thing I want to make clear is that if you are in an ephemeral tributary, but upstream of that tributary there is an intermittent or perennial reach, as long as there is still a surface connection to downstream water, then it would still be considered jurisdictional. In this case—where I am and where most of us are—the Rio Grande, Gila River, Pecos, or any of those major rivers that have an upstream intermittent or perennial and an ephemeral reach are still jurisdictional. The ephemeral reach would not be jurisdictional, but the intermittent or perennial would still be jurisdictional. About 86 percent of the waters within the Albuquerque District are ephemeral. That includes waters in west Texas and southern Colorado. In New Mexico itself, I imagine it's even a little bit higher than that. But within the Albuquerque District, we have lost 86 percent of our jurisdictional waters.

The new section is (a)(3) lakes, ponds, and impoundments of jurisdictional waters. The main thing here is that even if a water is impounded, as long as it has some sort of surface water connection or is inundated or flooded from an (a)(1), (a)(2), or (a)(3) water, it is still jurisdictional.

Even if there is a flood control dam or something above it, there is still potential for jurisdiction if it maintains a connection or is inundated by flooding.

The last one is (a)(4) adjacent wetlands. The big change here is that if there is a break, particularly a man-made break, there is a potential loss of jurisdiction. A wetland has to have some sort of connection by a culvert, a stream, or something to an (a)(1), (a)(2), or (a)(3) water. If there is a man-made break and no connection to that water, then the wetland is indeed non-jurisdictional under the new rule. Again, we no longer perform significant nexus tests.

The big thing, and it has been touched on before, is that now we have excluded features. These are waters that are not listed as waters of the United States (WOTUS):

- Waters not listed as WOTUS
- Groundwater
- Ephemeral features
- Diffuse stormwater runoff
- Ditches not identified as WOTUS
- Prior converted cropland (PCC)
- Artificially irrigated areas
- Artificial lakes and ponds
- Water-filled depressions incidental to mining or construction activity
- Stormwater control features
- Groundwater recharge, water reuse, and wastewater recycling structures
- Waste treatment systems

We'll go through them briefly. The key elements of exclusions are uplands and surface water connections. The Corps of Engineers has never asserted jurisdiction over uplands, so there is no change in this regard. Surface water connections are excluded. Certain features can act as surface water connections. As I said, if it is an ephemeral reach, but it is the direct connection for the upper reach of either intermittent or perennial water, that water can still maintain jurisdictional status. It's just that the ephemeral reach of that stream would not be jurisdictional.

Of the exclusions, the first exclusion is (b)(1) waters not listed as WOTUS. This is a catchall. If it's not an (a)(1), (a)(2), (a)(3), or (a)(4) water and does not meet the other exclusions, we throw it into this exclusion as waters not listed as WOTUS. Groundwater (b)(2) has been touched on before. The big thing is that ephemeral features (b)(3) are no longer jurisdictional. For (b)(4) diffuse stormwater runoff and directional sheet flow over upland, there is no major change. We have never asserted jurisdiction over that.

Under (b)(5) of the new rule, almost no ditches are jurisdictional. Previously, under the 2015 rule, or as we call it, the 2019 rule, or under the 1986 rule, ditches that maintain a direct or indirect connection were considered jurisdictional. For example, we still maintained jurisdiction over the Elephant Butte Irrigation District irrigation network here in Doña Ana County. Under the previous rule, that network was considered a water of the United States. It maintained a connection to and from the Rio Grande. Under the new rule, it is no longer jurisdictional. So, we've lost a lot of jurisdiction with this ditch exclusion as well.

We don't deal with (b)(6) prior converted cropland too much here. It's a Natural Resources Conservation Service call, usually for wetlands, but if something were considered prior converted cropland, we did not have jurisdiction over it. There's no change there. We've never had jurisdiction over converted cropland. There is no major change with (b)(7) artificial irrigated areas. For (b)(8) artificial lakes and ponds, if an artificial lake and pond had a connection to an (a)(1) through (a)(4) water under the previous rules, it would have been jurisdictional. But now, under the new rule, it is no longer. We've never had jurisdiction over water-filled depressions incidental to mining and other construction, (b)(9), so there is no major change there. It's the same with (b)(10) stormwater control features, (b)(11) wastewater recycling structures, and, finally, (b)(12) waste treatment systems.

The big thing with the new rule is that the Albuquerque District of the Corps of Engineers has lost jurisdiction over the majority of our waters. We have been issuing permits across ephemerals for years, and it has had a major impact on our workload. We have individuals, municipalities, and other groups working within ephemeral reaches, which are now exempt from permits, that fill arroyos and ephemeral streams. They are conducting work in those streams that have an impact both downstream and upstream, and can affect those intermittent and perennial reaches. We have issues with the ephemerals being non-jurisdictional in the sense that if they are blocked off, filled, and no longer meet that connection downstream, there are questions. Does the reduced surface water connection within the ephemeral reach now remove jurisdiction for the upper reaches, even though they are perennial or intermittent? Those are questions that haven't been answered yet. There are potential problems with this new rule, but we'll work through it, and we do the best we can.

To get further information on the Clean Water Act, visit https://www.epa.gov/nwpr. You can direct questions to the Environmental Protection Agency at CWAwotus@epa.gov. My email address is Justin.C.Riggs@usace.army.mil. People asking questions is where we get the best information. At this point, I would like to answer all the questions you have. I've got the Q&A open.

The first question says, "What is the status of ephemeral streams that are effluent dependent and flow intermittently?" We cannot use an effluent flow as a form of water to say whether something is intermittent or perennial. We have to go by the definition. If there is natural flow from a rainstorm or precipitation event, and

that's the only major form of water, we would assume that the stream is ephemeral, even if it has effluent flow. We would not consider the effluent flow because it can always be cut off. It's not considered a permanent type of flow, so we cannot consider it.

Another question asks, "Could you say anything about the changes in nationwide permits that were proposed in September?" Yes, we have a lot of changes—some good, some bad. Within the nationwide permit program, we have around 55 permits that we verify for individuals, municipalities, and other groups to use. We were directed to reissue those this year, and we have started that process. There are new changes, one of which is that many of our permits have a 300-linear-foot limit, stating that a permit holder cannot impact, change, or experience any loss exceeding 300 feet. Under the new proposed nationwide permits, most of those limits are gone. So, the rule reverts back to the limit of half an acre. Most nationwide permits have a threshold of around half an acre, but some were also limited to 300 linear feet, which is now no longer applicable. There is a proposal for federal agencies to be exempt from reporting to the Corps of Engineers. There are a few other minor changes, but the major change is that the impact thresholds are being reduced, effectively allowing for more impact than was previously allowed under the old nationwide permits.

The next question says, "Is that estimate of 90 percent measured in stream miles?" It is measured by stream miles. Yes.

Fernald: Justin, I have a question for you. Where do you think the state really needs to step in? There are a lot of things they could do. But if you were going to give a priority item for the State of New Mexico, where do you think they need to step in, either places where the federal role has been limited, or places you see that really need some action?

Riggs: The major action we need—and I'm talking as Justin Riggs now, not as a federal employee—is to address this loss of ephemeral waters. We have a major issue with that. We have lots of work going on in our waters. Again, they're happening in ephemeral streams, which the federal agency does not have jurisdiction over. So, it would be good if the state could have some sort of law/policy/rule—that's way above my pay grade—to address that issue, perhaps some sort of permit or some sort of Clean Water Act analog that the state can use to address this issue of the loss of ephemeral streams.

Finally, the last question asks, "The rule creates regulatory uncertainty, as definitions of ephemeral, intermittent, perennial, and typical year are subjective and not easily applied. What does this mean for the Gila that dries out similarly to the Rio Grande, although it isn't necessarily interrupted?" The Gila River is still considered perennial under both the previous and current WOTUS rules. There are significant uncertainties surrounding the definitions of ephemeral, intermittent, and perennial. We're working on that right now with the New Mexico Environment Department and the EPA, trying to figure out a better way to address those. But, again, the Gila River is considered perennial by the Corps of Engineers.

Fernald: Wonderful. Well, that's perfect timing, Justin. Thanks a lot for leaving time for questions.

Watershed Restoration in New Mexico

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Moderated By Connie Maxwell, NM WRRI Researcher

Connie Maxwell is an ecological planner who works with communities on local and regional levels. Her current work as a graduate research assistant with New Mexico Water Resources Research Institute (NM WRRI) is a collaboration with a broad cross-section of stakeholders in the South Central NM Stormwater Management Coalition to design and conduct watershed restoration within the Hatch/Rincon and Mesilla valleys. Building on this collaboration, she spearheaded the recently formed NM WRRI Water and Community Collaboration Lab (WCC-Lab), which fosters links between the best science, communities, stakeholders and students to inform decision-making and education on water and the environment. Maxwell is currently pursuing a doctorate at NMSU in the Water Science and Management Program under Dr. Sam Fernald's advisement, and holds a Master's degree from UNM in Community and Regional Planning with a concentration in Natural Resources and a Bachelor of Arts in English and Architecture from Columbia University. Maxwell co-founded the Alamosa Land Institute (ALI) in 2010 to engage in ecological planning and restoration with farmers and ranchers, and has been collaboratively introducing and testing innovative land management practices which focus upon restoring arroyos, riparian and agricultural valleys to slow and keep stormwater in watersheds, reduce sediment transport, and recharge aquifers.

We've got a great panel today, with several people highlighting some important initiatives around the state. I would like to begin with a brief introduction to some of the work we've been doing at the NM WRRI in southern New Mexico, as well as the work that is central to my focus as a water professional. A key recognition that has been central to this work is that agricultural communities and working landscapes are key to managing our watersheds for sustainability and community resilience. This is particularly true for the Hatch and Mesilla Valley watersheds in southern New Mexico. This recognition led us to instigate a relatively recently formed Water and Community Collaboration Lab (WCC-Lab). We recognize that collaboration is essential to research on complex water issues in New Mexico. The WCC-Lab fosters links between the best science, community stakeholders, and students to inform our decision-making, research, and education on water in the environment. The goal of our work is to be led by the challenges that communities actually face. This is an action research approach, where we collaboratively develop and test innovative and feasible approaches to the complex issues of water supply and usage in New Mexico. A key insight of this action research approach is that complex systems, such as ecosystems, require implementing proposed changes and studying their effects to reveal how the systems actually work. An early proponent of action research, Kurt Lewin, said, "If you want to know how things really work, just try to change them."

So, what are the problems? What underlies the problems that folks down here in southern New Mexico are facing? This is a key insight: what underlies both drought and increased flooding as social crises is a landscape-scale water storage problem. Of course, we have the diminished snowpacks and resulting spring runoff from less winter precipitation as a huge driving factor in droughts and surface water supply for our southern New Mexico region (Figure 1). Not only that, but we also have a large decrease in upland soil moisture levels, which has led to the loss of vegetation. This loss increases our scouring floods and further decreases infiltration, soil moisture levels, and downstream groundwater recharge.

So, what is the key to turning this around? A central part is recognizing that agriculture is the primary land management system, and management practices that slow and spread flow to floodplains support our watershed's buffering capacity to mitigate floods and droughts (Figure 2). These reconnecting floodplain management practices replenish soil moisture and aquifers, reduce runoff, flow energy, and sediment transport. A big goal of my work, in particular, has been to support increasing agriculture's function as a resilient system for recharge and flood control. Farmers and ranchers down here, but also foresters in other parts of the state, manage the floodplains where the water flows in the watersheds and have incentives to manage that—to use water where it can spread flow and so forth.

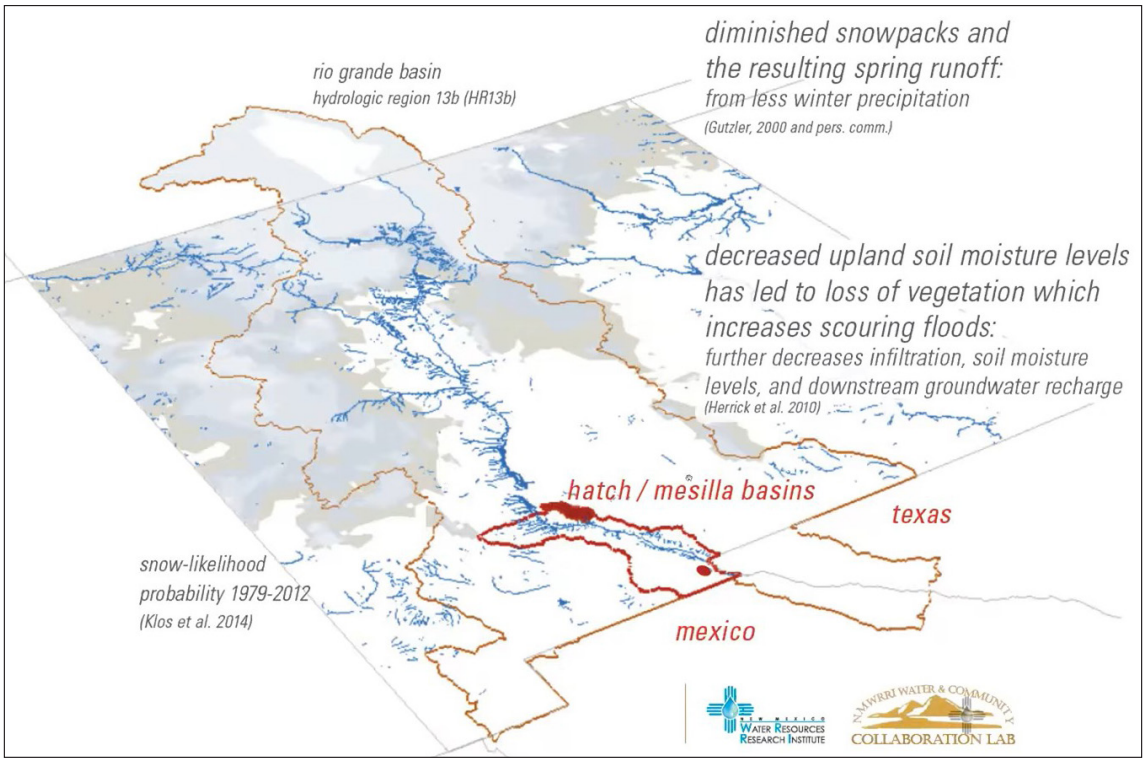


Figure 1. Address the critical natural and social processes - water scarcity and flooding.

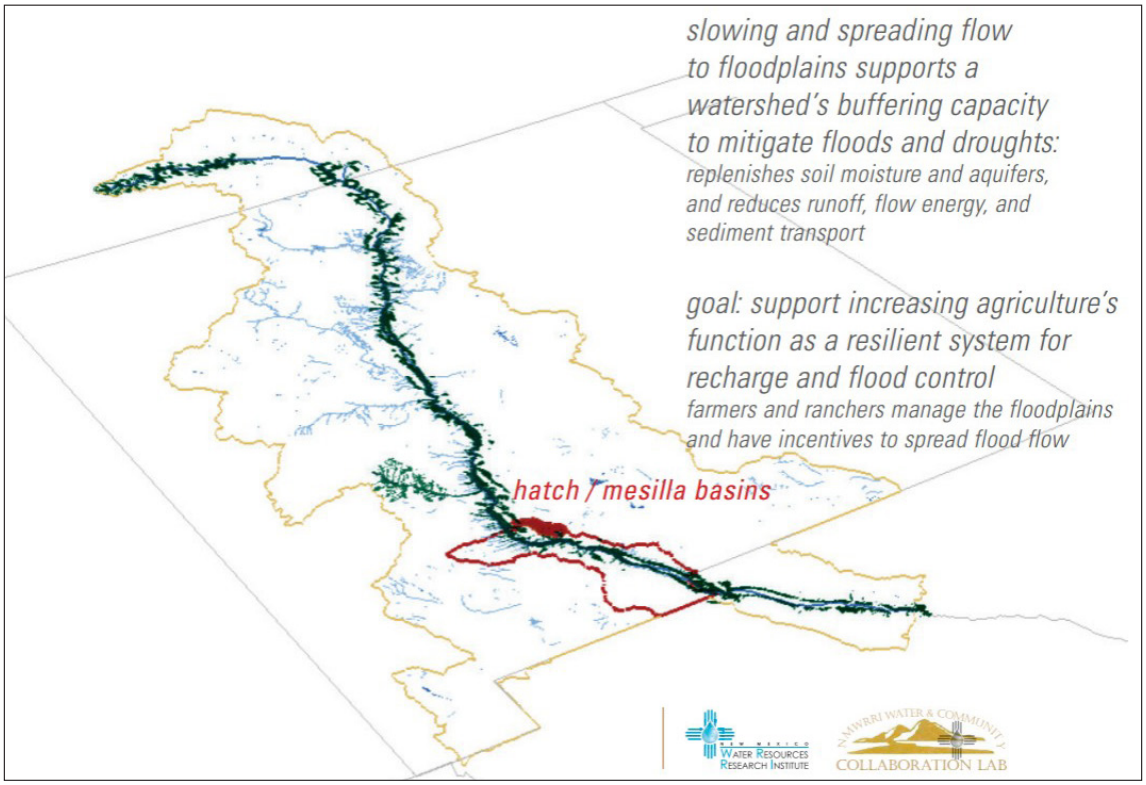


Figure 2. Agriculture is the primary land management system - working landscapes.

Two of the gaps that have been particularly looming in our southern New Mexico community have been the lack of tools to help land managers and water managers effectively implement some of these practices. A focus of my PhD work has been developing a decision support tool that asks, "Where do we reconnect floodplains, and how much benefit are we going to get out of that practice?" This particular tool is a modeling framework called the Flood Flow Connectivity to Landscapes (FlowCon) model (Figure 3). It identifies the optimal areas for infiltration and then estimates the actual benefits—how much peak flow can we really reduce?—and, therefore, we can predict the connectivity management benefits. Of course, tools are only part of it, and extending projects on a whole range of fronts is critical.

We've also been instrumental in facilitating and pursuing funding efforts, and in southern New Mexico, we've been particularly successful over the last year. We've secured four funding efforts (Figure 4). Two of them address issues in our most significant priority project, the Rincon Arroyo Watershed, and two of them address areas throughout the Hatch and Mesilla Valleys. Zack Libbin will be speaking about these initiatives in greater detail. Our collaboration has been fundamentally with the stakeholders in the Stormwater Coalition, and he'll let you know who those are. Our two initiatives in the Rincon Arroyo Watershed, a priority watershed, will enable us to implement watershed restoration through the New Mexico Environment Department's Watershed Implementation Grant, for which we at the institute were the primary recipient. We have also secured the first phase of a relatively large grant from the Natural Resources Conservation Service, which aims to restore the entire Rincon Arroyo Watershed (134 square miles). Additionally, over the next two years, we will be developing a watershed plan with the Reclamation Cooperative Watershed Management Program for the entire Hatch and Mesilla Valleys. The Elephant Butte Irrigation District led an effort to implement watershed-scale stormwater monitoring and capture to extend their aquifer recharge program, and we at NM WRRI will be adapting some of our tools to look at the future scenarios of this region—particularly looking at what watershed-scale stormwater monitoring and capture can do for us and other future water scenarios.

That provides an introduction to our approach as water professionals in southern New Mexico—in particular, my approach—and I look forward to hearing an update on other initiatives around the state.

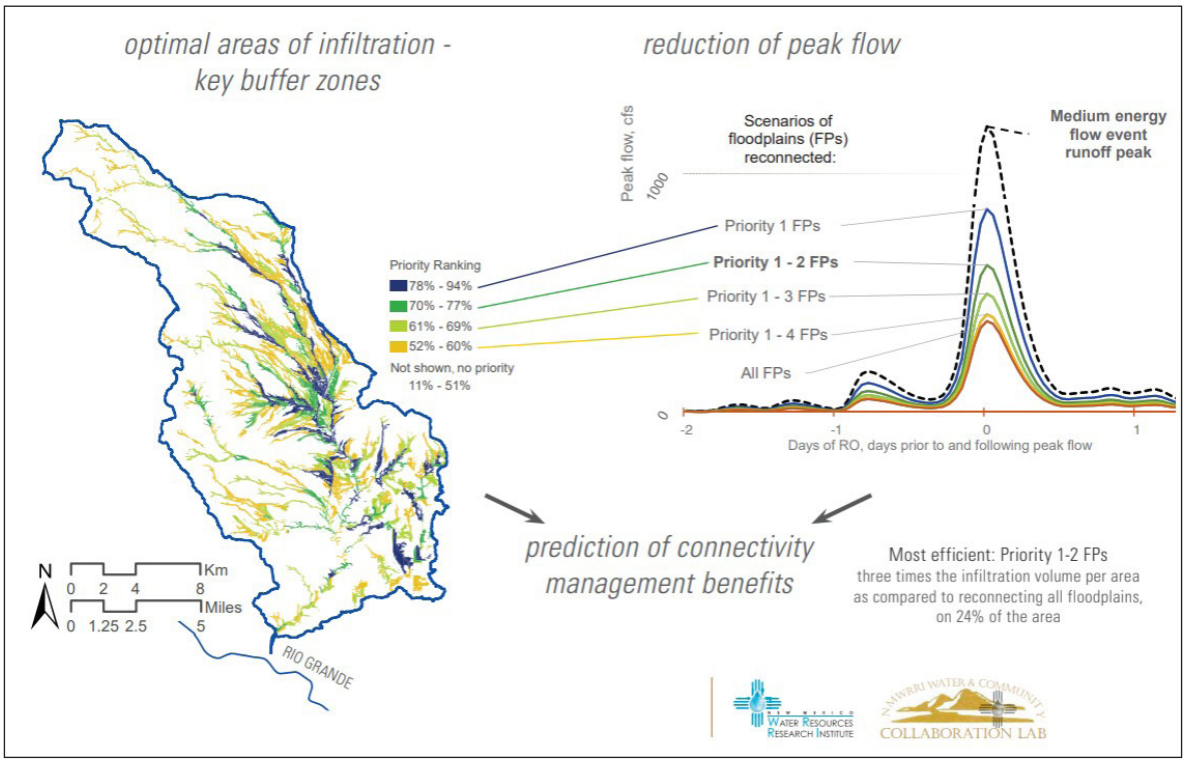


Figure 3. Decision support tool: the Flood Flow Connectivity to Landscapes (FlowCon) modeling framework - quantify the most efficient management efforts.

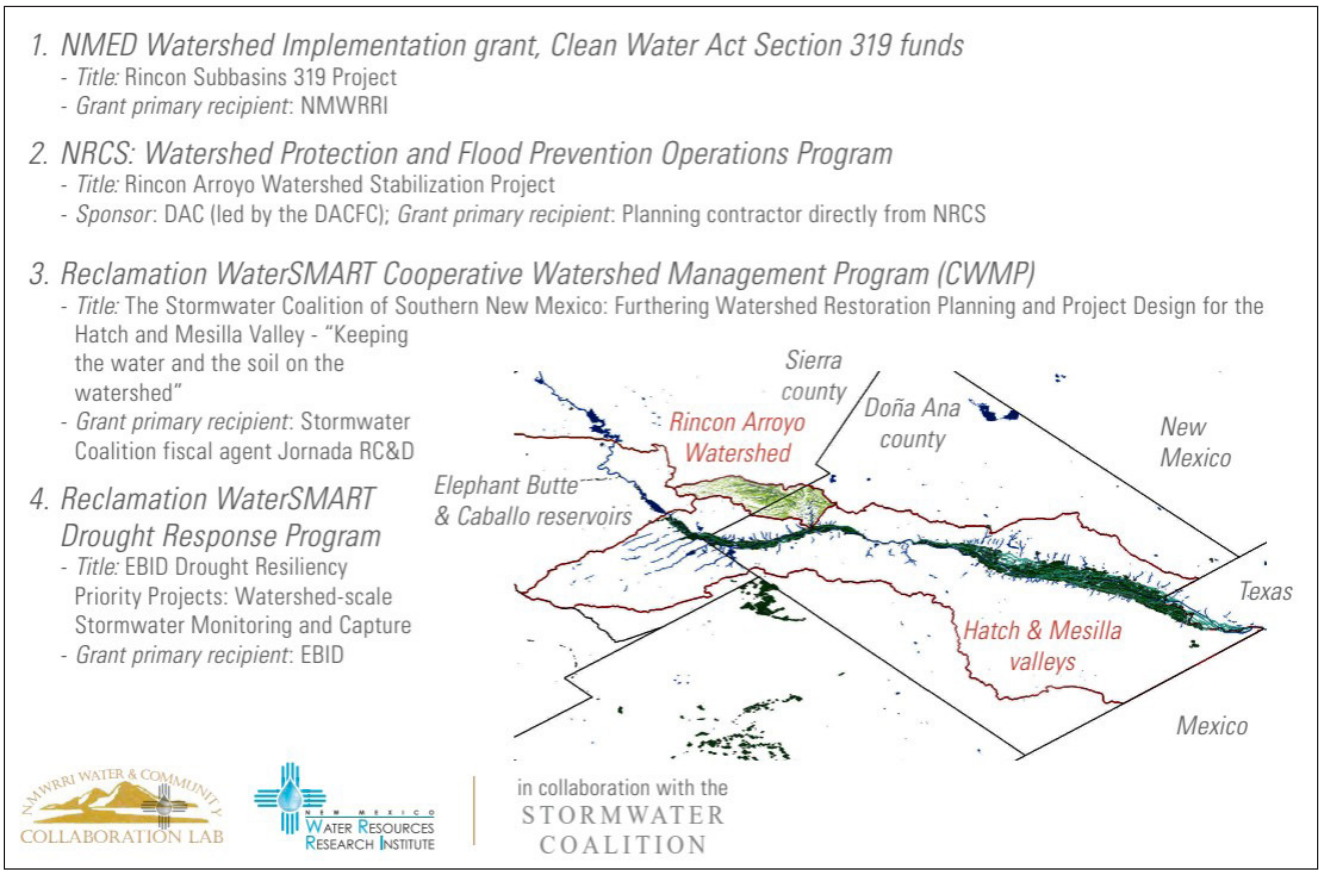


Figure 4. Support funding efforts - two grants address the Hatch and Mesilla Valley Watershed and two address the Rincon Arroyo Watershed.



Laura McCarthy, New Mexico State Forester

Laura McCarthy is State Forester in New Mexico where she is responsible for fire suppression on 43 million acres of state and private lands (e.g. non-federal, non-municipal and non-tribal lands) as well as statewide forest and watershed restoration programs. Previously, she was Associate State Director for the Nature Conservancy in New Mexico and manager of the Rio Grande Water Fund. Laura's prior work includes more than a decade with the USDA Forest Service as a firefighter and planner in Idaho, California, Vermont and New Hampshire.

Laura's professional life was significantly altered by the Cerro Grande Fire in 2000, which fostered her interest in fire and forest restoration practice and policy. The Las Conchas Fire, a decade later, deepened her engagement in water source protection after she watched post-fire debris flows shut down municipal and agricultural water use.

Laura enjoys her role building bridges that connect people to nature, including land and water managers, and urban, rural and traditional cultural communities. She has earned several awards, including New Mexico Environmental Leader of the Year in 2015 and the Yale School of Forestry and Environmental Studies Distinguished Alumna Award in 2017.

I'm Laura McCarthy, and I'm going to cover our new Forest Action Plan for the entire state, and also the Forest and Watershed Restoration Act that was passed in 2019 and implemented in 2020. Our State Forest Action Plan is required by the federal government to enable the state to receive approximately $9 million per year

in federal funding. However, it's also an important tool for us to come together on a multi-agency and multi-stakeholder basis to set goals and objectives for a 10-year period. I won't cover all aspects of the plan, which includes 10 strategies and 192 actions, but I will focus on three strategies that are particularly relevant to watershed restoration. I'm also going to dive into the interactive priority maps that are based on the assessment, and all of this is available at https://nmfap.org.

Figure 1 shows two maps. On the left is the fire risk to communities, with the darkest red indicating the highest level of risk. On the right is a composite map, compiled from all the data in our assessment, that serves as the statewide blueprint for identifying the most important watersheds for us to treat. You can see the little watershed delineations. These are HUC 12 watersheds. You can also see the correlation between the priorities and the fire risk. I also want you to see that we conducted intensive mapping of water. The way we mapped the water was based on whether a watershed supplied water directly to communities, municipalities, mutual domestics, or any kind of agriculture, or provided water to people downstream. That was a different approach to setting priorities, but I think it accurately captured what is important to New Mexico. Then, you can see on our statewide all-priorities map that we've added bosque and riparian restoration (Figure 2).

We have 10 strategies, as I mentioned, and the first one that I want to cover is restoring forests and watersheds. What I would like to draw attention to is strategy 1.1: Conducting appropriate treatments in large-scale priority areas. Small work is good, and small work adds up, but it's essential if we're going to make a difference in terms of watershed restoration that we go big. This means setting priorities and focusing on an area until it's completed and then moving on to the next priority. I also want to draw attention to strategy 1.5: Developing collaborative strategies to promote a dynamic patchwork mosaic of riparian and wetland vegetation and habitat as water availability and community priorities allow. Riparian restoration, I know, is particularly important to many of the attendees here. This is one of the first times we've called this out in the statewide Forest Action Plan.

The second strategy is fire management. I want to focus, in particular, not just on how we respond to fires, but also on our proactive work in prescribed fires. In 2019, House Memorial 42 prompted us, along with a large stakeholder group, to examine the expansion of prescribed fire use in our state. It culminated in a report that was shared at a Water and Natural Resources Interim Committee meeting

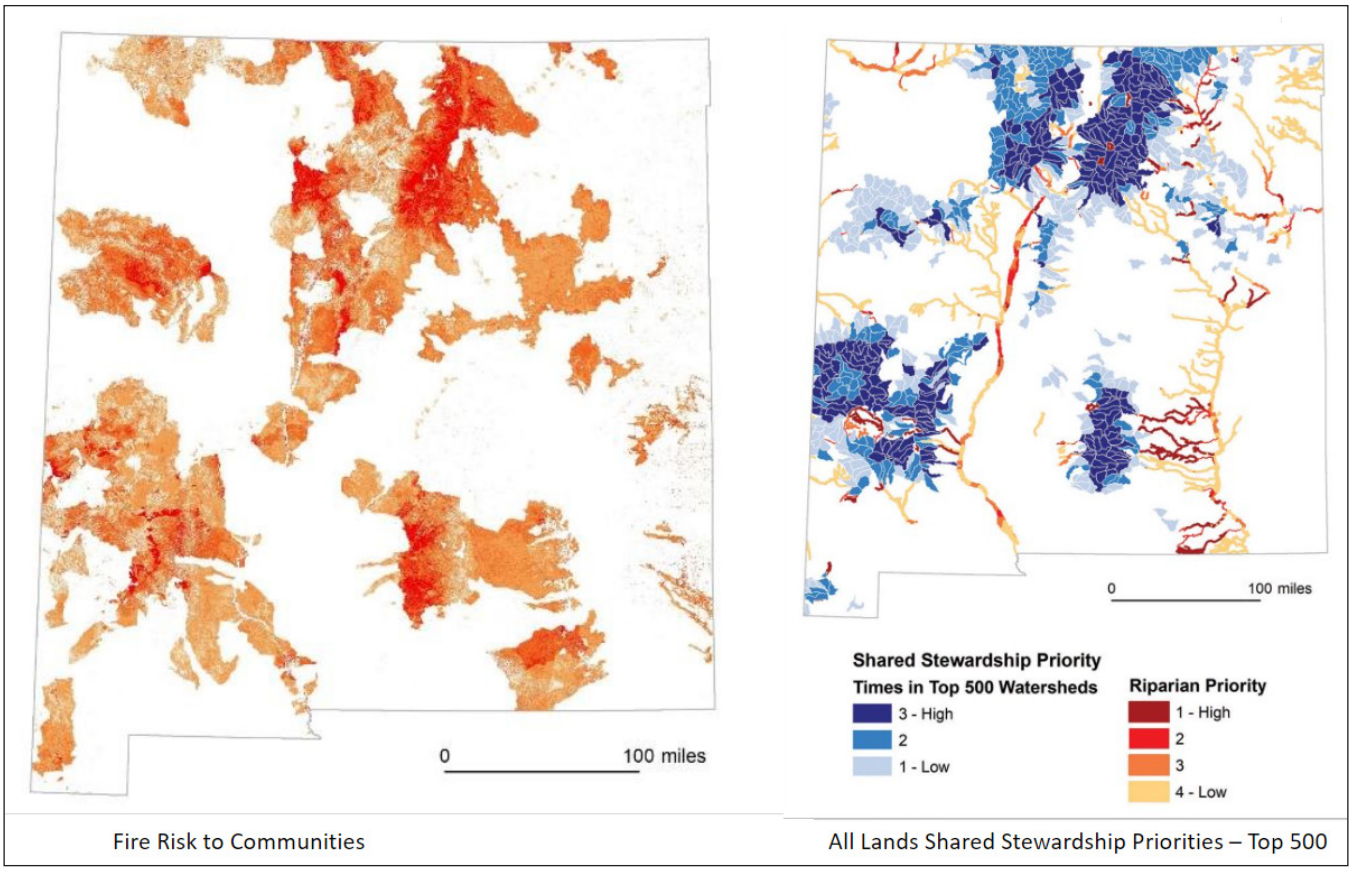


Figure 1. Fire risk and stewardship priorities.

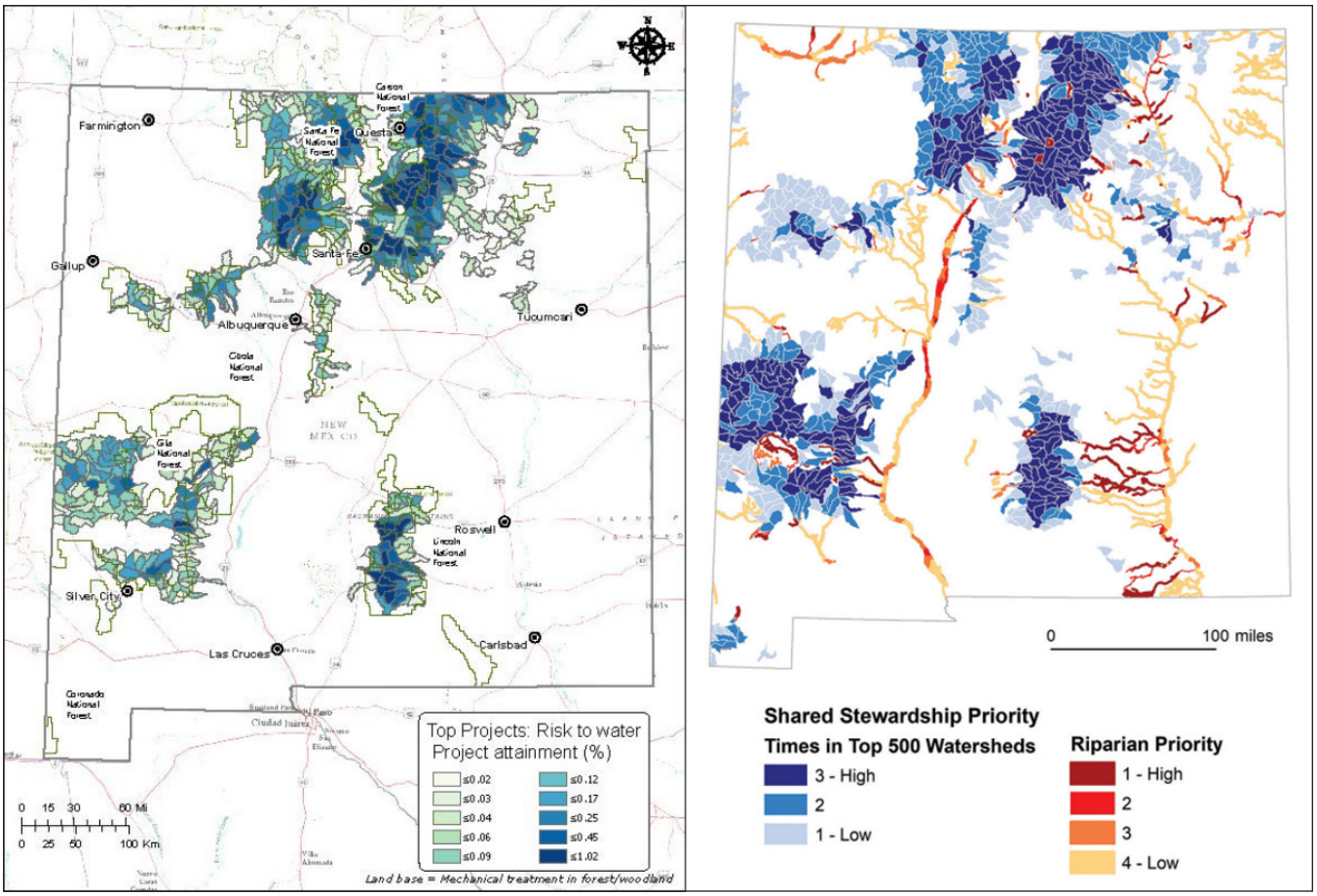


Figure 2. All priorities map.

in July. Now it appears that a prescribed fire act for New Mexico will be introduced, making it more possible for private and state lands to have prescribed fires. It ties to our forest management strategy because prescribed fire enables us to scale up a lot faster.

The third of our 10 strategies that I want to draw attention to is reforestation. We have a large backlog of burned lands that are contributing sediment to downstream water users, degrading water quality, and not properly storing water in headwater areas. Reforestation is very challenging. It's complex, as you can see from these strategies:

- 6.1. Improve and increase seed collection and storage
- 6.2. Expand and improve nursery capacity and seedling production
- 6.3. Improve landscape assessment and site selection to increase seedling survival and tree reproduction
- 6.4. Use demonstration planting projects to advance reforestation strategies
- 6.5. Increase monitoring and utilize adaptive management

We are far away from having the infrastructure and the best practices that we need to reforest burned areas, which are a super-harsh environment now, and make sure not only that the trees survive in that burned environment, but also that they are able to withstand the climate that we expect to have in the year 2100. This reforestation strategy is relatively new and cutting-edge, and it will be a significant challenge. However, I hope that we're successful and that you hear a lot about it in the years to come.

I'll turn now to the Forest and Watershed Restoration Act of 2019. There was a multi-year effort to pass this legislation, and numerous groups and organizations contributed. It is a recurring funding source for forest and watershed restoration, with funding taken from two existing funds commonly used for water infrastructure and derived from the New Mexico Land Grant Permanent Fund. The Act established an advisory committee comprised of six agencies and three public members. That includes the Office of the State Engineer and the Environment Department (among others), and a public member representing a water interest.

It has been an interesting learning experience to determine how this advisory board needs to work together to review and approve projects for watershed restoration

funding. We've completed one cycle and are currently in the process of another. We are funding a wide range of activities, primarily treatments, but the law, as written, can also be used for planning purposes. For example, the upper Rio Chama watershed successfully secured funding for the upper watershed plan. We have an economic development project in Taos County focused on wood utilization, with the goal of accelerating the pace and scale of watershed restoration.

I'm going to end with a call to action. It's really important that people who work in water and people who work in forests have time to communicate with one another. My call to action for anyone who cares about water security is to get involved in planning large-scale forest and watershed restoration projects. We have the funding streams, we have our planning goals, we know where our priority places are, and we need the engagement of all different interests to come up with the best possible projects. This was driven home to me yesterday. Rebecca Roose, who is presenting later today and serves as one of our advisory board members for the Forest and Watershed Restoration Act, sent along a synopsis of a study about the Colorado River's water supply variability by Utah State University. Two findings were particularly relevant. One is that larger wildfires are correlated with low river flows, and the second is that the tight relationship between river water supply and soil conditions is a predictor of wildfires. So, it confirms what we already intuitively knew. It's all interlinked, and we need to focus as much as possible on the water-forest link to ensure resilient water supplies for the future.

Maxwell: That's terrific. I have one question. This is something I've seen addressed in the Rio Grande Water Fund previously, in terms of priority areas for wildfires. If a community wants to become part of the forestry restoration plans, it obviously looks first to the priority areas. Is there another parallel process that one could use to instigate conversations about particular issues? Do you have a means of collecting impacts throughout the state on folks who have, let's say, leases within the forest itself?

McCarthy: There are multiple ways of going about it. I would recommend either engaging with a local Soil and Water Conservation District or our agency, the New Mexico Forestry Division within the Energy, Minerals and Natural Resources Department. We have six district offices. Everybody in the state is in one of our districts. Each of those offices has a district forester who has many responsibilities, but one of them is direct engagement in collaborative groups. Whether you go through the Forestry Division district office or through a Soil and Water Conservation District, they are talking to each other constantly. Two roads lead to the same destination.

Maxwell: Terrific. I have another quick question: How can forestry students get involved? Some of what you said applies to that, but I'm sure there are some specific opportunities for interns.

McCarthy: First of all, we're at a unique point where we have several job opportunities. If you are interested in a forestry job, please check the State Personnel Office website and do a search for the word "forest." A number of jobs will come up. Some of them are entry-level, and we need great people in our agencies. Second, collaboratives are great places to get ideas for projects that you could do as part of your student activity and get credit for, potentially, while contributing to something real in a place important to you. Finally, we hire several seasonal or emergency wildland firefighters. While the season is wrapping up now, thank goodness, it will start again in February or March, which is great intermittent work that is ideal for students.

Maxwell: We have one more question. Our ranch in the Gallinas Canyon has a large spring and creek that runs into the Gallinas River Watershed in Las Vegas, New Mexico. Are you aware of the instream use leases that have recently been established? Is there funding for private landowners to help restore their watershed?

McCarthy: I'm going to address the second part, which is the funding for private landowners, because that is more in our area of expertise. That would be a great reason to contact the District Forester. Of the $9 million in federal funds that come to our agency, $6 million per year is distributed to private landowners. So, if you're not taking advantage of that, you might be missing out. They are also aware of a number of other funding sources, whether they come from the Natural Resources Conservation Service or elsewhere. There is a whole range of options. Talking to the District Forester is like talking with an expert who can help match what you want to do with your land or how you want to contribute to watershed restoration with the right funding source.

Maxwell: Great. Thank you so much, Laura.



Collin Haffey, The Nature Conservancy

Collin Haffey is a forest and watershed health manager with The Nature Conservancy in New Mexico, where he works to support the Rio Grande Water Fund (RGWF). The goal of the RGWF is to restore a natural fire regime to forests, build resilient communities, and provide water for one million people. His other conservation work focuses on forest restoration, reversing post-fire ecological type-conversion, and helping communities prepare for and respond to climate change driven disturbances.

Thanks for the invitation. My name is Collin Haffey, and I've been working with the Nature Conservancy for three years now. I had the pleasure of working with Laura for about 18 months, and I really learned a lot from her. I feel similarly that it's always nice when the forestry and fire folks get involved in water conferences. Every time I'm out in New Mexico enjoying our beautiful waterways, I'm always thinking about the forests that they're connected to and the interplay between watersheds and forests. Forests and watershed health are closely tied to clean, fresh water.

I will provide some background and history. Our forests used to resemble the one in Figure 1, which was kept open by frequent, low-severity fires that have been suppressed to a significant extent over the past 100 years. Now, most of us have grown up in New Mexico with forests that resemble the one in Figure 2, characterized by fewer large trees and a greater abundance of smaller ones. These trees are part of the restoration programs that Laura mentioned. Some of the work we do is removing some of these trees. Because of our successful century of fire exclusion and fire suppression, we've actually built up so much fuel in the system that now our forests are becoming sort of traps, and we're not able to suppress the types of fire that are burning.

The year 2020 was a great example of what happens when, as the saying goes, nature bats last. We've seen massive fires in Colorado, California, Washington, and Oregon. New Mexico was luckily somewhat spared from any catastrophic fires. We felt the effects of the smoke all summer from the fires in neighboring states and across the West, so it really drives home the issue, as Laura discussed. This is a national issue, not just a state or program issue, such as the Water Fund.

As for the science, the tight connection between forests, fire, and water also extends to the connection between forests, fire, and climate. As the climate has continued to warm since the 1980s and those fuels—the trees—have continued to accumulate, we've seen an almost eightfold increase in high-severity fires. High-severity fires are tree-killing fires, the kind that often devastate our watersheds. We've seen this increase in just the past 30 years or so, across the entire West. We've seen this locally as well. Figure 3 shows the Jemez Mountains with Bandelier National Monument outlined, and the Rio Grande running along the right side of the image, highlighting the high-severity fires, also known as tree-killing fires, that occurred from the 1970s to the 2010s. We've seen this increase in both regional and local patterns.



Figure 1. Healthy forest.



Figure 2. Unhealthy forest marked by many small trees.

If we examine the Las Conchas Fire of 2011, we can see that the high-severity fire devastated entire watersheds, from the top of the mountain to the Rio Grande discharge,

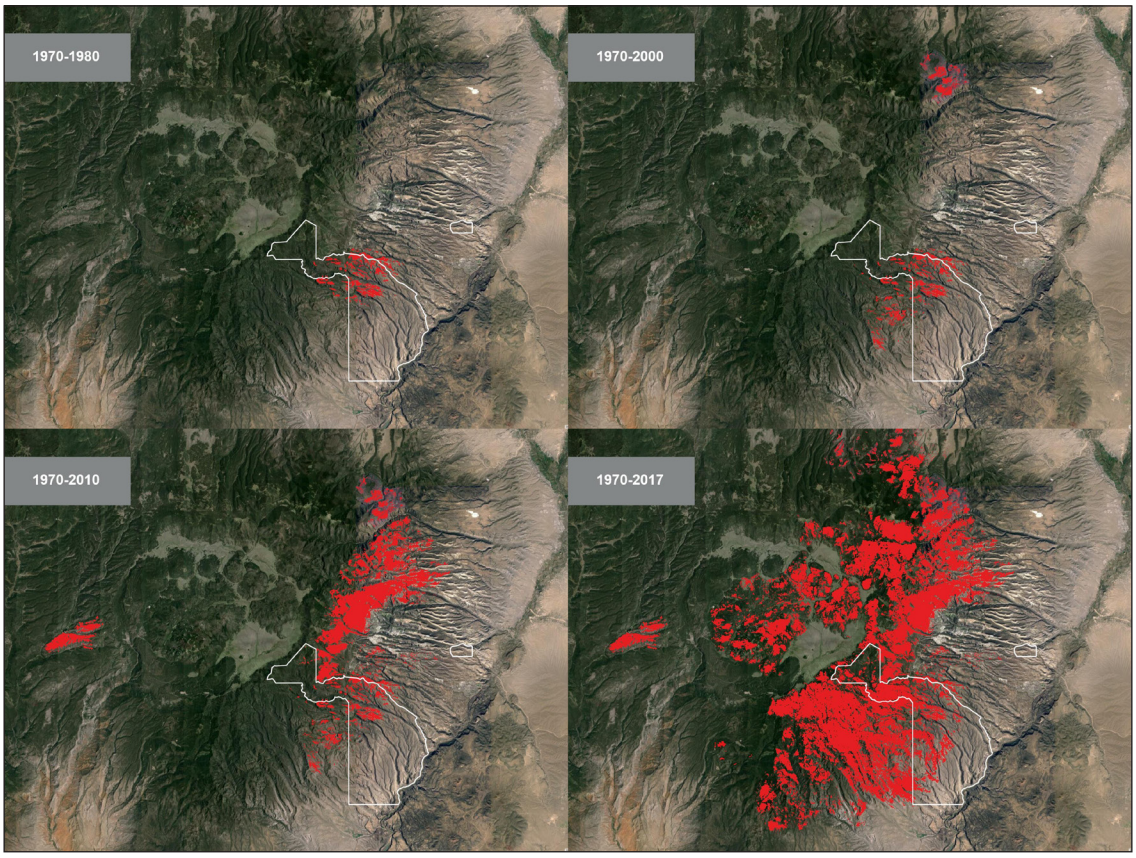


Figure 3. High-severity fires in the Jemez Mountains, 1970-2017.

resulting in significant postfire flooding and degraded water quality.

So, what's the solution? Because of this tight connection between forest, fire, and water, the solution isn't all that complicated. We need more good fires and fewer bad fires. Therefore, we need more of the rejuvenating fire that recycles nutrients and supports the growth of large, tall trees. We need less of the fire that kills trees, devastates watersheds, and causes flooding.

The question is, how do we do that? We achieve this in several ways, including the use of mechanical treatments similar to the techniques outlined in the Forest Action Plan that Laura described. We've employed those tactics across the landscape, and we've seen success. Here's just one anecdote out of the Santa Fe National Forest, the Venado Fire of 2018 (Figure 4). The area in black is untreated, meaning it has not undergone any forest restoration work. The yellow areas are those that haven't been burned yet. The blue area shows where the high-severity fire made a crown-fire run, and it stopped in its tracks once it hit the treated area where the forest had been restored. This demonstrates to me the real importance of ensuring that fire is reintroduced into our forests in a healthy manner. It demonstrates the difference between good and bad fires and their effects.

One way to accelerate forest restoration on the ground is to explore different funding options. Laura outlined one in the Forest and Watershed Restoration Act. I'm going to talk about two more examples from the Rio Grande watershed. One is an early pilot project of the Santa Fe municipal watershed, where funds from water users were used to pay for forest restoration within the municipal watershed. Through Laura's leadership, the Nature Conservancy, and our programs worldwide, we expanded that model to include the entire Rio Grande upper basin, providing water for a million people in downstream communities, including both rural and urban areas such as Albuquerque. Along the way, this clean water is feeding acequias and small farms, as well as the middle Rio Grande agricultural district. So, it is incredibly important work, and that connection is really strong. We've been able to use the funding from some of our downstream water users, particularly the Albuquerque Bernalillo County Water Utility Authority in the Middle Rio Grande Conservancy District, to fund some forest restoration in critical basins of the upper Rio Grande.

All of our processes are science-based. Similar to the Forest Action Plan, early in the Water Fund days, we developed a strategy for identifying key basins where we wanted to conduct restoration work. Then, just as

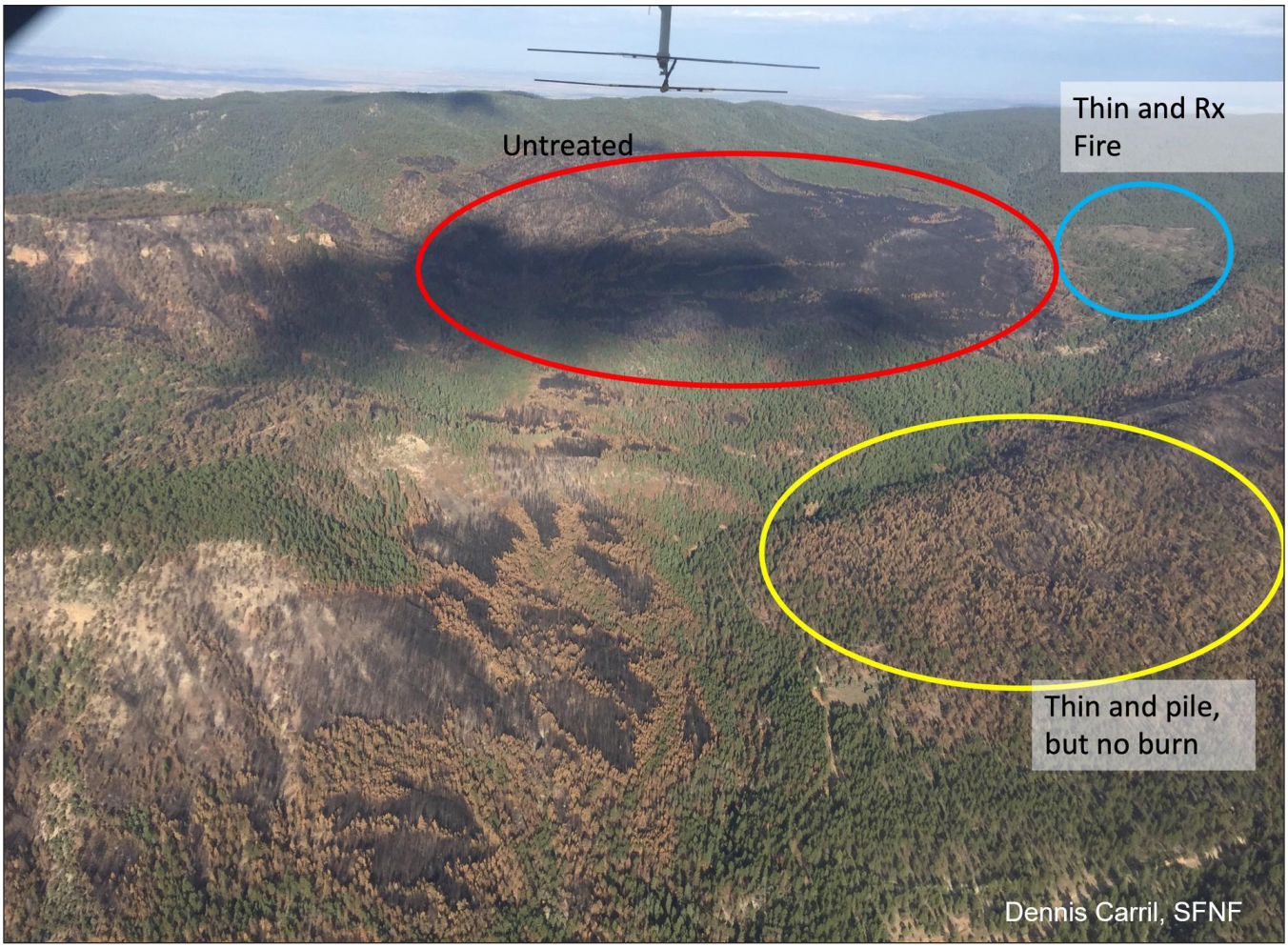


Figure 4. Comparison of treated and untreated forest, Venado Fire of 2018 (Photo by Dennis Carril, Santa Fe National Forest).

Laura described, we've updated those alongside the new Forest Action Plan. Again, we are looking at these high-priority basins within the Rio Grande, focusing on larger geography.

We're six years into the Water Fund. To date, we've directly supported 40 different projects, including collaborative work that spans from conception to implementation, from ideas to the ground. Some of our collaborative groups include the 2-3-2 Partnership, Chama Peak Land Alliance, Greater Santa Fe Fireshed Coalition, Jemez Mountains Firewise Group, Sandia Collaborative, Southwest Jemez Mountains Collaborative Forest Landscape Program, and Taos Valley Watershed Coalition. Those are what make the world work. We're connected with multiple partners and take pride in this. We have 90 signatories we're working with, which include state agencies, federal agencies, tribes, non-governmental organizations, and businesses. Our partners span the gamut, and again, we're working at multiple scales. Someone asked earlier, "How do you get involved?" We have multiple pathways through the Water Fund to engage, whether you want to participate at the highest level or delve into the weeds at a local collaborative. We have opportunities for people to participate.

To summarize some of the successes since the launch—and we wouldn't have achieved any of this without partnership—we have treated 140,000 acres. We're reaching a critical point in our restoration activities, where, because they're strategically placed, focused, and collaborative, they hold people accountable; we're able to increase the pace and achieve a scale that approaches or matches the scale of the disturbances and challenges we're facing. We have treated 140,000 acres, but we have almost twice that in the planning pipeline, so more acres to come. That will allow for quick investment of state, federal, or private money to go right into on-the-ground restoration. All the time we're doing this, we're creating jobs, and we're supporting the local economy. As we enter into the economic uncertainties of the next year, the restoration economy in New Mexico has an opportunity to play a critical role.

In my opinion, the greatest nexus between water, forests, and fire is beer. For the second year in a row, our neighbors at Second Street Brewery in Santa Fe have been kind enough to brew a beer that supports forest restoration. If you're out in Santa Fe or at a Whole Foods around the state, I think you can still pick up some OktoberForest. It's a great way to support a local business and show your support for forest restoration. We don't receive any compensation for this, but it's a valuable outreach opportunity for us.

For those interested, you can sign up and join our mailing list by visiting http://riograndewaterfund.org. We hold an annual signatories meeting, and then we conduct periodic meetings throughout the year. With that, I will open it up to any questions.

Maxwell: Thank you so much, Collin. I'll kick it off with a question for you. I know I've heard Laura speak in the past about the evolution of mechanisms to make these collaboratives function from a financial perspective. I recall that the initial Santa Fe initiative employed a tax mechanism to raise funds, whereas the Rio Grande Project has utilized a charitable mechanism. I was wondering if you had any thoughts about that. There are various ways that ecosystem service payment ideas work (e.g., some people trade, while others receive incentives). I was wondering if you have had any insights over the past little while.

Haffey: Right now, the Rio Grande Water Fund is completely voluntary, and so there's no discussion about trying to put a bond or tax together. We utilize discretionary funds from the water authority and conservancy districts, as well as funding from our other partners, including federal agencies and foundations, which may be used for either general operations of the water fund or specific projects. We've used that model pretty successfully. As we start to look toward the future, one of the biggest limiting factors is matching funds for federal grants. What I hope we can do is find a way to encourage non-federal contributions to the Water Fund that can be tied to federal funds, which we can then leverage, depending on the funding source, at a ratio of five to one or one to one. Providing a one-to-one match is crucial to attracting federal dollars into the state. Matching increases our selling points. We can say that your dollar goes further, that you're able to contribute more, that we turn your $1 into at least $2, if not $5. We hope to tap into the wealth of knowledge of our district foresters at the state forestry office, as we work with them, to explore other funding sources. So, part of what we do is matchmaking between funds for a project.

Maxwell: Terrific. Collin, thank you so much.



Zach Libbin, Elephant Butte Irrigation District

Zach Libbin is a dedicated District Engineer at the Elephant Butte Irrigation District (EBID) in New Mexico. With extensive experience in water resource management and engineering, Zach plays a pivotal role in overseeing the district's irrigation infrastructure and ensuring efficient water delivery to agricultural lands. His work focuses on maintaining and improving the canal systems, addressing water distribution challenges, and implementing sustainable irrigation practices. Zach is also actively involved in community outreach, educating farmers and residents about water conservation and efficient irrigation techniques.

Zach holds a Master's degree in Civil Engineering from New Mexico State University, where he specialized in water resources engineering. Before joining EBID, he worked as a Junior Engineer and later as a Principal Engineer at Libbin Consulting Engineering. His career is marked by a commitment to innovative engineering solutions and collaborative efforts to enhance water management in the region. Zach has also served as the Chairman of the South Central Stormwater Management Coalition, where he led initiatives to improve stormwater management and reduce flood risks.

Good afternoon. As Connie said, my name is Zach Libbin. I'm the District Engineer for the Elephant Butte Irrigation District (EBID). I'm also the co-chair of the South-Central New Mexico Stormwater Management Coalition (Stormwater Coalition), and I'm also the chair of the steering committee for the New Mexico Watershed and Dam Owners Coalition. I'm stepping in for John Gwynne today, who had an emergency. John is the chair of the Stormwater Coalition. Today I'll be speaking specifically from the view of the Stormwater Coalition, and I'll try not to let John down. I would also like to thank Connie for the beautiful graphics in this slideshow.

The Stormwater Coalition was officially formed by a joint powers' agreement. Work was done long in advance of that, albeit under a somewhat different name. The coalition was formalized in 2011, with a joint powers' agreement between the Doña Ana County Flood Commission, the Village of Hatch, EBID, the Doña Ana Soil and Water Conservation District, Caballo Soil and Water Conservation District, Sierra Soil and Water Conservation District, Sierra County Flood Commission, and the City of Anthony. It came from the recognition that stormwater—any water, but specifically stormwater—doesn't respect political boundaries. It became apparent that we needed a regional watershed management approach. Flooding is a somewhat obvious part of stormwater; erosion is harder to see. The goal of the Stormwater Coalition was to plan and manage all these efforts, focusing on watersheds on a more regional level. John Gwynne says, "We have changed our philosophy from trying to capture and hold stormwater to trying to slow it down in the watersheds and infiltrate it where we can." As I mentioned, erosion is often difficult to detect, and managing sediment and silt can be equally challenging. It is definitely a significant problem for EBID, the Flood Commission, and the International Boundary and Water Commission (IBWC). For example, the Flood Commission can spend significant money to address sediment that has accumulated at a flood control dam, in order to restore some of the dam's capacity, only to see it fill up again in the next couple of years, as sediment is an ongoing issue. These stormwater issues can also be an opportunity. In times of drought and severely limited supply, stormwater also presents an opportunity to capture a portion of our water supply, from the perspective of the EBID and the aquifer, encompassing the entire water system.

So, the Stormwater Coalition began by addressing primarily communication and collaboration, working to define goals and discuss regional flood control and broader regional issues. That's still our primary focus, but we've moved on to trying to implement some projects as well. The largest one is the Rincon Arroyo Watershed, which we have selected as a priority project, and one I will elaborate on further. We could have started with a much smaller watershed, but the Rincon Arroyo Watershed is significant for several reasons, including its sediment. The Rincon Arroyo brings an incredible amount of sediment into the river, which is one of the reasons EBID likes to focus on it, as the IBWC struggles to maintain the amount of sediment that comes into the river. Our strategy encompasses upper watershed restoration, extending all the way down to the valley, where the agroecology approach includes stormwater harvesting, sediment capture, and aquifer recharge (Figure 1). We are trying to slow down the water in the watershed and allow it to infiltrate.

The largest project we are attempting to move forward

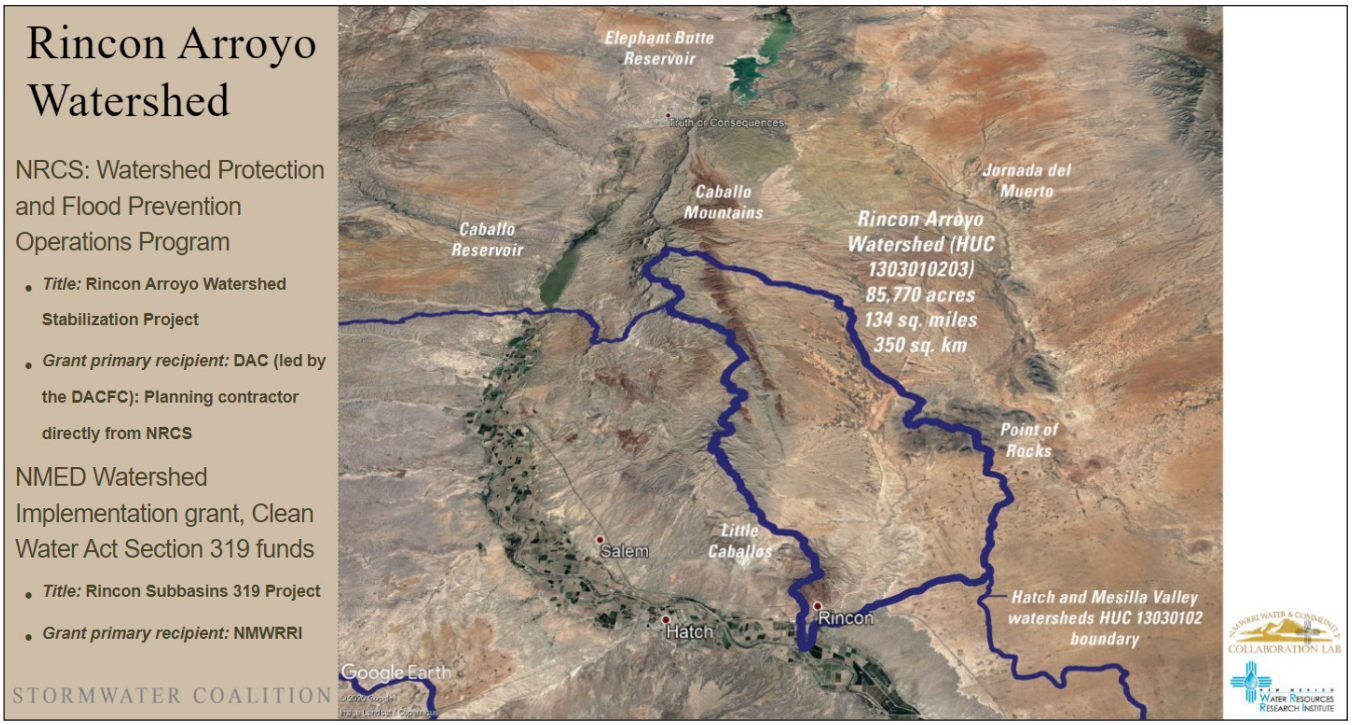


Figure 1. Rincon Arroyo Watershed strategies.

for the Rincon Arroyo is a Watershed Protection and Flood Prevention Operations Program (Watersheds Program) with the Natural Resources Conservation Service (NRCS). There is considerable potential for a watershed-scale approach. The primary recipient is Doña Ana County, led by the Doña Ana County Flood Commission. The NRCS has started contracting for a planning effort to determine possibilities for working on that watershed and implementing some of these efforts that we're talking about here. This is the larger funding opportunity, and planning has been funded so far. The NRCS's programs take a long time, as the wheels of progress turn slowly. We must be patient with some of those.

In the meantime, the NM WRRI received an NM Environment Department Watershed Implementation Grant through their 319 Clean Water Act funds. This is a smaller project, not a pilot. Instead, it's a smaller implementation project that we can learn from; it will help us learn how we can implement our projects on a broader scale.

So, within all these watersheds, and similarly with the watersheds that Laura and Collin were discussing, storm runoff can have huge energy, and this high energy turns into not only damaging flows but also erosion and sediment yield. As shown in Figure 2, when we're talking about 14,000 cfs for a 25-year storm, that is a huge amount of water, and it has damaging effects. This becomes the largest contributing sediment yield in the Hatch and Mesilla Valleys. A study conducted by Tetra Tech, as part of an IBWC initiative, estimated an annual sediment yield of 36.2 acre-feet per year. Considering that the IBWC has not performed maintenance for roughly 20 years, the number of cubic yards of material that needs to be moved just to keep up with the annual yield makes it a challenge to even consider catching up. It's an incredible amount of sediment, and the best way we can deal with it is to try to keep it within the watershed.

This is, of course, somewhat different from the forest and upper watershed issues, but in general, we end up with similar issues and attempt to implement similar techniques, employing softer engineering approaches to slow down and spread out the water. When I'm talking about implementing the project on the Rincon Arroyo Watershed, as an example, we're looking at many small-scale flood control measures. That's tricky and hard to explain to

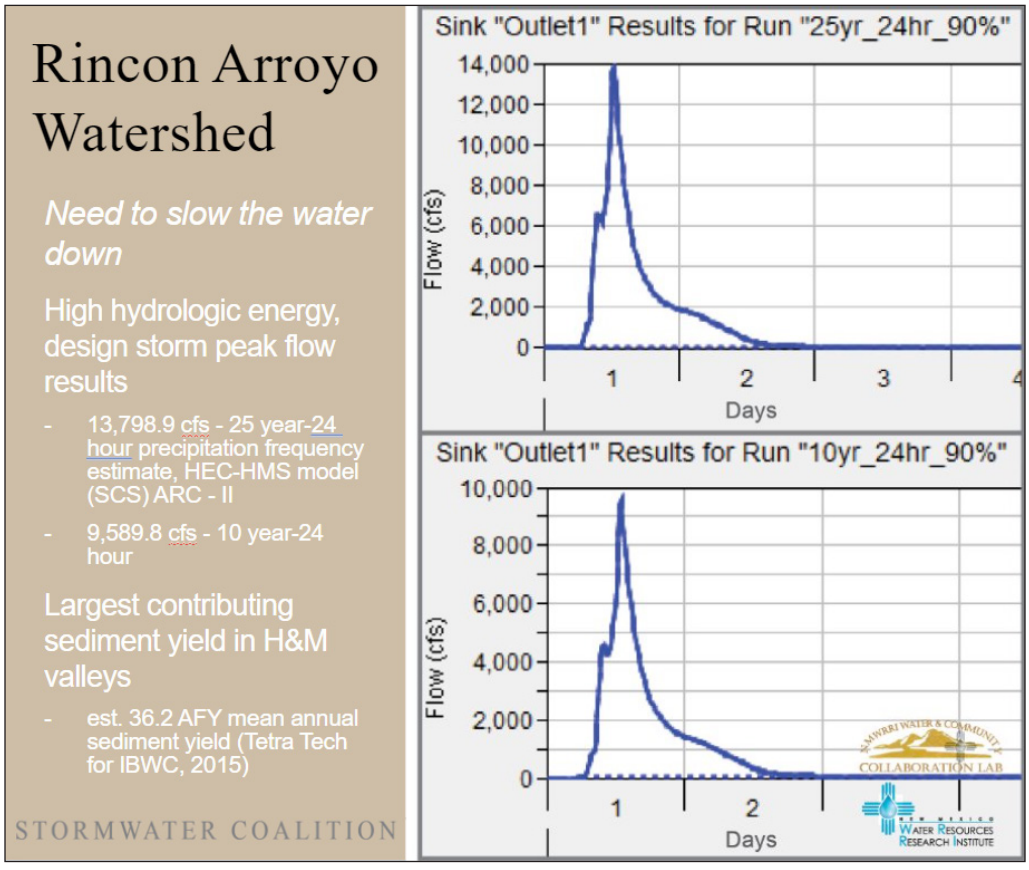


Figure 2. Storm peak flow and sediment yield in the Rincon Arroyo Watershed.

NRCS, for example. They're mostly thinking about dams, and we're talking about hundreds of smaller measures to control that sediment, such as log jams, riparian buffers, berms, swales, terraces, and retention ponds.

We have applied for and received a couple of funding opportunities. The first is the Cooperative Watershed Management Program, which examines a larger area and specifically supports the Stormwater Coalition as the applicant, with the Jornada RC&D serving as a fiscal agent. The idea here is that the Bureau of Reclamation is supporting the Stormwater Coalition and getting the ball rolling on larger efforts and becoming a bit more organized. The next one is a Drought Response Program funded by the Bureau of Reclamation with EBID as the primary recipient.

The largest issue we face is the degradation of our upper watersheds. The erosion and sediment transport are incredible. When you see pictures of 20-foot cliffs that have eroded, it is no surprise where the sediment in the river is coming from. Connie has worked on watershed analysis and lessons from the Rincon Arroyo. The idea is to apply our learning from the Rincon Arroyo to other watersheds in the Hatch and Mesilla Valleys. We also want to expand the early warning system and then develop lower watershed infrastructure to capture that sediment. We're trying to address water supply issues from those larger storms.

Early warning is an effort that the Doña Ana County Flood Commission and EBID are both taking, which involves installing rain gauges and weather stations across the entire valley and watersheds to get a handle on these storms when they come in, be better prepared for flood control, and improve our data and our science for these erosion control efforts.

Certainly, no one here is surprised to hear that we are in an ongoing and persistent drought. These efforts by the Stormwater Coalition can also help us increase our water supply and improve our resiliency to drought. We are developing opportunities and projects to address some of these issues, potentially without the need for lawyers and without being overly dependent on judges. In supporting Laura's call to action, we can also include our local lower Rio Grande watersheds here, too. No one is surprised to hear that El Paso and Las Cruces are both growing, with El Paso growing toward Las Cruces, and that we have an over-appropriated water supply. We need to face these water issues.

We also have a need for coordinated watershed planning in the Organ Mountains-Desert Peaks National Monument. Some of us had concerns about the monument and wilderness designations within our watersheds, but now we need to find approaches that allow us to work within these designations while still implementing some of these efforts.

I've also already mentioned the watershed-scale stormwater capture efforts of the Stormwater Coalition with EBID as the primary sponsor. A part of that is a design-decision support tool being put together by NM WRRI.

To wrap up, the Stormwater Coalition is a regional effort to try and address these more local issues. Our call to action remains the same—specifically, raising awareness about watersheds, both the forested upper watersheds that Laura and Collin discussed and these watersheds, more local to southern New Mexico, which have faced desert conditions and still require attention. So, with that, I will stand by for any questions, but I know we're out of time, Connie.

Maxwell: We are. Thank you, Zach. I think you can see there are quite a lot of issues down in our area. There are numerous initiatives underway for watershed restoration in New Mexico, but there is still a long way to go. Thank you, everybody, very much.

Produced Water Research in New Mexico

Editor's Note: The following papers represent a transcription of the speakers' remarks made at the conference; no follow-up papers were submitted by the speakers. Remarks were edited for publication by the editor. The speakers did not review this version of their presentation, and the editor is responsible for any transcription and editing errors.



Moderated by Robert Sabie, NM WRRI Researcher

Robert Sabie Jr. is a research scientist at the New Mexico Water Resources Research Institute. Sabie's research focuses on applying geographic analyses to address water issues in New Mexico and other arid landscapes. His particular interests include using aerial and satellite remote sensing for land-cover mapping and measuring evapotranspiration, produced water decision modeling, and participatory research. He holds a BA in environmental policy and planning from Western Washington University and a master's degree in applied geography from New Mexico State University (NMSU). He is currently working toward completing his PhD in the Water Science and Management program at NMSU.

Our last session of the conference is this session on produced water research in New Mexico. This session will be broken down into two different parts. The first part will describe the New Mexico Universities Produced Water Synthesis Project, and the second part will outline the New Mexico Produced Water Research Consortium. I am going to ask each panelist to describe their specific research project.

Before we begin the individual talks, I will provide an overview to ensure everyone is on the same page. What is produced water? In New Mexico, it is defined as "a fluid that is an incidental byproduct from drilling for or the production of oil and gas." The emphasis here is that it is a fluid and not water. I think there are legal issues regarding whether it's defined as a fluid or water, and Stephanie will talk about that in the next presentation. It's naturally occurring, high-salinity water recovered during oil and gas production, and it may also include fluids that were used during drilling, such as hydraulic fracturing fluids.

This is important in New Mexico because, since 2011, oil production, in particular in the Permian Basin in the southeastern part of the state, has been increasing exponentially. For context, New Mexico is the third-largest oil-producing state in the United States, and Lea and Eddy Counties, located in the southeastern corner of the state, are two of the top oil and gas-producing counties in the Country. When water in the geologic formations, combined with oil and gas, is brought up, there's a water-to-oil ratio produced, ranging anywhere from 3:1 to 13:1. If you bring up one barrel of oil, the oil and gas companies sometimes have 13 barrels of water that accompanies that water that they have to manage. In New Mexico in 2019, according to the Oil Conservation Division, 163,137 acre-feet of produced water was generated. If you think about things in gallons, that was about 53 billion gallons of produced water. Of course, this water is high in total dissolved solids (TDS), and high in salinity, ranging on the low end of around 1,000 mg/L up to more than 400,000 mg/L. For context, seawater typically ranges between 30,000 and 35,000 mg/L, indicating a significant amount of dissolved solids in the produced water.

Where is this water disposed of after they bring it up? A lot of it is injected into underground saltwater disposal wells, or it is injected for enhanced oil recovery. Now, the industry is trying to find ways to treat and reuse water. Evaporation ponds and offsite commercial disposal, discharge, and beneficial reuse are also options, but those are less common in New Mexico right now. I think Mike Hightower and Rebecca Roose will talk about those issues in a little bit with their consortium work.

Of course, this topic isn't new in New Mexico. Here is a list of some of the collaborative projects that have happened over the past 17 years:

- 2003: New Mexico Forum on Reclaiming Produced/Brackish Water for Beneficial Uses
- 2004: NRCE report, *Water in the Desert: Engineering/Legal/Logistical Study to Implement the Conversion of Oil and Gas Produced Water to Useable Water in Lea and Eddy Counties, New Mexico*
- 2007: Brackish Groundwater National Desalination Research Facility opened
- 2016: NM WRRI collaborates with New Mexico Tech, New Mexico State University, and Los Alamos National Lab on New Mexico Environment Department–funded project focused on produced water in Lea and Eddy Counties

This list is not exhaustive. There have been numerous individual research projects over the past couple of decades on this topic, but this list highlights some of the ongoing collaborative projects. In 2019, there were two parallel efforts that started: the New Mexico Universities Produced Water Synthesis Project, and the New Mexico Produced Water Research Consortium.

There are two primary questions we aim to answer. Of course, there are a lot of different caveats to each of these, but the New Mexico Universities Produced Water Synthesis Project is trying to assess the impacts of produced water management decisions on New Mexico's water budget. The research consortium is examining how treated produced water can be safely utilized as an alternative water source outside of the oil and gas industry. I think that's enough background information to hand it off to Stephanie, and we can get into the nuts and bolts of these two different research projects.

Part A: New Mexico Universities Produced Water Synthesis Project



Stephanie Russo Baca, Utton Transboundary Resources Center

Stephanie Russo Baca is currently the staff attorney and Ombudsman Program Director at the Utton Transboundary Resources Center, located at The University of New Mexico (UNM) in Albuquerque, New Mexico. In both these roles, Russo Baca's mission is to support and represent constituents in a fair and unbiased manner. She guides the activities of the Joe M. Stell Ombudsman Program, a statewide program that provides impartial adjudication information and procedural guidance to unrepresented water right claimants in New Mexico. Russo Baca contributes significantly to the Utton Center's overall mission of providing objective, research-based public service to New Mexico's communities on issues related to energy, climate change, ecological conservation, food systems, and international natural resource management. She holds both an Indian Law certificate, and a Natural Resources and Environmental Law certificate from the UNM School of Law.

As an introduction, I will provide a brief regulatory overview of the work conducted by my two research assistants and me, which involved analyzing the relationship between the current regulatory legal framework and the Produced Water Act. Sarah McLain has joined me today, and she'll be available for any questions at the end.

I'll start with an overview of the produced water numbers. Figure 1, using data from the Oil Conservation Division (OCD), shows that in 2019, we had over 163,000 acre-feet of produced water, which is about 53 billion gallons of water. To give you an idea of how much produced water that is, the total maximum storage of El Vado Reservoir is about 180,000 acre-feet.

Figure 2 is the current state regulatory framework. We know that the Oil and Gas Act established the OCD, which is the primary regulatory body overseeing the use or disposal of produced water in the oil and gas industry. OCD is a division of the Energy, Mineral and Natural Resources Department (EMNRD) that regulates oil and gas activity in the State of New Mexico. The Oil Conservation Commission (OCC) has concurrent jurisdiction authority with the OCD to the extent necessary for the commission to perform its duties as required by law. We also have NMED, the New Mexico Environment Department, which is the agency tasked with protecting New Mexico's environment, resources, and public health and safety. The New Mexico Water Quality Act established the Water Quality Control Commission (WQCC), which adopts water quality standards and assigns responsibility for administering its regulations to constituent agencies, like OCD and NMED. We also have the Office of the State Engineer, which, of course, has authority over the supervision, measurement, appropriation, and distribution of all surface water and groundwater in New Mexico. I wanted to provide you with this brief overview because I will be discussing the changes introduced by the Produced Water Act for these entities.

1 bbl = 42 U.S. gal,
1 AF = 325,851 U.S. gal

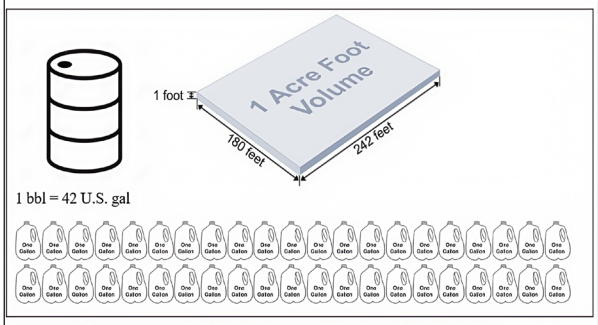


Figure 4: One Barrel of Oil Equals 42 U.S. Gallons. One AF Equals to 325,851 U.S. Gallons.

Produced Water in NM

Year	Total Gas Reported in MCF	Total Oil Reported in bbls	Total Produced Water Reported in bbls	Total Produced Water In AF
2015	1,275,099,499	148,095,382	9,053,669,58	116,695
2016	1,264,376,132	14,663,4156	856,032,243	110,336
2017	1,305,848,826	172,406,971	888,895,075	114,572
2018	1,510,728,077	248,868,022	1,047,829,177	135,058
2019	1,820,965,260	331,461,078	1,265,677,874	163,137
2020 Jan - Aug	1,132,123,248	206,021,263	676,442,153	87,188

Figure 5: New Mexico Oil Conservation Division Natural Gas and Oil Production from 2015 until 2020.
Source: OCD data
https://wwwapps.emnrd.state.nm.us/ocd/ocdpermitting//Reporting/Production/ExpandedProductionInjectionSummaryReport.aspx

Figure 1. Produced water in New Mexico by the numbers.

- EPA
  - CWA
  - NPEDS
  - SDWA
  - UICP

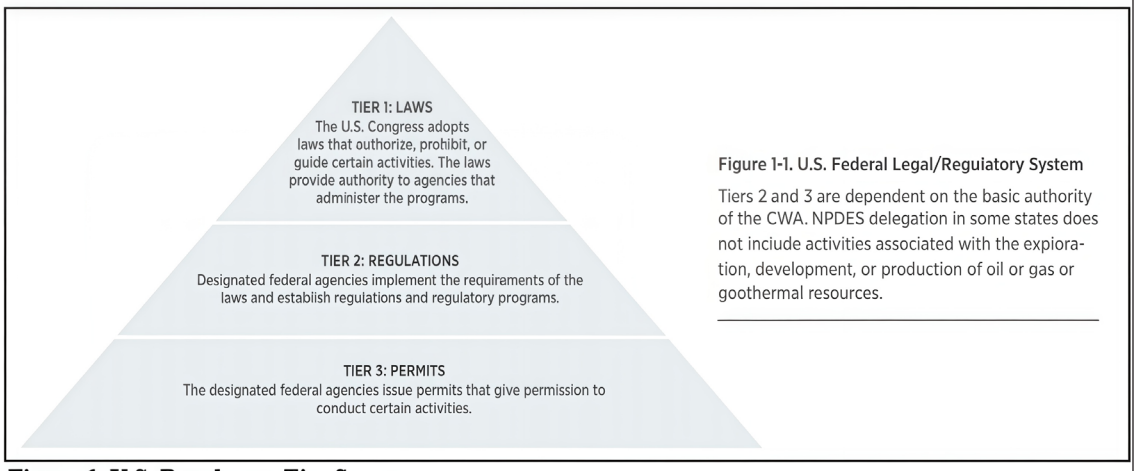


Figure 6: U.S. Regulatory Tier System
Source: Produced Water Report: Regulations, Current Practices, and Research Needs
www.gwpc.org/sites/default/files/files/Module%201.pdf.

Figure 2. Federal regulatory framework.

In addition to the state regulatory framework, there is the federal regulatory framework. There are three tiers, as you can see in Figure 2. Federal law is the first tier. We know that the federal Water Pollution Control Act, also known as the Clean Water Act, established the National Pollutant Discharge Elimination System, or NPDES permits that we might be more familiar with, and that it regulates the discharge of wastewater to water bodies that are considered waters of the United States. We just heard about that earlier today in previous presentations. Tier 2 is agency regulations. The Environmental Protection Agency (EPA) is the agency that establishes comprehensive rules for implementing the NPDES program. We know that some states issue NPDES permits themselves, but here in New Mexico, the EPA issues them directly. Although, of course, based on Shelly Lemon's earlier presentation, that might be changing. So, stay tuned.

I'm going to talk about the underground injection control (UIC) primacy program. New Mexico has primacy for well Classes I–V. One caveat is that EPA directly implements Class II programs for all tribes, except for the Navajo Nation and the Fort Peck Tribes. Ninety percent of produced water generated in the United States is injected into underground geological formations through injection wells permitted under UIC Class II programs. The federal Class II program is delegated to OCD, and then WQCC handles Classes I, III, IV, and V, although there are some caveats, which I'd be happy to explain further. The key point is that the UIC primacy program is regulated by the state through OCD and WQCC.

I'm going to delve into the key provisions of the Produced Water Act, as well as the analysis we conducted on the statute before its passage and the changes that have occurred since its enactment. The Produced Water Act clarified the roles and regulatory authorities of New Mexico state agencies. It went partially into effect on July 1, 2019, and then fully into effect on January 1, 2020. So, as Bob mentioned, produced water now has a clear definition. It is an "incidental byproduct from drilling for or the production of oil and gas." There is also a difference between treated produced water (water reconditioned by mechanical or chemical processes into a reusable form) and recycled produced water (water reconditioned by a recycling facility permitted by the OCD).

One question a lot of people had was, "Is there going to be a new water right established through produced water?" The answer is no. The Office of the State Engineer does not require a permit for the use of produced water. It's considered a "disposition by use," not a "beneficial use." It doesn't create a new category of water right that is perfected when water is treated, recycled, or reused. That was made very, very clear.

Also, a key provision of the Produced Water Act is that OCD regulates produced water within the oil and gas field. OCD now also has the authority to assess civil penalties, up to $2,500 per day for noncompliance with each violation, up to $10,000 a day, with a cap of $200,000. That doesn't mean that a court in the appropriate jurisdiction cannot issue penalties if they are accrued over $200,000. If there is a violation that harms an individual, such as a private party, that individual can also file a separate suit. There's nothing in the Produced Water Act that prevents that.

Additionally, many individuals are researching the specific amendments to the Oil and Gas Act (NMAC 19.15.16.21) through the Produced Water Act, which requires new disclosure and reporting of water use types in the completion of fracking a well. There are now very clear rules on how it's broken down for different types of water. So, whether you're reusing produced water, using saline water, or fresh water, you must now disclose not only the exact location of that water but also its type.

The Produced Water Act also encouraged the reuse of produced water within oil and gas operations. Now, any contract between two producers or a midstream company, for example, is against public policy and void if it requires freshwater resources when recycled, treated, or produced water is available to be used. It does not mean that they can't use fresh water, but the contract can't require it anymore if recycled, treated, or produced water is available and can be used.

There is one more thing that happened just this last month: the OCC had a hearing on October 15, 2020, where they agreed to set a hearing date for a proposed rule that would make the spilling of produced water illegal. This was in response to a petition by the WildEarth Guardians. You can look on OCC's website for more information: https://www.emnrd.nm.gov/wp-content/uploads/sites/6/October15Minutes.pdf.

Let's get into how treated produced water may potentially be used outside of the oil and gas industry. The WQCC is tasked with adopting water quality standards. Remember, though, from the previous slides that they still have to delegate authority when making a regulation or adopting a standard. WQCC is going to be adopting these standards, and then NMED has the authority to issue permits for the use of treated produced water outside of oil and gas. Before this ever happens, these standards for treated produced water outside of the oil and gas industry are being developed through a two-phase process that NMED is leading. I will let Director Roose explain this further, but I want to give you a brief overview.

The first phase involved public engagement by NMED, EMNRD, and the Office of the State Engineer. They held five public meetings all over the state between October and November 2019. The second part of the first phase is the Produced Water Research Consortium. On September 9, 2019, NMED and New Mexico State University agreed to identify and fill science and technology gaps associated with the use of treated produced water. This agreement created the Produced Water Research Consortium, which is led by NMSU. The second phase of the implementation process will involve developing the science-based standards, followed by formal rulemaking. Formal rulemaking includes drafting regulations that will then be submitted to WQCC. There'll be public comment and a hearing. It is my understanding that no date has been set for when the draft regulations will be submitted, but I'll let Director Roose address that. That's all I have. Sarah McLain and I will stick around to answer any questions once the other presenters are done. Thank you.



Martha Cather, Petroleum Recovery Research Center, New Mexico Tech

Martha Cather is a Senior Scientist and Section Head at the Petroleum Recovery Research Center (PRRC) at New Mexico Tech. She holds a BS and MA in Geology from the University of Texas in Austin. Since joining PRRC in 1988, she has specialized in petroleum data access, geographic information systems, reservoir characterization, and public outreach.

In her role, Martha has led various projects, including the Small Producer Program for the Research Partnership to Secure Energy for America (RPSEA) and the Southwest Regional Partnership of Carbon Sequestration. She has also been involved in the Carbon Utilization and Storage Partnership (CUSP) for the Western USA and the San Juan Basin CarbonSAFE Phase III, Project 1. Martha's work has significantly contributed to the fields of reservoir characterization and carbon sequestration, making her a key figure in the industry.

I am going to discuss the New Mexico produced water database that I have been compiling as part of the New Mexico Universities Produced Water Synthesis Project. First of all, I wanted to talk about the challenge and why anyone would care about a database of produced water. The biggest issue is that we cannot discuss using or managing produced water effectively if we don't know much about it. 'Produced water' is a broad term that encompasses a wide range of aspects. There are three types of water sources: water produced from wells, water that comes in from outside the system and is injected into wells (although this is not as common as it used to be), and water that is recycled through wells as part of pressure maintenance or enhanced oil recovery systems.

If you're going to use water, it's essential to know its origin and location. Where is it coming from, not just from what area but also from what formation? What is the depth? The geological formation from which the water originates has a lot to do with its quality. You also need to be aware of volume. How much water is being produced? There is a tremendous volume of produced water out there, but it's important to recognize that this is a very dispersed source. Individually, the little points that make up the production of this water can be separated by a few hundred feet, or they can be separated by miles. It's important to know where it comes from. When it comes to injection, which I'll go into a little bit further later, you also need to know where the water is going.

Essentially, we're trying to get an idea of the progress of a water molecule from its coming out of the ground to its going down to its final disposition in some deep disposal well somewhere. We need to know about the disposition. Is the water recycled? Is it used in the field for pressure maintenance or enhanced oil recovery? Is it reused for other purposes? Or is it disposed of in disposal wells? What is the variability of this water? If anyone is going to treat this water for any purpose, they need to know: Does the volume remain constant over time, or does it change significantly? Does the quality stay the same, or is it changing? We need to know about variability both with water that is produced and with water that is reinjected somewhere. Then, of course, the biggest challenge is how to access that data more easily.

The effort I put in this year was mostly focused on building a geospatial database of oil field water volume that can be, and is now, linked to existing produced water quality data. A second objective was to survey water managers in the oil industry to gain a better understanding from them about aspects that may not be captured in the statistical data provided by the State of New Mexico or other sources we have. The result is what I call the New Mexico Produced Water Database 2020. If you know me or the research I've been conducting at New Mexico Tech, you'll know that I've been involved in building water quality databases since approximately 2002. There may be versions that some of you have seen, and I'd like to discuss how this version differs from the previous ones.

First of all, in this particular database, I included 25 years of oil, gas, and water production and injection data. Most of this data is from the Oil Conservation Division of the State of New Mexico. It is available from them on a monthly basis, but it is not easy to use. The database it produces contains gigabytes of data, and most people can't utilize that. We've extracted a bit of it and put it in a fairly commonly used database program—Microsoft Access. It's big, but not unwieldy. We have data on water production, water injections, and a lot of information about individual wells that are producing this water and where it is being injected. This data contains information such as the spud date, when the well was drilled, the pool or formation it is being produced from or where it is being injected, the number of days it has been produced or injected, and a rough estimate of the annual production or injection volume. That can be important if you're trying to figure out the injection rate. Therefore, there's a variety of data associated with each individual well.

We've also included water quality data where available. There are at least two relatively recent data sources: a version of the produced water quality database that I compiled in 2016 with the help of NM WRRI, and the U.S. Geological Survey's extensive nationwide data set. I downloaded all the data for New Mexico and included that in this database. There are two separate water quality databases, two sources of water quality data. In many cases, data is duplicated, but I prefer to keep the databases separate because I simply did not have the resources to go through and cross-check the data.

I did clean up some of this data. The USGS database contained numerous wells that were either not true oil and gas wells or had insufficient identification information, making it difficult for me to locate them in space. There was no latitude or longitude associated with them. I also included a few summary tables and some fields in the database that could be useful for aggregating and statistics. I'll show you a little bit of that. I also included some prebuilt queries. My assumption is that if you're downloading this database, you have some familiarity with Access. Some of the queries are easy to build, so I left them in there.

There are two things this database is not. This is not a database of water spills, whether produced water or any other type of spill; it simply records what is produced or what is injected. This database is also not currently live and had a finite cutoff date of mid-2020. So, there are no more live updates. However, this database has been viewed as a stepping stone to making some of this information available online.

What can we do with this database? Well, you can use it for plain old statistical analysis. Run your queries in Access and then export them to the spreadsheet of your choice and graph away. You can answer questions like, "How much water is produced or injected in New Mexico? What county, township, well, or region has the most production or the most injections in a year or over the last 25 years? Can we distinguish water injection or production versus water that is recycled through enhanced oil recovery projects?" There are many different questions you can answer with this, including water quality questions such as, "Where's the best produced water in the state? What about the worst? How do ratios of things change through time?"

Figure 1, for example, shows that the water disposed versus water injected has changed from 2005 to 2019. In 2005, most water was injected into injection wells (not disposal wells), which are typically used for water flooding, such as enhanced recovery, pressure maintenance, or other similar purposes. Now, as of 2019, there's a whole lot more water being disposed of down saltwater disposal wells.

As I mentioned, I've seen numerous talks over the last couple of days about the billions of gallons and hundreds of thousands of acre-feet of produced water. That is correct, but once again, not all of the produced water is available. You're not going to take all of that water out of

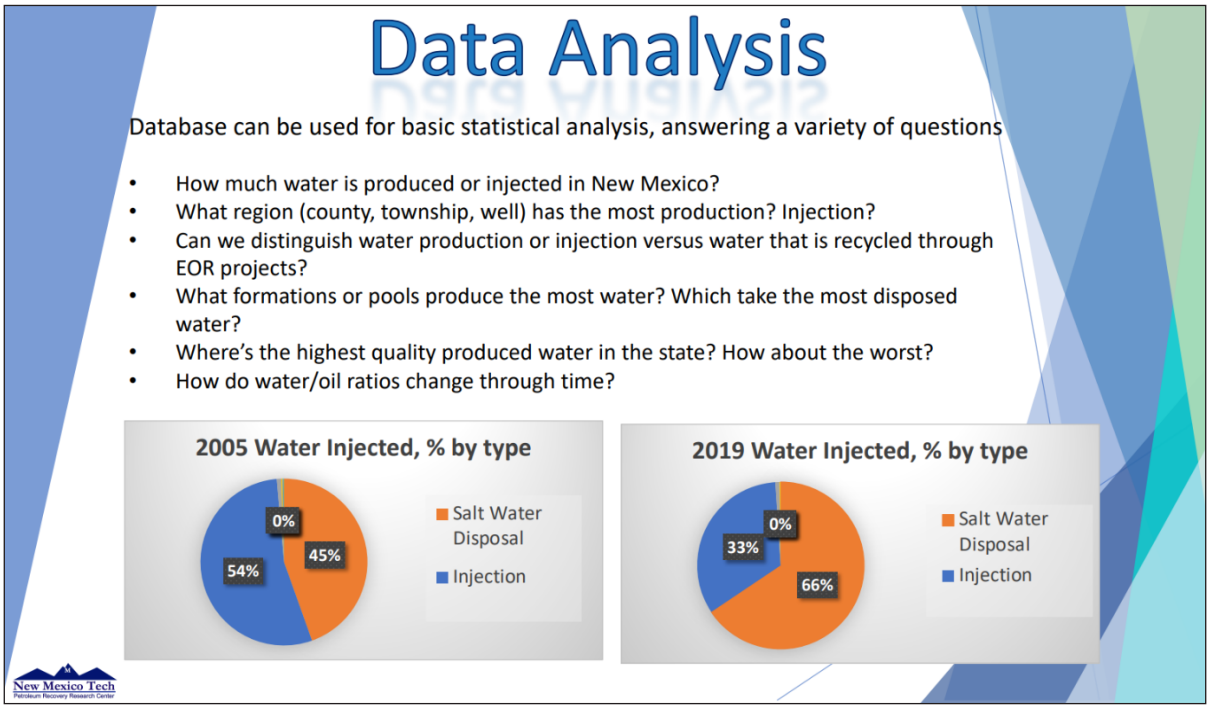


Figure 1. Comparison of water injected, % by type, 2005 and 2019.

the system. Essentially, Figure 1 shows that a significant portion of the water injected is already being utilized for another purpose.

Among other things we can do, we can also map this data. Because I include geospatial data, you can map individual points, wells, and you can code them by whatever strikes your fancy. For example, you can create bubble maps of production or injection volumes or rates, water quality, currently active wells, or you could map all the wells that produced over 100,000 barrels of water in 2019. You could also aggregate this data. We've included some identifiers for townships and sections that match some of the easily available GIS data.

Figure 2 is a sample of some things you can do. The left-hand map shows injection wells; the right-hand map shows saltwater disposal wells. You can see that a lot of disposals are going on in the southeastern part of the state. There were 12 wells that injected over 25 million barrels of water in 2019 in the highlighted township in Eddy County. There's a waterflood going on over here in the highlighted township in Lea County. A significant amount of water has been injected, but it is distributed across 122 wells. If I were looking for water to treat, I might look down in this part of the state, just based on volume alone.

Going forward, we would like to post this static database on our Go-Tech website (http://octane.nmt.edu/gotech/), a data website that has been operated by the Petroleum Recovery Research Center since about 1995 or so. While it may not be particularly beautiful in the way many modern dashboards are, it works. It has been working for a long time for simple volumetric data queries, which are questions that many of our users have. The goal is to get this database up and running on Go-Tech, and then we can update it monthly with volume data.

Another project in the works is a collaboration with the Produced Water Consortium, Groundwater Protection Council, and New Mexico Bureau of Geology to develop various implementations of this data, such as dashboards utilizing mapping applications or graphical data displays, and possibly even providing operators with a means to enter data into it. We also aim to engage more water producers and managers to enhance our data set, as some of the existing data is outdated. Some of the water quality data is only up to 2014. We need to gather more data, which means we need individuals who are willing to share their data with us, as well as some of their usage practices. I still don't think you can gain a full understanding of the system just by obtaining statistical data from the Oil Conservation Division. You really need to have a much more hands-on understanding of where water is going if you're going to create a water budget using produced water. With that, I think I'll call it quits there. I probably took up more time than I needed to already.

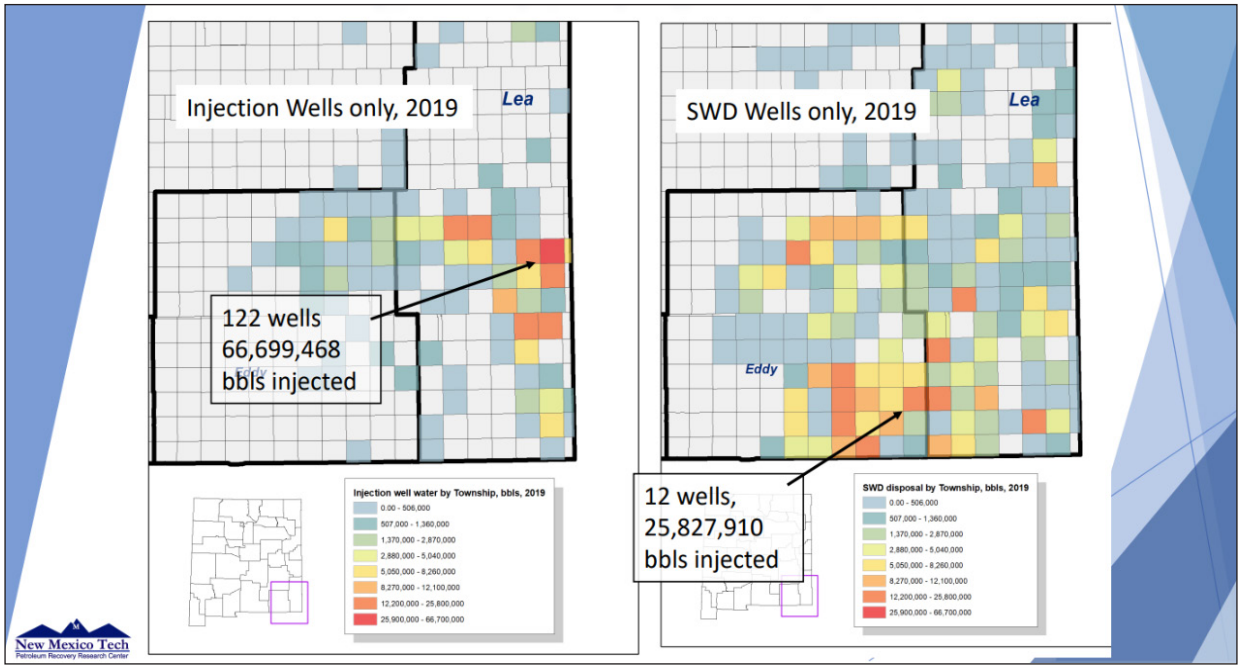


Figure 2. Spatial analysis using produced water database, injection and saltwater disposal wells, 2019.



Bruce Thomson, The University of New Mexico

Bruce Thomson is a Research Professor and Professor Emeritus in the Department of Civil, Construction and Environmental Engineering at The University of New Mexico and was previously director of UNM's Water Resources Program. He has been at UNM since the late Pleistocene epoch and is among the last licensed engineers in the state who still knows how to use a slide rule.

My collaborators are Janie Chermak in economics and Katie Zemlick in the Office of State Engineer. If you have any questions, comments, or suggestions, please contact me at bthomson@unm.edu.

I like to start my talks by reminding everyone how important oil and gas are to the New Mexico economy, and especially to the state government. In round numbers, a third of the state government is funded by revenues from oil and gas, with the money allocated to universities, schools, hospitals, and so forth. We must remember that, whatever we do, this is a crucial component of New Mexico's economy.

For my project, I've taken all this data that Martha has referred to, mostly from the Oil Conservation Division and an organization called FracFocus, as well as some from the State Engineer and State Land Office, and I've taken a deep dive into it and tried to identify trends so that we can understand where the industry is going. We've put a little bit of economics into it. The top left graph in the upper right-hand corner of Figure 1 is annual oil production in the southeast and the northwest of the state. You can see that it is going asymptotically. It's really doing well, but it's dependent on the price. The price is reflected in the graph on the top right, in the far upper corner, and you can see that as the price of gas goes down, the activity has dropped rather dramatically. In recent months, so has oil production. I think the state budget was based on oil at $55 or $60 a barrel. Last I checked, it's about $40 a barrel, so that gives you some idea.

The reason we're interested in the explosion, particularly in southeastern New Mexico in the Permian Basin, is due to development in unconventional formations, including tight sands and shales. Along with that is directional drilling. You can see there are some definitions or examples in the lower left-hand corner of Figure 1, where you've got the horizontal drill, a directional drill, that is following the formation. We make a big deal about fracking, but we need to remember that fracking has been practiced for 70 years. In fact, fracking has been practiced in many water wells, particularly out in western New Mexico. Again, we're trying to understand where the industry has been and where it's going, following what Martha was talking about.

In 2019, there were almost 1,100 wells that were fracked. The total volume in acre-feet is 40,000 acre-feet of water used for fracking in 2019, according to FracFocus. Coincidentally, to put it in perspective, 40,000 acre-feet is the same volume of water consumed by the City of Albuquerque. It's also important to remember that water for fracking generates a lot of revenue for farmers and water rights holders particularly down in the southeast. They are talking about $1 a barrel, sometimes more. There is increased interest in using produced water for fracking, but the high salinity is a challenge, especially for slickwater fracks. Slickwater fracks are those where little to no gelling agents are used, instead relying on very high velocities. Some of these velocities are many, many tens of feet per second in the wellbore, compared to five feet per second, which is the maximum in distribution systems. These are very large velocities. They add friction reducers, and the problem is that in high-salinity water, these big, long polymer molecules clump up, and they don't work. The oil industry would like to use produced water. It's a way of getting rid of some of it, it's cheaper, and usually, there's lots of it. The challenge is with the high salinity, and as Stephanie mentioned, we don't know exactly what volume of water used for fracking is represented by produced water. There are some estimates in the 10 to 20 percent range, but that's based on anecdotal conversations with folks in the industry. This new regulation, passed by the Oil Conservation Division, will require that type reporting. It is a shame we didn't do that about 10, 15 years ago, but it's going to be useful information. One thing I wanted to point out is that even if all 40,000 acre-feet of water used for fracking were fresh water, that volume is a very small fraction of the water used for irrigated agriculture in Lea and Eddy Counties. I understand this is a provocative sentiment because

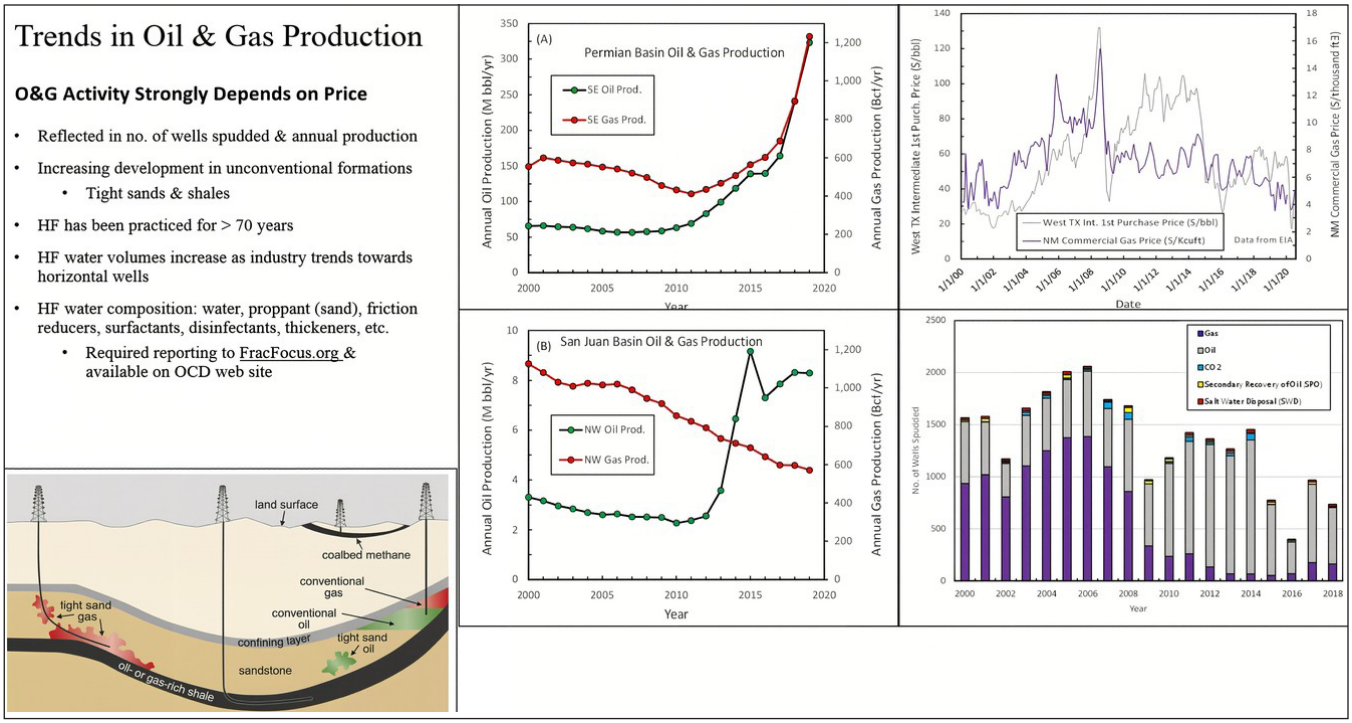


Figure 1. Trends in oil and gas production.

agriculture is a special part of the social and cultural history of New Mexico, but the volume of water used for fracking is relatively small compared to the total water use.

Let's talk about produced water. We usually lump produced water and flowback together. Flowback is the water generated immediately after a frack job. It resurfaces in a few weeks or a few months, at most, whereas produced water is generated throughout the well's lifespan. My numbers are a little bit different from what Martha said, but they're around 160,000 acre-feet, four times the volume of water used for fracking. It's a lot of water. Figure 2a shows the volume of produced water in New Mexico. The green line is not increasing as rapidly as oil production has. The volume in northwestern New Mexico is very small.

What is interesting, and I think perhaps the most interesting statistic in my presentation, is the produced water to oil ratio (Figure 2b). Ten years ago, around 10 gallons of water came up with every gallon of oil, and that has decreased. Most recently, it has decreased to around three gallons of water per gallon of oil. If you take that line in the middle graph of Figure 2b, it's a perfect straight line. It is dangerous and, of course, nonsense to do so; but if you extrapolate it, it says that by 2025, we won't have to worry about the problem at all. It'll be at zero. Of course, that's nonsense, but it is sort of interesting to look at that trend. It's remarkable. Why is that? Why is the ratio of water to oil less than it was several years ago? The reason is that we're going into these tighter and tighter formations. Because they have low permeability and low hydraulic conductivity, they don't release as much water. We've talked about the high salinity, which presents all sorts of problems. Not only is it a salinity problem, but it's also complicated water chemistry compared to seawater. Seawater is approximately 95 percent sodium and chloride, whereas produced water contains calcium, magnesium, sulfate, and silica. Sometimes, there are hazardous constituents present.

Martha also touched on this, and we can look at the trend. Figure 2c shows how we dispose of our produced water. The top line is the total volume of water injected. The green line represents the water injected for principal secondary recovery (SRO), which includes waterfloods and other methods. The red line is the water sent to saltwater disposal wells. Again, you can see a rather dramatic increase in the water sent to saltwater disposal wells. The reason is that as we go to these tighter unconventional formations, you can't have waterflood. The hydraulic conductivity is simply too low.

Last, I will reiterate that managing produced water is a major challenge. Fresh water for fracking is a relatively minor challenge by comparison, and as we learn to get better frack jobs with produced water, that problem will diminish. There is difficulty in permitting new saltwater disposal wells. They can be very expensive, particularly as they go to greater depths. I think Alex Rinehart may talk about that a little bit. Mike Hightower, who will present later, will discuss the cost of disposing of salt

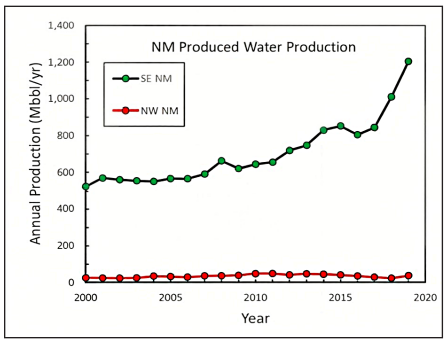


Figure 2a. New Mexico produced water annual production.

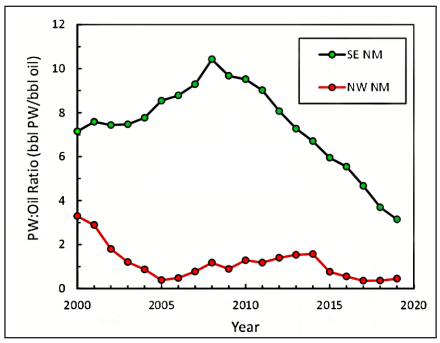


Figure 2b. Produced water to oil ratio.

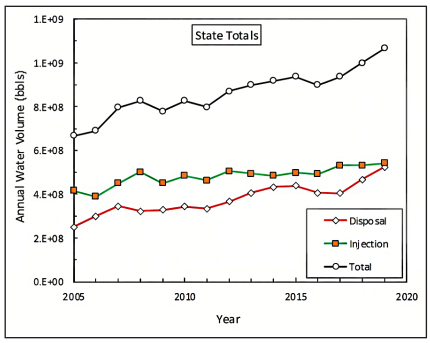


Figure 2c. Produced water disposal.

water, ranging from $2 to $4 per barrel. Some of these saltwater disposal wells can cost up to $20 million each. What's interesting is the payback. Charging these large rates per barrel of water, the wells will pay back in one to two years. Desalination of produced water seems unlikely in the near term. We'll have further discussion about that. Desalination would generate a huge volume of waste; if we desalinated all the water, it would produce waste that is 500 feet tall and a third of a mile in diameter every year. I propose that we take all that and convert it into a ski hill and charge the Texans to go skiing.

My concluding thought is that more so than any other industry I'm aware of, the oil and gas industry responds very rapidly to economic considerations. They respond to the price of oil and the costs associated with drilling and producing it. The economic aspect needs to remain a fundamental consideration. For references, see my and Jamie Chermak's report 'Analysis of the Relationship between Water, Oil, and Gas in New Mexico' (NM WRRI technical completion report no. 390, https://nmwrri.nmsu.edu/publications/technical-reports/tr-reports/tr-390.html). If you have any questions, or you want to talk about this further, please contact me. Thank you very much.



Alex Rinehart, New Mexico Tech

Alex Rinehart is an assistant professor of hydrology at New Mexico Tech, where he focuses on rock failure during CO_2 underground storage, basin-scale hydrology, and applied hydrogeology. Before this position, he worked as a hydrogeologist at the New Mexico Bureau of Geology and received his PhD in geophysics from New Mexico Tech, where he also worked in experimental rock mechanics at Sandia National Laboratories.

Editor's Note: This paper transcribes the speaker's remarks from the conference. No follow-up paper was submitted, and the remarks were edited for publication by the editor. The speaker did not review this version, and the editor assumes responsibility for any transcription or editing errors.

This is going to be a slight change in pace. We've been hearing a lot about data streams and policy-related issues, among other things. This talk is going to be almost entirely about physical science. One of the things that happens when you don't use produced water, as Martha and Bruce talked about, to generate secondary recovery but instead just dispose of it into the subsurface, is that you increase the pressure in the formation you're injecting into. That has led to seismicity, which I'm sure folks have heard about. This study combines data from Mairi Litherland, a seismologist at the New Mexico Bureau of Geology, and Martha's compiled database, which Luke Martin, Joseph Grigg, and Raven Goswick utilize. This study then links the seismicity observed by Mairi with

the injection data and the geology. Joseph Grigg is the geologist on this. I need to give him a lot of credit. He's put in a lot of work lumping pools together and figuring out how to think about the geologic framework that surrounds the injection and, ultimately, as we'll talk about, controls the seismicity.

Figure 1 demonstrates the key point. On the right, we have all the saltwater disposal wells in 2020. Those are all the black dots. The map shows Artesia, Carlsbad, Hobbs, and Lovington. These lines are mapped by the Texas Water Board, I believe, and they represent old faults that occurred approximately 300 million years ago, which cut through rock during the middle of the Permian era. Often, induced seismicity occurs along these old faults that are connected to the bedrock. On the left, we have all the earthquakes from 2017 through June 2020. We've been having quite a few earthquakes, but they are low in magnitude. The maximum magnitude is something like 3.2 or 3.3. Most of these events are less than magnitude 2, so they aren't felt. These are low-magnitude earthquakes, but we have a number of them.

The question becomes how or whether we see any sort of correlation between saltwater disposal and earthquakes. To answer that, we need to know a little bit about geology in the Permian Basin. In the Permian Basin, there are numerous shallow sea deposits that were deposited beginning in the early Paleozoic and, I believe, continuing through the Permian, after which the seas receded. We have three portions of the Permian Basin in New Mexico: the Central Basin Platform, the Northwest Shelf, and the Delaware Basin (Figure 2). The Delaware Basin is the deepest portion. These others are shallower. Oil and gas have been developed in these regions for over 70 years. The old faults cause a lot of these structures, and so that's why we have shallower parts of the basin on the Central Basin Platform and deeper parts of the basin in the Delaware Basin.

What are the rocks that make up the Delaware Basin? We have a whole bunch of units, consisting of old rocks. We have something like 20,000 feet of sediments. Joseph Grigg went through and lumped all the pools. Martha's database contains all this gorgeous detail, and then you need someone who is careful and trained, like Joseph, to go through and figure out how to categorize the information. You need a good geologist on the project. Joseph lumped together all the different pools into the different major formations. We then went through and correlated the injection volume from saltwater disposal into the different formations. Figure 3 shows historical data, not just the last decade. The total injection into what's called the Delaware Sands (Bell Canyon, Cherry Canyon, and Brushy Canyon Formations) is 2.9 billion barrels. That's a big chunk. There is saltwater disposal in these deeper units, in the Pennsylvanian and the Permian. Additionally, in the Silurian-Devonian, we have an estimated three billion barrels of saltwater disposal injection. Below that, we have a little bit.

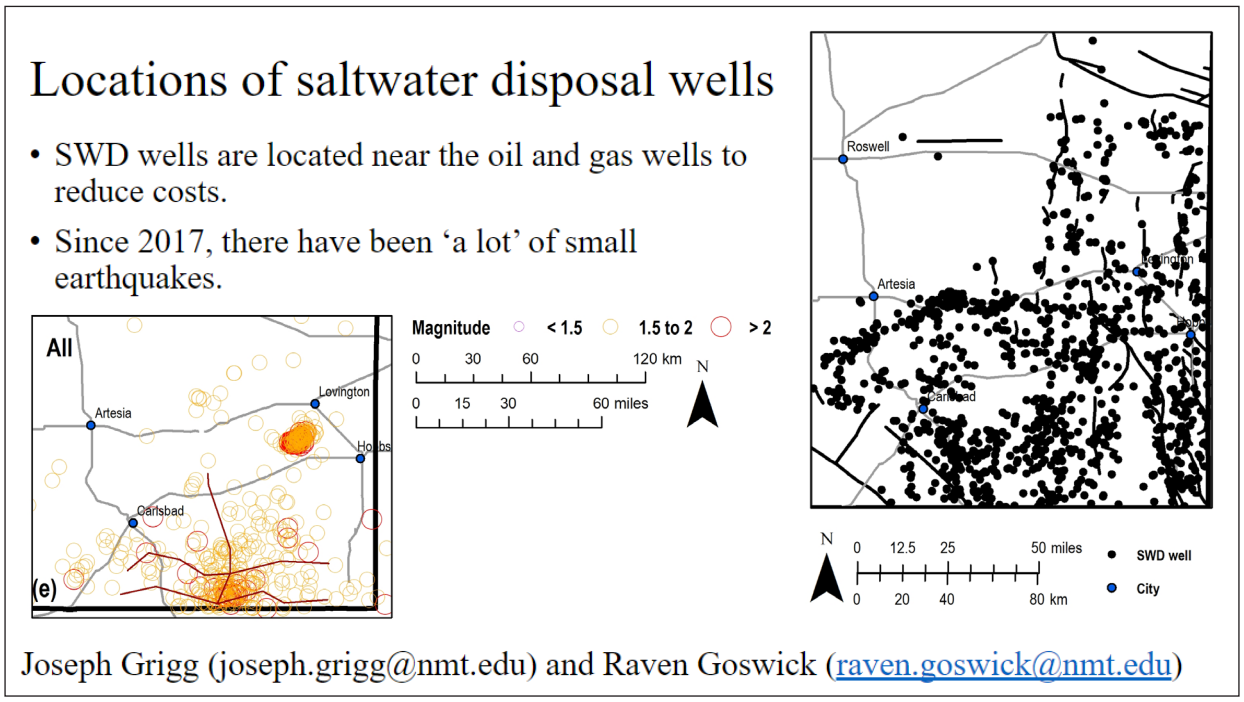


Figure 1. Saltwater disposal wells and earthquakes in the Permian Basin.

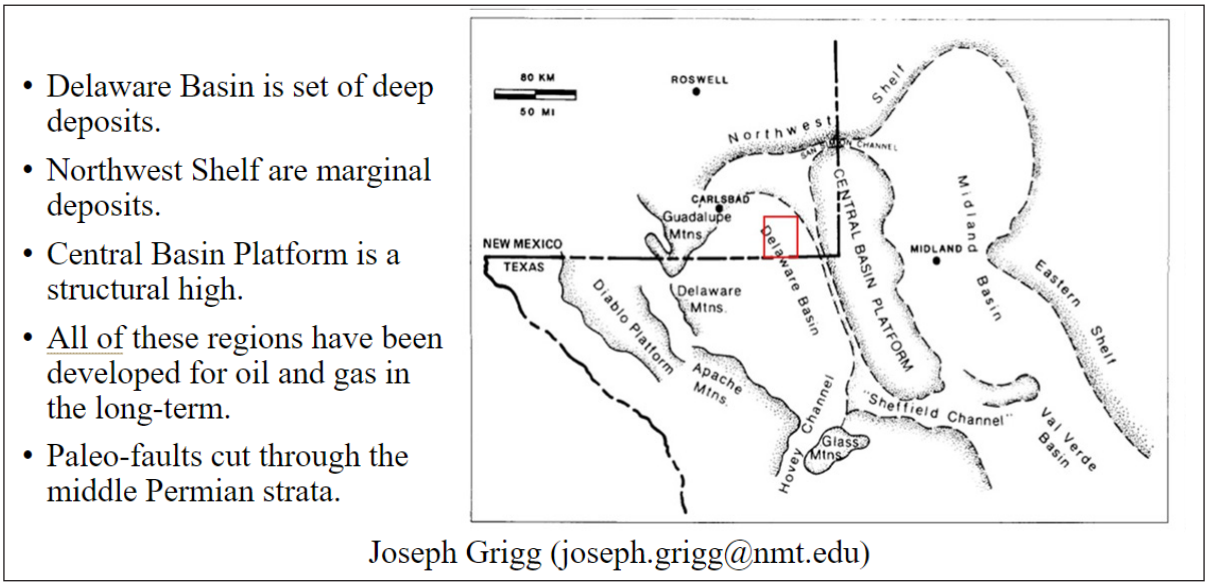


Figure 2. Structure of the New Mexico portion of the Permian Basin.

Now it's important to note that the Precambrian is down at the bottom of Figure 3. For this particular well, it's maybe 2,000 feet below the peak injection horizon. The Siluro-Devonian is deep and contains many units, so when we think about this system, we decided to divide the injection horizons into "shallow," which is all this stuff up above the Woodford Shale. Where there is no injection, it is because these are tight units. You cannot inject into them efficiently. The "deep" units are the Siluro-Devonian and on down. This is a large volume of water that we're going to think about in terms of shallow injection—in this case, from 4,000 feet down to 16,000 feet. The Siluro-Devonian is from 16,500 down to 19,000 or so.

When earthquakes initiate with this induced seismicity along old faults, they often initiate in the Precambrian. We expect a higher susceptibility to earthquakes with deeper wells. This is consistent with observations in Oklahoma, but the situation can be a bit more complicated. Mairi Litherland, the seismologist at the Bureau of Geology, has been working very hard on monitoring the seismicity in the Permian Basin. When examining the earthquake locations, we're considering locations based on this network. Figure 4 shows the locations of the seismometers, including, for various reasons, both historical and geometric, where the stations are, how many components they pick up, and the very low magnitude of the seismicity we're seeing. Litherland can determine epicenters and surface locations, but it's difficult to pinpoint, in terms of depth, where the earthquakes are initiated. As I said, that's both a function of the network geometry and the very low magnitudes that we have.

Let's look at what has been going on in terms of earthquakes in the last three years. Figure 5 is a map of earthquake locations and a time series with magnitude on the right-hand side. In 2017 and 2018, we experienced relatively little seismic activity in the Delaware Basin, as well as throughout the Permian Basin. There was a little bit of activity, mostly focused southeast of Carlsbad, close to the Texas line. In 2019, we developed a cluster and noticed that we had more earthquakes in that year. Then, in the first six months of 2020, several significant events happened. We experienced a significant increase in seismic activity within the same cluster in the central part of the Delaware Basin. Near Lovington and Hobbs, we had an additional cluster, and within that cluster, several events occurred in late June. That seismicity has ended, and Mary is deploying, along with Texas and the USGS, more seismometers to monitor the area, but I believe it is stable right now. So, when we look at this, we have a cluster up here (near Lovington and Hobbs), and then we have a broad cluster down here (southeast of Carlsbad).

Let's look at the pattern of saltwater disposal. We'll immediately separate the injection volumes into deep and shallow wells. Because it takes time for the pressure to build up—oftentimes, there can be a five-year lag—we went all the way back to 2011. Figure 6 shows a 10-kilometer grid based on the saltwater disposal wells. When we examine the shallow injection volumes and geometry, the geometry remains relatively unchanged over time. There was a slight increase in injection in shallow wells in 2015. In terms of deep wells, we began to see more injection occurring at greater depths as we progressed through 2015.

Now, from 2016 to 2020, what ends up happening? Well, the shallow injections stay about the same (Figure 7). We're not seeing any large, dramatic changes in the

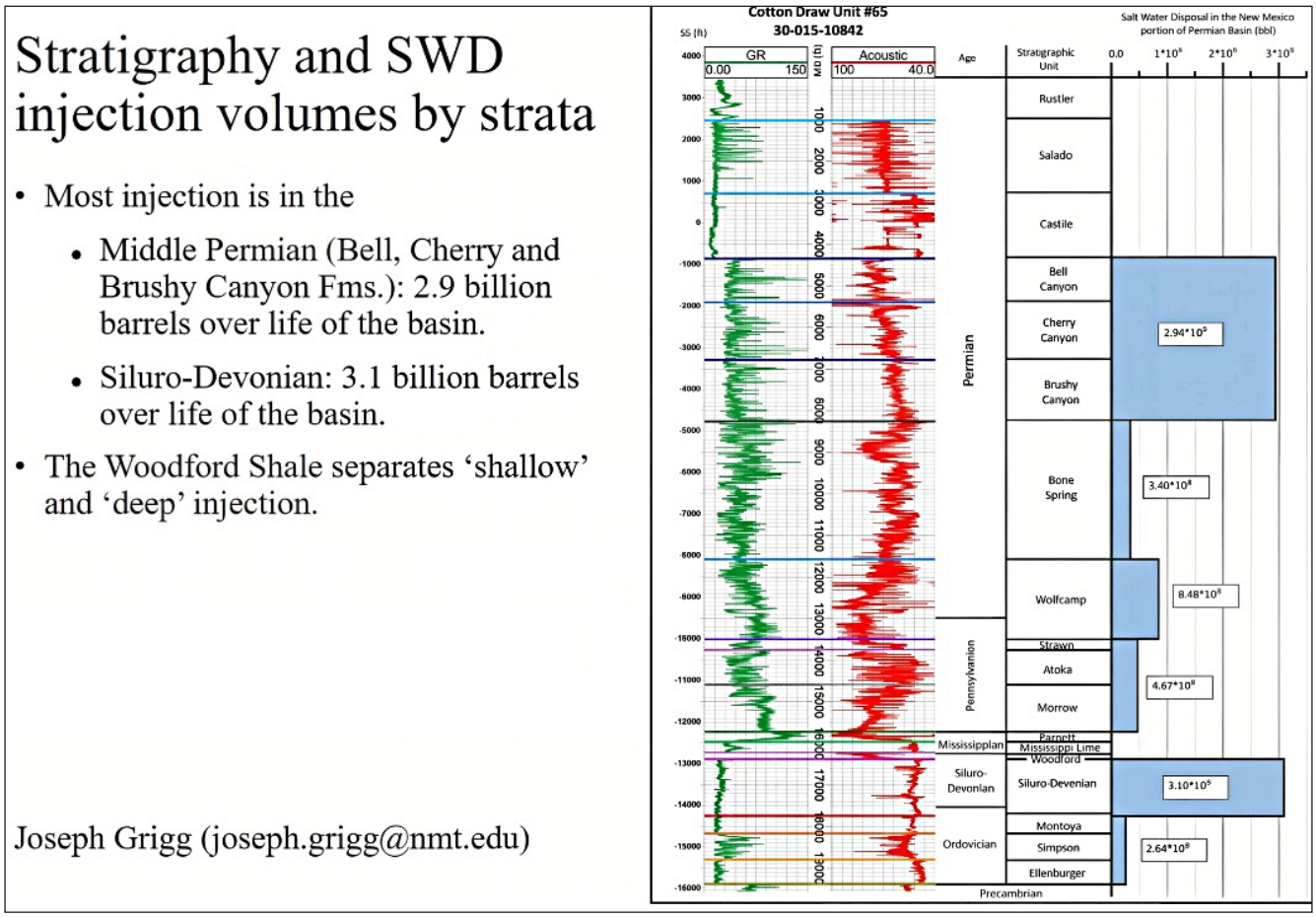


Figure 3. Stratigraphy and saltwater disposal injection volumes by strata.

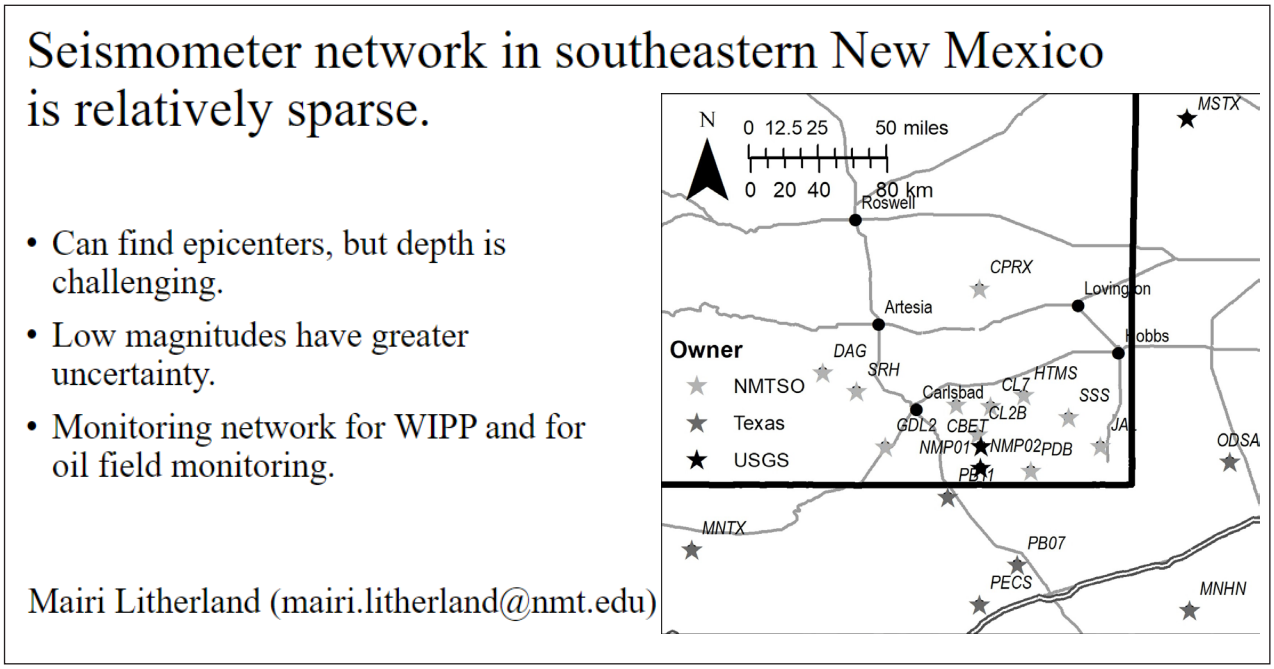


Figure 4. Seismometer network in southeastern New Mexico.

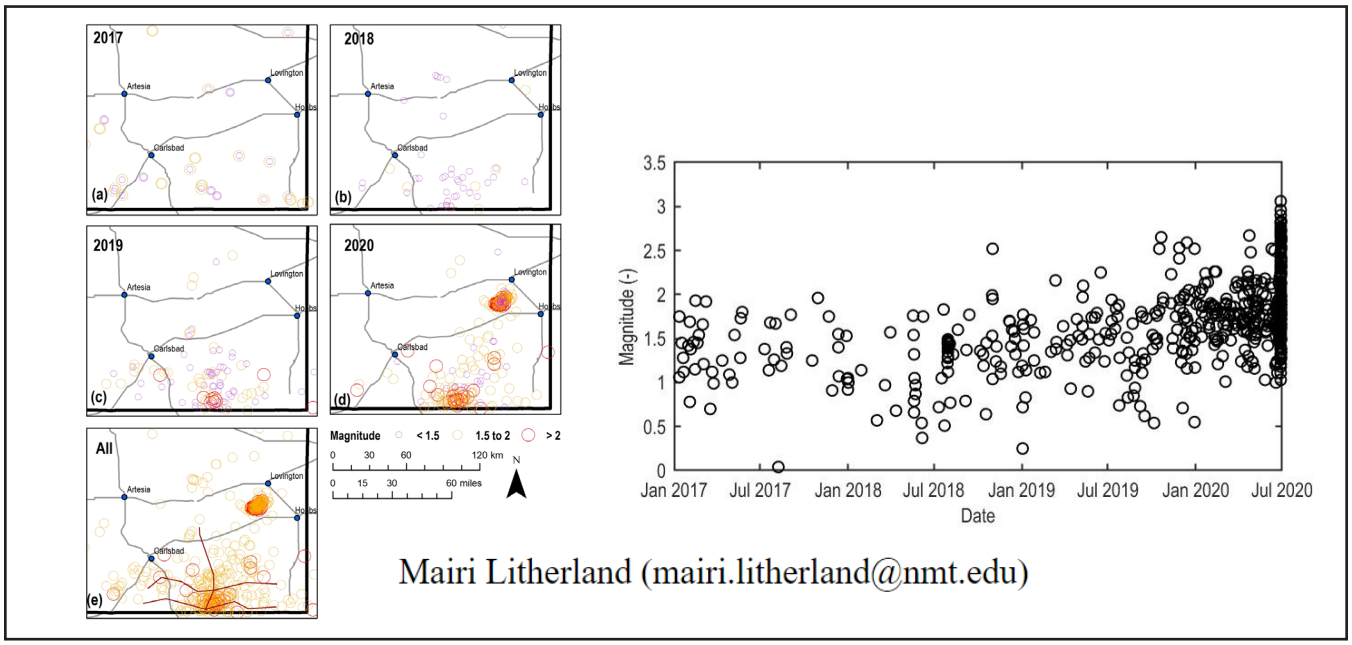


Figure 5. Earthquakes have increased in frequency and magnitude, 2017–2020.

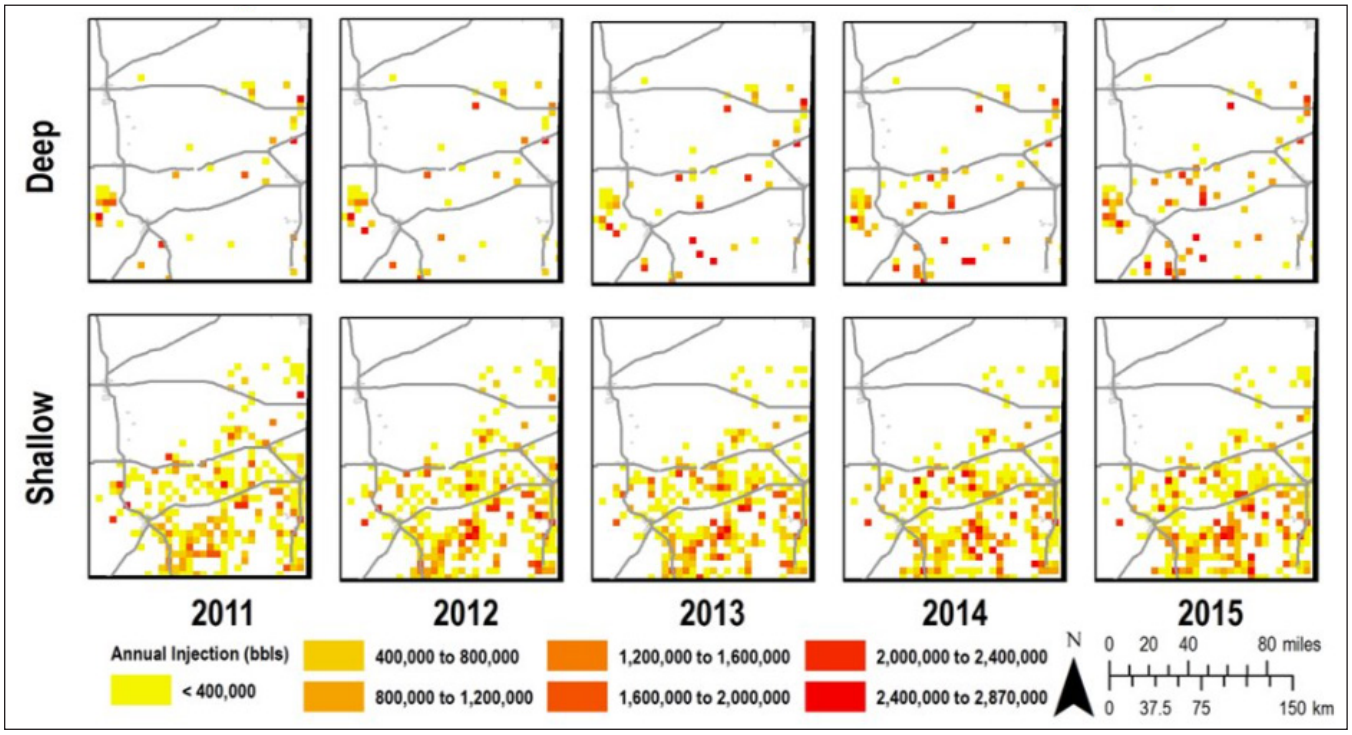


Figure 6. Earthquakes associated with deep injection; increased seismicity correlates with increased rate of deep injection, 2011–2015.

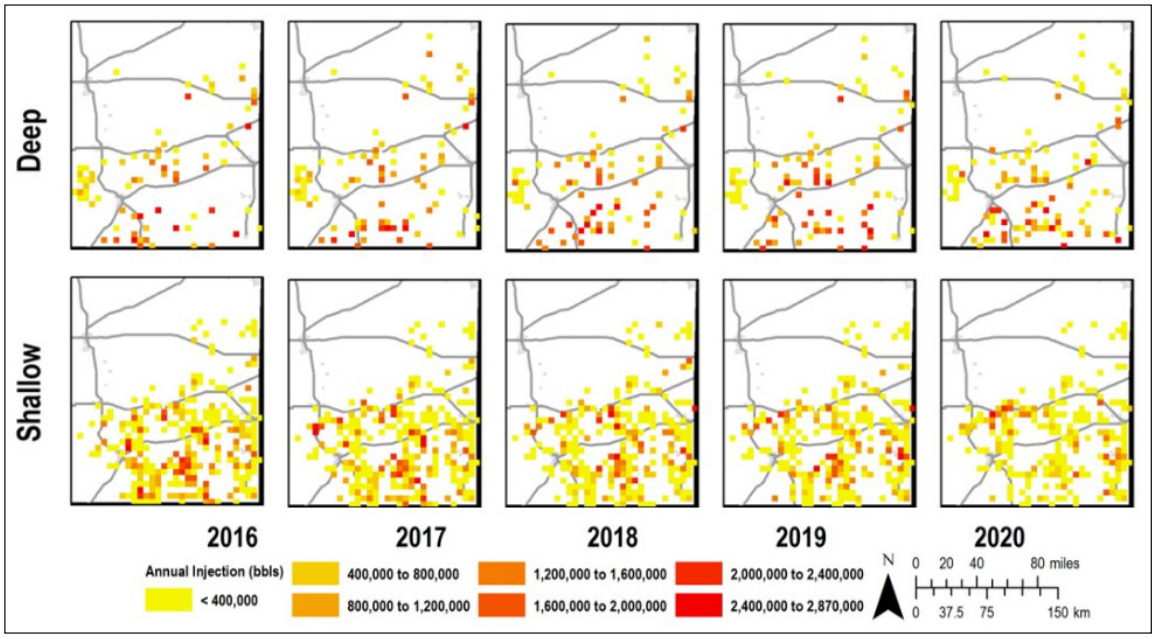


Figure 7. Overview of Permian Basn Geology: Structure, 2016–2020.

geometry or the volumes of the shallow injections. Deep injection ends up accelerating, more or less, around 2017 and then continues to build through 2020. Remember that this is just the first six months of 2020. You could extrapolate by multiplying these colors by two. We end up seeing both more wells and more areas being injected into and at higher volumes. When we squint at Figure 7, we see a new cluster in the mid-right, and this grouping at the bottom. There is also a smattering of wells through the middle.

What does that look like when we put earthquakes on top of it? Well, if we look at the total signal, total injection, it's all over the place (inset c of Figure 8). There is no clear correlation between total injected volume and earthquakes, and that's because of the shallow wells. The shallow wells don't correlate spatially or temporally with the seismicity (inset b of Figure 8). The deep wells, on the other hand, do (inset a of Figure 8). These wells correlate both in space and time with the injection volumes, which correlate in space and time with the increased seismicity (Figure 8). We have a significant amount of injection in southeastern New Mexico, and we are unsure about the situation in Texas. There may be saltwater disposal injection south of the border. Then we see this gradation up to the cluster near Lovington. In most places where we observe deep injection, we also see small amounts of seismicity. There is some correlation with the old paleofaults, but not entirely. The large cluster in southeastern New Mexico is in an area we think is largely unfaulted. Faults appear to have some control, but seismicity is largely a function of deep injection. That's all I have. Thank you.

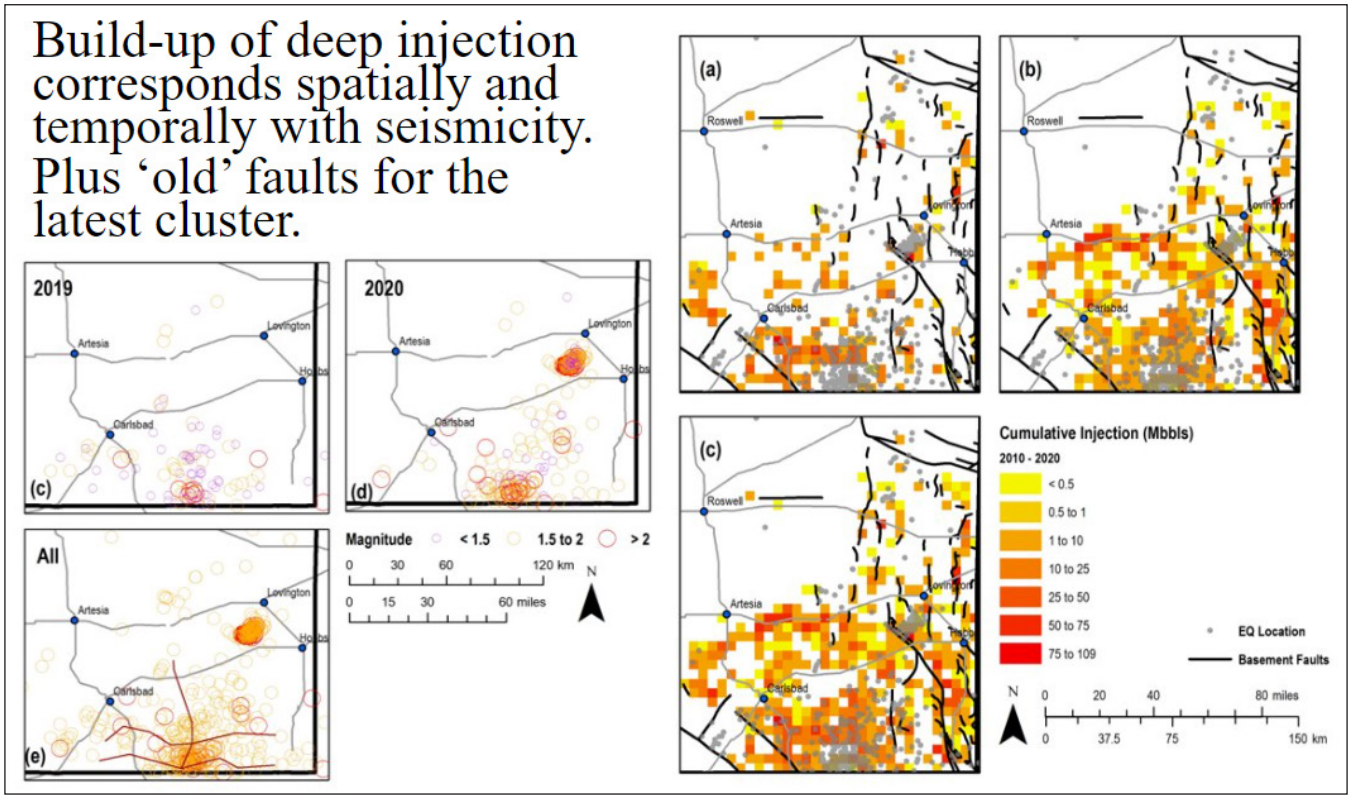
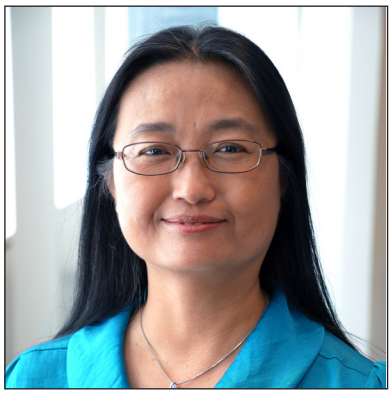


Figure 8. Correlation of deep injection with seismicity.



Pei Xu, New Mexico State University

Pei Xu is a professor in the Department of Civil Engineering at New Mexico State University and the research director of the New Mexico Produced Water Research Consortium. She leads basic and applied research on water quality, water reuse, membrane processes, photocatalysis, resources recovery from wastewater, and renewable-energy-powered water treatment and desalination systems that could significantly reduce treatment costs and energy demand. The goal of her research is to address critical water challenges in arid and semi-arid regions by utilizing alternative water supplies, including brackish water, produced water, desalination concentrate, and industrial and municipal wastewater. She was selected as a Leshner Fellow on Food and Water Security by the American Association for the Advancement of Science (AAAS), a PESCO Endowed Professorship, and the C. Herb Ward Family Endowed Interdisciplinary Chair at NMSU.

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It's a great honor to participate in the panel discussion. I would like to briefly introduce the treatment of produced water for beneficial use.

From previous discussions, we see that in the Permian Basin, we generate a large amount of produced water. The question is, when we compare produced water production and also different fit-for-purpose uses, how much water do we have? The graph in Figure 1 compares the produced water production in different basins. Produced water is highlighted in gray, hydraulic fracturing in blue, and

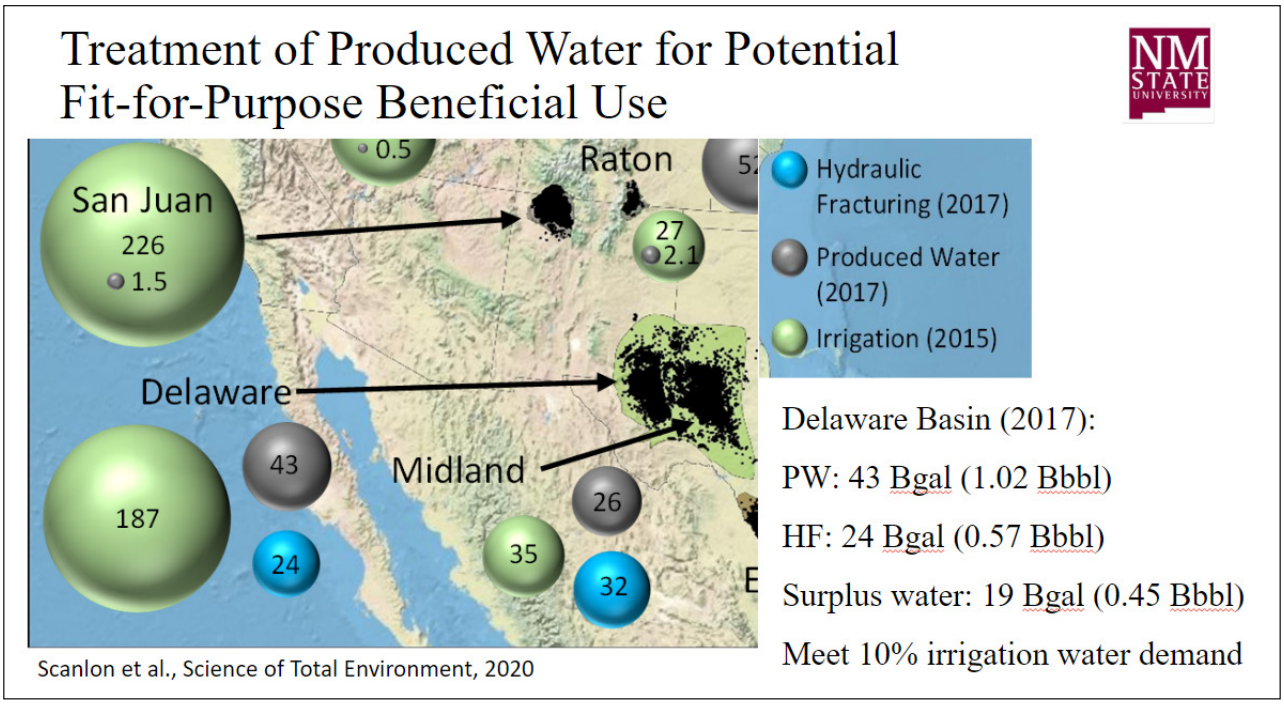


Figure 1. Hydraulic fracturing, produced water, and irrigation water use in the Permian Basin.

irrigation in green. For example, in the Permian Basin in 2017, the produced water generated in the Delaware Basin is about 43 billion gallons. Right now, in the Permian Basin, about 10 percent of produced water is used for hydraulic fracking. If we assume that we can use produced water for 100 percent of hydraulic fracking water, that would be 24 billion gallons of water. We still have 19 billion gallons of surplus water that needs to be disposed of through saltwater disposal wells. If we can reuse this water, it will meet 10 percent of irrigation needs in the Delaware Basin.

It looks very promising that we can treat and reuse that water, but for safe reuse, we need to remove the contaminants, depending on the water quality requirements for different applications. For example, we need to remove suspended solids, oil, grease, and high salinity from produced water, which can inhibit its beneficial use. Depending on the application, we also need to desalinate the water and remove dissolved organic matter (e.g., petroleum hydrocarbons, volatile and semi-volatile compounds), metals, dissolved gases (e.g., hydrogen sulfide, ammonia), and naturally occurring radionuclides. Dr. Yanyan Zhang will present after me on the characterization of produced water, discussing its toxicity and the need to reduce it before we can reuse the water.

When we treat produced water, cost is a big concern. The cost increases with the salinity of the produced water, and with the level of product water we aim to achieve. Figure 2 shows the various technologies we will utilize to meet the diverse fit-for-purpose applications, such as generating clean brine for hydraulic fracking, industrial uses, agriculture, and groundwater recharge, as well as, in extreme cases, some potable uses. The cost of the treatment increases for better treatment technologies, which are limited in availability. When we have produced water, the salinity increases. For example, if we only want to generate clean brine for hydraulic fracking, we may need to use simple physical and chemical separation processes to remove oil and grease. We can disinfect the water using ultraviolet light or chlorine. We would also remove iron for hydraulic fracking. However, when we increase the beneficial use requirements—for example, agricultural uses or groundwater recharge—we may need to desalinate the water, and the salinity of the produced water in the Permian Basin is quite high. The median is about 100 g/L. For such high-salinity produced water, we may need to use thermal desalination technologies, which would significantly increase the cost. On the other hand, when we think about the high salinity of the produced water, it may provide some opportunities to recover resources from the water. For example, we can recover some minerals and even rare earth elements if they exist in the water.

We are exploring treatment technologies that offer lower costs and high energy efficiency. We have already built a treatment technology database based on our previous projects funded by the Department of Energy. Through this project and the New Mexico Produced Water Research Consortium, we are conducting a literature review to update the technologies we have

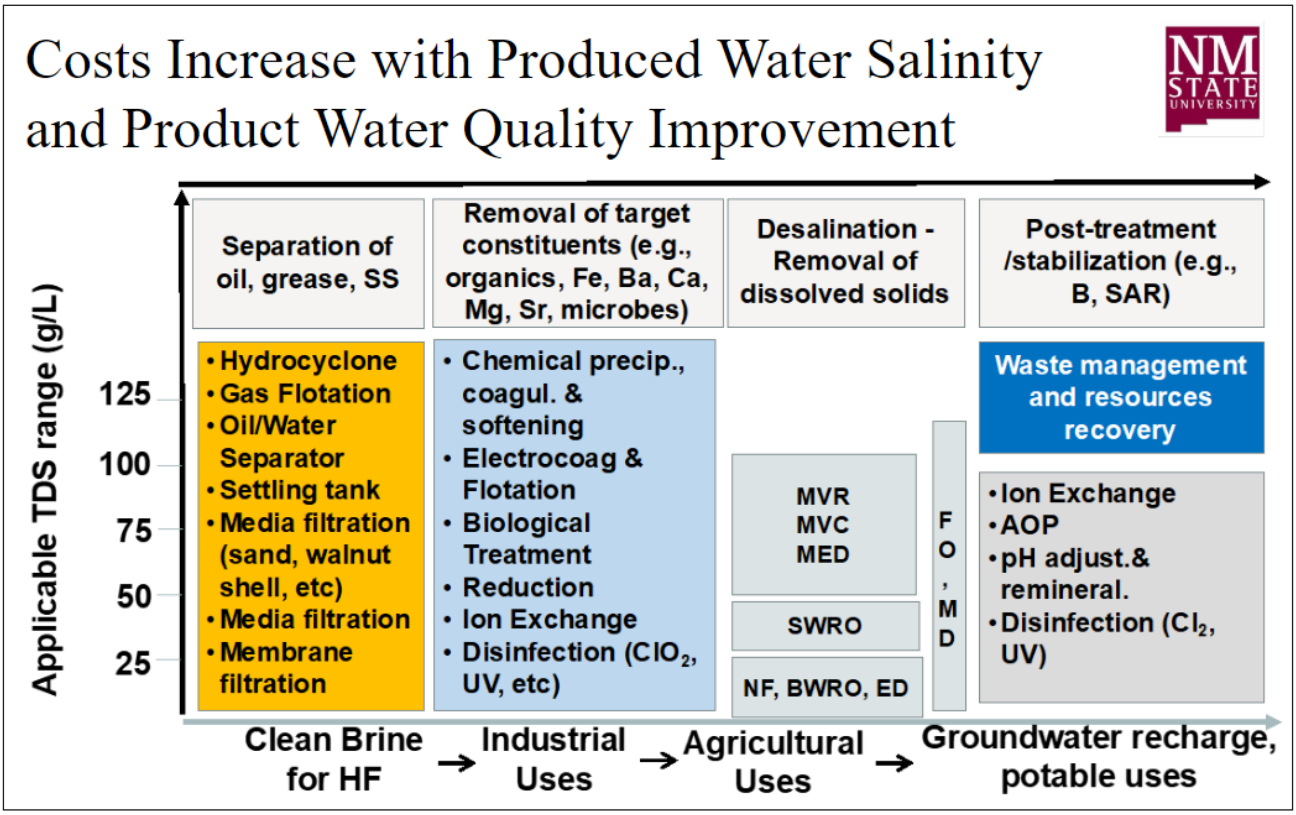
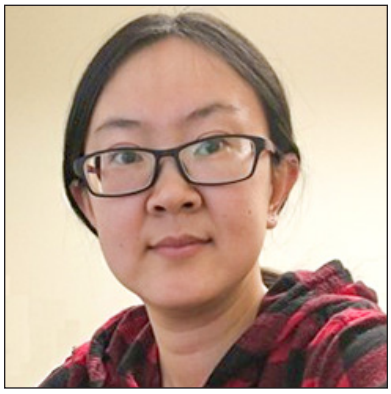


Figure 2. Produced water treatment technologies for different beneficial uses.

evaluated in the past. We're also working with technology developers to request information regarding existing and emerging treatment technologies. Besides this effort at NMSU, we are also developing innovative processes for produced water treatment, pretreatment, and minerals recovery. For example, we are using electrocoagulation to remove suspended particles from the water and then generate clean brine for hydraulic fracking. We are using membrane distillation and an innovative photocatalytic membrane distillation to generate potable-quality water for beneficial use. Another option is to use solar energy to evaporate the water and generate a concentration from which we can recover minerals. Dr. Yanyan Zhang's group at NMSU is working on the chemical precipitation of produced water to generate struvite as fertilizer and is also developing a new technology for microbially induced calcite precipitation. Just in case you missed it, the poster presented by Lin Chen, a PhD student, showcased work on recovering rare earth elements from produced water using solvent extraction and ion-exchange purification.

This is a very high-level, brief overview of the technologies we're working on for the treatment of produced water for beneficial use. If you have any questions, please feel free to contact me at pxu@nmsu.edu. Thank you so much.



Yanyan Zhang, New Mexico State University

Yanyan Zhang is currently an assistant professor in the Department of Civil Engineering at New Mexico State University. She obtained her PhD in environmental engineering from the University of Missouri in 2012. Before joining NMSU in 2016, she had her postdoctoral training on the treatment of oil sands process-affected water at the University of Alberta in Canada. Her current research interests include pathogen detection and inactivation, biofilm and resistance to disinfection processes, antibiotic resistance in urban and natural environments, and the development of integrated biochemical and physicochemical systems for oil and gas industrial wastewater treatment, as well as resource recovery.

Today I'm going to talk about the Produced Water Characterization Project conducted by Dr. Pei Xu, Dr. KC Carroll, and myself. As you know, some constituents in produced water may pose a significant impact on public health and the environment. That's why we are conducting a comprehensive assessment of produced water quality for safe disposal and beneficial reuse. We collected some produced water from saltwater disposal wells in the Permian Basin and environmental samples to assess whether hydraulic fracturing and produced water disposal activities have an impact on the local environment. The environmental samples we collected included river water from the Pecos River, groundwater from a local ranch well, and tap water from a local restaurant.

We are using advanced analytical methods to characterize inorganic, organic, and radionucleotide material in produced water. We found that salinity is very high in the Permian Basin, with total dissolved solids ranging from 90 to 120 g/L. Sodium chloride is a major contributor to salinity. We also have calcium, magnesium, and strontium, which cause high hardness of produced water. High concentrations of sulfides in the produced water can cause a chlorine problem when we reuse those produced waters. High concentrations of ammonia can cause toxicity. To achieve beneficial reuse for agricultural irrigation, we must remove boron from the produced water. We also found toxic organic compounds in the produced water, including phenols, BTEX, oil, and grease. Arsenic is a heavy metal in produced water. We also need to be aware of radioactive materials, including alpha particles, beta particles, and photon emitters. In the produced water, they have a very high concentration. We use metagenomic sequencing to identify many bacterial contributors for corrosion and found that Halanaerobium is the primary bacterial cause of corrosion. We also developed an advanced toxicity assay to evaluate the risks associated with the reuse and disposal of produced water. We were using a luminescent bacterium, freshwater algae, and a fish cell line to evaluate the risk. The good news for all the environmental samples we took is that all of them met the nationally recommended water quality criteria.

Next, we tried to link the toxicity to the chemical components in the produced water. Salinity, organic compounds, and heavy metals all contribute to the toxicity of produced water. After identifying the major chemical components that contribute to toxicity, we can develop treatment techniques targeting those compounds. The results from this project can help us explore the potential beneficial reuse of produced water, including hydraulic fracturing and some other industry reuse, such as for mining and power plants. We can also use produced water for road construction and dust control. After desalination, we can utilize the water for agricultural irrigation, rangeland rehabilitation, environmental and recreational purposes, and groundwater recharge. Thank you.



Saeed Langarudi, New Mexico State University

Saeed Langarudi is a research assistant professor and graduate faculty member at New Mexico State University's College of Agricultural, Consumer, and Environmental Sciences, where he teaches an online, graduate-level system dynamics course. Saeed's research focuses on the dynamic interactions between natural resource extraction and socioeconomic development, as well as the behavioral decision rules that drive these interactions. His research informs natural resources managers and policymakers on designing high-leverage interventions that can potentially revive and maintain the balance of our socioecological systems. Saeed is a committee member of the Computational Social Science Society of the Americas and a member of the Iranian System Dynamics Society, for which he co-chairs the Security Thread of the international conference.

Editor's Note: This paper transcribes the speaker's remarks from the conference. No follow-up paper was submitted, and the remarks were edited for publication by the editor. The speaker did not review this version, and the editor assumes responsibility for any transcription or editing errors.

Our team, which includes me, Bob Sabie, Babak Bahaddin, and Sam Fernald, aims to synthesize the ongoing research efforts presented in previous talks and integrate them within a coherent, accessible analytical framework. To achieve this goal, we will develop a hybrid simulation model that can address some of the pressing issues in produced water management. As my colleagues described in the previous presentations, how produced water is managed could significantly affect our ecological and societal systems. These effects, in turn, will have a profound impact on our water system. Previous talks described how each of these effects could be measured and analyzed. However, to have a complete picture of how these effects impact our water system, we need to find a way to synthesize and integrate these research efforts, but this is not easy.

As we saw earlier in this session, the problem of managing produced water has multiple levels of complexity. It is complex because it is dynamic and spatial, and it involves heterogeneity. The problem is dynamic because the system evolves over time: oil production, for example, as well as water use for hydraulic fracturing and decisions for treatment and disposal, all change as new decisions are made or new regulations are implemented. The problem is spatial because producers and regulators rely heavily on spatial information. Managers must make decisions regarding where to dig a new oil well, for example, where to dispose of the produced water, where to inject treated produced water, and so on. These geographical distributions change over time as the seasons change. The problem is heterogeneous because agents representing stakeholders or wells act differently based on different inputs. Different analyses and different interests change the dynamics. To model such a complex problem, we need research methods and tools that can characterize and represent nonlinear system-level as well as heterogeneous and spatial interactions over time.

There are two different dynamic simulation methods that can be used to achieve this goal: system dynamics and agent-based modeling. System dynamics is an equation-based approach that characterizes a problem in terms of stocks and flows, representing its dynamics through the accumulation of feedback. Therefore, it is a very suitable method for modeling water dynamics and water systems. Agent-based modeling, on the other hand, is object-oriented and characterizes the problem as a set of simple individual rules. This type of modeling is suitable for network analysis or when spatial dynamics are important. We need to combine system dynamics and agent-based modeling to capture all the important complexities that we discussed earlier. However, the use of hybrid system dynamics and agent-based modeling is a very young research area with few established guidelines. Our literature review identified that only 77 papers are relevant to hybrid system-dynamics–agent-based modeling. Among these papers, only one addressed the topic of energy-water interactions, and only 31 papers provided some details about how a hybrid model could be constructed. Therefore, we don't have much to start with. It sounds like our effort is more like an exploration, and we are trying to break some new ground here.

We began conceptualizing a model to use interviews conducted with subject matter experts. Figure 1 is only a rough draft, a work-in-progress conceptualization. It demonstrates how we plan to utilize the knowledge created by New Mexico universities and integrate it into a comprehensive simulation tool.

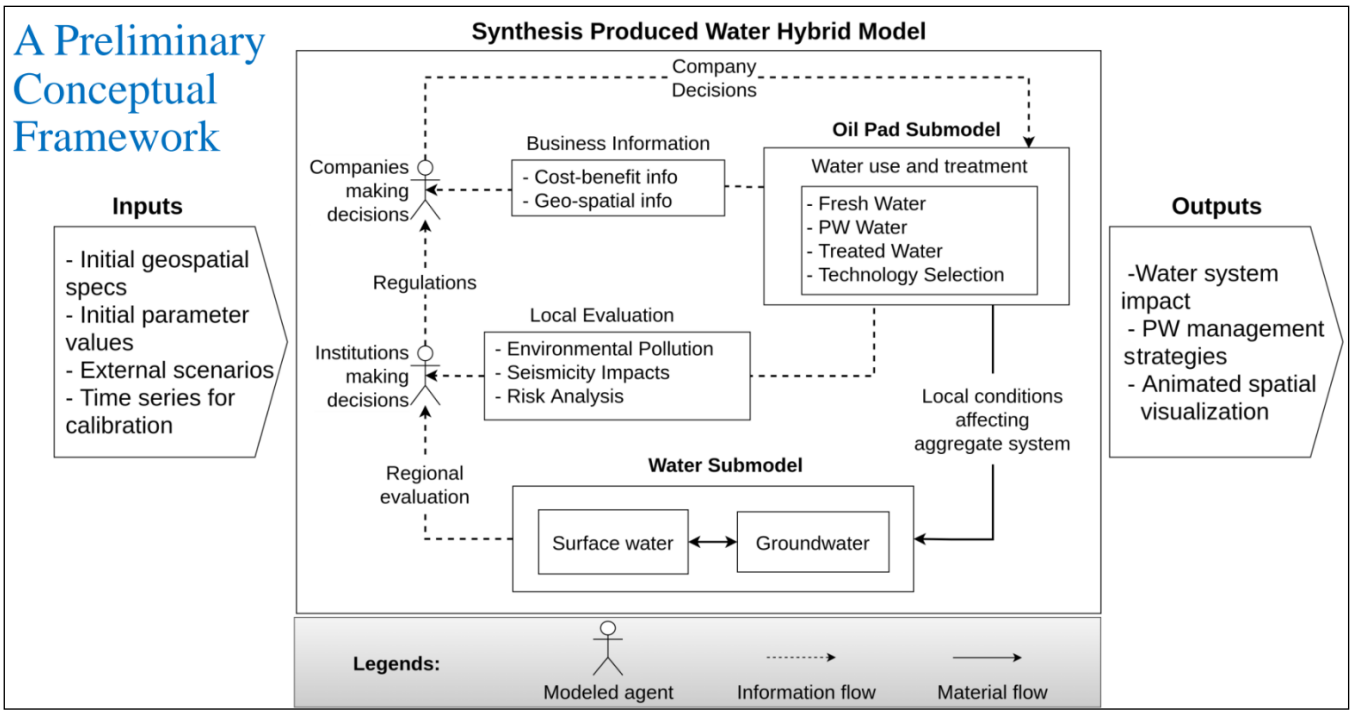


Figure 1. Preliminary conceptual framework.

All the synthesis research teams will participate in conceptualizing and formulating the tool. The team also provides inputs to the model in the form of geospatial specification of the variables, parameter values for the model, external scenarios (e.g., climate, economic, or population projections), and data that can be used to calibrate the model. The Utton Transboundary Resources Center, represented by Stephanie Russo Baca, will provide input that will inform the regulations and institutional processes of the model. This includes the mechanisms by which institutions update policies and regulations based on regional and local evaluations, as well as public perception. Bruce Thomson from UNM and Martha Cather from the Petroleum Recovery Research Center will assist us in gathering various time series data, as well as knowledge of how oil production, fracking, and produced water production operate, and how they will impact the system. We hope Bruce will provide us with advice during the model formulation phase. Our New Mexico State University team will provide information about how treatment technologies are selected and how they will impact water quantity and quality. Pei Xu will lead these aspects, while Yanyan Zhang and KC Carroll will provide information on the environmental pollution of different technologies. Alex Rinehart's research at New Mexico Tech will provide information about the seismicity probability influenced by different produced water management decisions and activities. Finally, our water institute's team will provide the hydrology expertise, data, and models to formulate the water sub-model.

We can see here that once different pieces of the puzzle are put together, a very complex feedback system emerges, which will be challenging to model and analyze using traditional approaches. Our next step is to work on the technical challenges of creating a hybrid system-dynamics–agent-based model. We will also continue our interviews with subject matter experts and industry managers to unveil the decision processes and feedback that rule the system. Then, we will parameterize and quantify the model, enabling us to predict the impact of produced water management on the water system at both local and aggregate levels. The model can also hopefully recommend some successfully produced water management strategies. Thank you very much.

Part B: New Mexico Produced Water Research Consortium



Rebecca Roose, New Mexico Environment Department

Rebecca Roose joined the New Mexico Environment Department (NMED) in May 2019 as the director of the Water Protection Division. Roose leads surface and groundwater quality, drinking water protection, and water infrastructure finance programs for the state. Prior to joining NMED in 2019, Roose worked for the U.S. Environmental Protection Agency. At EPA headquarters, she devoted 11 years to supporting EPA, states, and tribes with the implementation of federal water protection programs. During her last two years at EPA, she served as senior advisor for tribal capacity development in the American Indian Environmental Office. Roose earned her law degree and a certificate in Natural Resources Law from The University of New Mexico, as well as her bachelor's degree in Geography from Valparaiso University.

Editor's Note: This paper transcribes the speaker's remarks from the conference. No follow-up paper was submitted, and the remarks were edited for publication by the editor. The speaker did not review this version, and the editor assumes responsibility for any transcription or editing errors.

I am going to overlay a regulatory policy perspective on the really great technical presentations we're hearing. It is very handy to have an overview of the technical research being done in the state and see the amount of expertise we have.

Jumping right in, I want to highlight where the New Mexico Environment Department (NMED) fits into this whole great discussion about the research that's being done. This will cue off some of the points Stephanie made earlier. From the Produced Water Act, NMED clearly has jurisdiction over the treatment and use of produced water for purposes outside of the oil and gas sector. That's first and foremost where we come into this conversation, but I want to add an important caveat to that. Even though jurisdiction over infield recycling of produced water for fracking is not under NMED's jurisdiction—it's not under our regulatory purview—we are 100 percent on board with the policy objective and value of, first and foremost, recycling and reusing as much of this produced water in the oil field as possible. We work closely with our colleagues at the Oil Conservation Division to that end and support those provisions of the Produced Water Act that help to incentivize and drive more infield recycling.

When we're coming into the conversation and you hear me talk about produced water, more than likely you're going to hear me talk about the path from where we are right now to potentially getting to authorized uses of treated produced water outside the oil and gas sector. The Water Quality Control Commission is responsible for adopting regulations. NMED will be the department that essentially drafts those regulations and presents them to the commission, and that is why NMED is so invested in research through the Produced Water Research Consortium.

When the Water Quality Control Commission adopts any regulations under the Water Quality Act, they're required to consider the following:

- Character and degree of injury to/or interference with health, welfare, environment, and property
- Public interest, including the social and economic value of the sources of water contaminants
- Technical practicability and economic reasonableness of reducing or eliminating water contaminants from the sources involved, and previous experience with equipment and methods available to control the water contaminants involved
- Successive uses, including domestic, commercial, industrial, pastoral, agricultural, wildlife, and recreational uses
- Feasibility of a user or a subsequent user treating the water before a subsequent use
- Property rights and accustomed uses
- Federal water quality requirements

It's essential to note that there is a tremendous amount of rigor, rightly so, to ensure that the water quality regulations we put in place in the state protect water quality, safeguard wildlife uses, serve the public interest, and consider a number of other factors. These are some of the overarching guiding principles that NMED must consider when developing draft regulations that will be presented to the commission.

One of the things the department discussed right away when the Produced Water Act was passed and went into effect was that we, as a regulatory agency, do not believe

that we have the science in front of us to develop science-based rules to propose to the commission for permitting the off-field, outside oil and gas, uses of treated produced water.

We set out a phased rulemaking approach. Phase one may involve some near-term rules that will fill some of the current gaps while we wait for the science to come in. These rules would clearly demonstrate that untreated produced water use outside of the oil and gas industry is prohibited. We are also considering if there is a way for us, through rulemaking, to increase the amount of information made available to NMED to further inform our phase-two regulations. That piece of that phase-one rule—whether we ultimately end up with rules or find another way to go about this—is so important because, as a regulatory agency, we can't regulate something that we don't know is out there. We can't protect our water resources from potential contamination if we don't know what is in the water being used, treated, and reused. That's an important piece, and it certainly complements many of the consortium's efforts.

Phase two would get into the rules for, as the Produced Water Act puts it, the "discharge, handling, transport, storage, and recycling or treatment of produced water or byproduct thereof outside the oilfield." That's ultimately what we come back to as our charge. We are committed to establishing rules based on sound science, and we aren't there yet. The timeline for phase two is to be determined, which brings us to the consortium.

The Produced Water Act was passed and went into effect. We reviewed our current knowledge and identified areas where we lack understanding, both within the state and nationally. We then partnered with New Mexico State University through a Memorandum of Understanding, which we signed in September 2019. The consortium really started to kick off last fall with Mike Hightower coming on board as the program director, and he cast a wide net to recruit experts from different sectors. It was very important to NMED, in partnering with the university, to set up this consortium, which draws on expertise from a range of views, perspectives, and sectors. We've got amazing experts from academia. Mike can correct me, but around 11 to 13 different universities or institutions of higher education joined. We have experts from environmental organizations, government agencies (state and federal), and industry, including midstream companies and water treatment companies. Tons of expertise came together. Since January, the consortium has been working to advance the process of filling these critical science and technology gaps. NMED is glad to be involved as a core partner. I chair the government advisory board, which comprises 11 or 12 representatives from state and federal agencies, and we support the technical research conducted within the consortium. We're very invested in that.

While we're focusing heavily on our partnership with the consortium and ensuring that the research progresses in a manner that will allow us, as a regulatory agency, to rely on the data and findings that emerge, we're also undertaking a few other initiatives, which are available on our website: https://www.env.nm.gov/new-mexico-produced-water/. We have focused on public participation, and, as Stephanie mentioned earlier, held a number of meetings last year. We released several resources in 2020. We've got a set of frequently asked questions on the website that is not just NMED-specific. It's broken down into three sets of questions: one related to our role, another related to the Office of State Engineer, and a third related to the Oil Conservation Division. That's a handy resource, which was informed by the questions that arose during our public outreach in fall 2019. On the Public Participation page (https://www.env.nm.gov/new-mexico-produced-water/public-participation-2/), we provide a detailed summary of the feedback we received during those meetings. After this technical panel today, if you'd like to get your finger on the pulse of what our fellow New Mexicans think and feel, what questions and concerns they have, what interests they have in produced water, the "Summary of Initial Public Input on Produced Water" document, released September 2, 2020, is a great resource.

We will continue to keep our eyes and ears open, engage in conversations like this, and collaborate with our partners, other state agencies, and the outstanding researchers who are actively focused on these issues. We are really looking at the results of these efforts to inform our future science-based regulations for treatment and reuse outside the oil and gas sector, all while staying keenly focused on our mission to protect our precious natural resources and human health along the way.



Mike Hightower, New Mexico Produced Water Research Consortium

Mike Hightower is a research professor at The University of New Mexico in the Center for Water and the Environment, and program director of the New Mexico Produced Water Research Consortium, a joint effort by the New Mexico Environment Department and New Mexico State University. Mike is a technical consultant to Sandia National Laboratories, specializing in water treatment, desalination, and energy and infrastructure resiliency research, where he worked for 38 years. Mike holds bachelor's and master's degrees in civil and environmental engineering from NMSU and has experience in aerospace, weapons, energy, and natural resources research, analysis, and engineering. His focus over the past two decades has been on developing innovative distributed energy and water technologies to enhance critical infrastructure and natural resource security, resiliency, and sustainability.

I'm going to take a few minutes to talk about the New Mexico Produced Water Research Consortium. I'm the program director, and Pei Xu from New Mexico State University is the research director. The consortium has approximately 60 participants and around 160 technical experts from a diverse range of sectors, including government, industry, academia, NGOs, producers, and midstream companies. We've made a lot of effort to go out and bring in a broad spectrum of support and input for our research program. The consortium spent the first six to nine months examining the analysis of some of the issues: What are the methods for measuring water quality and quantity? What are some of the general technologies people are interested in? We haven't conducted any research yet, but we are planning to move forward.

I would like to discuss the reasons for the need for research, the directions we will pursue, and the opportunities for the State of New Mexico, as well as why we believe some of these directions are appropriate.

Figure 1 sets the stage for why we're seeing other states moving toward this opportunity to use these nontraditional water resources for beneficial reuse, whether for industrial applications or other types of applications. If you look at the United States, we're essentially tapped out on fresh surface water availability. We haven't built any new large reservoirs in 30 years; all of our major groundwater aquifers have been impacted by overpumping and mismanagement, particularly in the western United States, where we are located, and where significant oil and gas production occurs. These kinds of issues are driving the

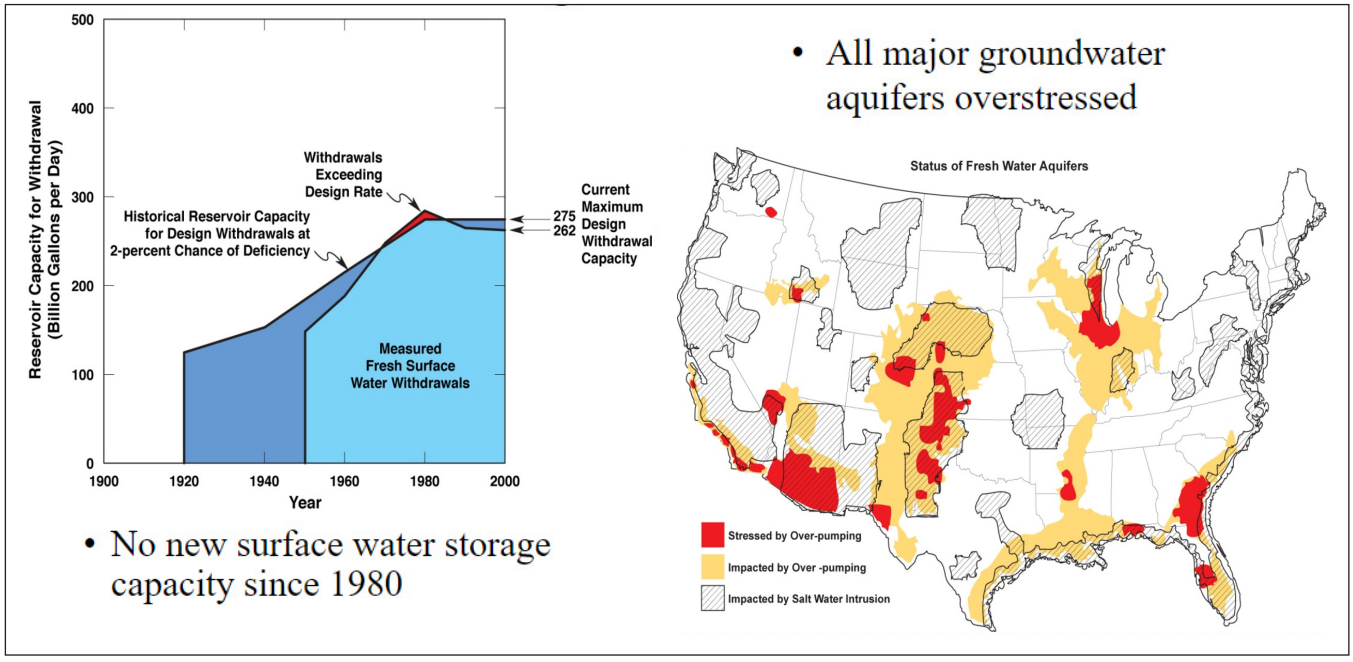


Figure 1. Water stress driving use of non-traditional waters.

Environmental Protection Agency, the Department of Energy, and other federal agencies, such as the Department of the Interior, to explore major initiatives related to the reuse of nontraditional water resources.

Figure 2 shows a bigger driver. If you look at climate change issues and climate history, we're in a very severe arid cycle. Most of these arid cycles last 300 years in the midlatitudes. We're about 150 years into the current arid cycle, which began around 1850 to 1860. Not only do we not have a lot in our savings account from available fresh surface water or groundwater to address these issues in more aridity over the next century or so, but we will also have to look at other resources. We've seen in the past that these large stresses, combined with low water availability, led to the abandonment of numerous historical sites, including Petra in the Middle East, Anasazi and Chaco Canyon, and Angkor Wat. We don't want to be the next abandoned, so we need to explore these alternative resources.

The Environmental Protection Agency, along with other federal agencies, is working on the National Water Reuse Action Plan (WRAP), which was initiated in late February 2020. This plan examines water stress across the United States and is based on the 2014 GAO report. It shows that most states are presenting either local or regional water stress and issues. Finding the next potential water supply is the driving force behind exploring these nontraditional water resources. That's why you see a lot of water organizations talking about "one water"—the fact that wastewater is going to become, with treatment, a new water supply.

The EPA program's focus includes produced water. Bob mentioned that New Mexico has been looking at produced water closely since the early 2000s. NM WRRI was involved in a 2003 study on a statewide produced water reuse program, and there has been significant work in New Mexico on this topic since then. Due to the work New Mexico has undertaken in the past, our consortium and the State of New Mexico have been asked to collaborate with the Groundwater Protection Council to lead activities associated with this national EPA program on produced water. That's quite an honor and one we take seriously. We currently have a Memorandum of Agreement with the Groundwater Protection Council to work in some of the areas Martha mentioned, specifically regarding public access to the water quality database information.

I'll talk about the heart of why we are looking at treatment. Bruce mentioned that produced water has a high salt content, which is not amenable to many desalination technologies. However, there are areas within produced water where we can see that certain types of treatment will benefit the State of New Mexico. Several pretreatment applications, where produced water is treated specifically for use within the oil and gas sector, as Rebecca mentioned, have advantages for New Mexico's water supplies, including the fact that pretreatment could

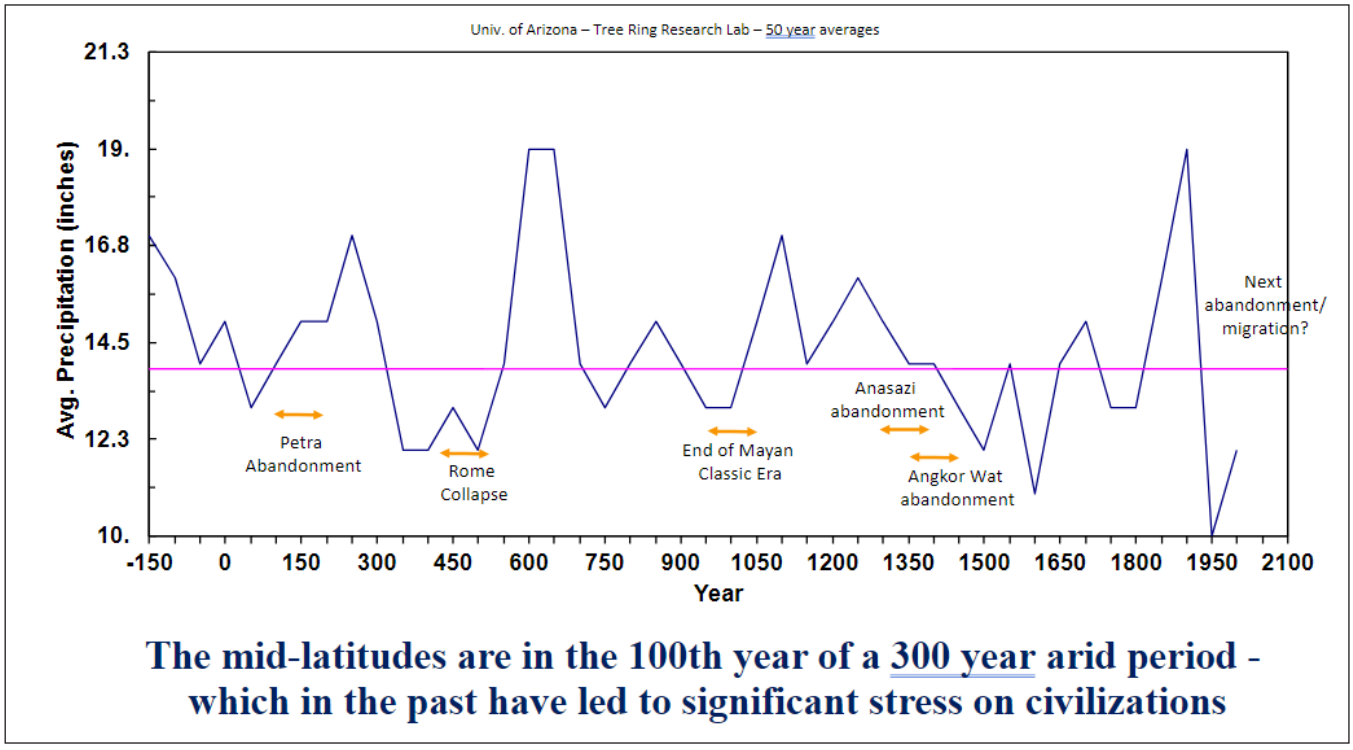


Figure 2. Southwest climate history based on tree-ring data.

eliminate the need to use freshwater for fracking. There is a movement in a number of states to look at these pretreatment standards as a way to eliminate or reduce freshwater use in industry. In many cases, people are looking at partial treatment because, as Bruce mentioned, the large number of salts associated with full treatment of produced water. Reclaiming some of the water, while not removing all the solids, would allow you to reuse some of the water and still reduce disposal volumes. It addresses some of the earthquake issues that Alex talked about. Even some of these different types of treatments that are not full desalination can still offer several benefits, including mineral recovery, creating additional usable resources, reducing the risk of earthquakes, and seeing reuse in oil and gas applications. Many of the treatment technologies people traditionally use could be applied to parts of produced water treatment, providing us with an opportunity to use additional water resources and address some of the climate change issues we're seeing.

Figure 3 shows some of the trends we're seeing within the oil and gas industry. It shows three qualities of water. In New Mexico, we have three types of produced water. Some very clean produced water comes from coalbed methane in the Raton Basin. It is in the 3,000 TDS range and sometimes a little bit better than that. There is a lot of conventional produced water from conventional oil and gas in the 35,000 TDS range, which is around seawater salinities. For those qualities of water, reverse osmosis and other types of technologies work quite well. There are some fouling issues caused by suspended solids, oils, and greases, but for some of these waters, these types of technologies are available. As mentioned before, as we enter more unconventional waters, we're looking at 200,000 to 250,000 TDS in some cases, which will require thermal technologies, which in the past have been very expensive. The point is that, even as we examine some of the high costs associated with these treatment technologies, we've seen a significant increase in disposal costs for the oil and gas industry. When I was working on this in the early 2000s, we were looking at 8 to 10 cents a barrel, which works out to be about two dollars per thousand gallons. In those days, treatment of brackish water was 4 to 5 dollars per thousand gallons. It was not economical 20 years ago to treat water. Fast forward to 2020, where we're looking at current disposal costs ranging from around 50 cents a barrel to 3 dollars a barrel. So, we're looking at an order of 20 to 80 dollars per thousand gallons. Even thermal technologies have an opportunity to be cost-effective in this area.

We're seeing a change in the target we're trying to meet. It was very difficult, even 10 or 15 years ago, to meet some of the disposal targets. However, with the large volumes of disposal and the reduction in disposal space due to saltwater disposal wells, the costs are increasing. The higher pressures in deeper wells are causing an increasing number of problems with earthquakes. The more water we can reuse on the surface and the less we dispose of it, the better off we will be from both an economic and environmental standpoint. Different applications are going to be the trend—different levels of treatment applied in different ways for different types of water. I don't think that there is a silver bullet out there, but I think that some imagination in how we put these treatment drawings together, which produced waters we select to treat, and how we treat them, has some benefits for the state.

Figure 4 comes from Bruce Thomson. He mentioned the fact that the State gets a third of its revenue from oil and gas, but I'm really interested in what Professor Janie Chermak in the Economics Department at UNM has come up with in looking at the social and economic benefits of using produced water for various purposes in the state. I've pointed out, at the very bottom, the broad range of what she has come up with, but all of them are positive. There is nothing in her evaluation that says that this could be negative. It would be if we can't treat the water to a standard that is protective of public health and safety. Even the lower range of estimates for the volumes of treated produced water we might be able to use is on the order of one or two Albuquerques a year. That is a significant amount of produced water, and it presents an opportunity for substantial socioeconomic benefits to the state. We're trying to identify, in the next couple of years as we move forward, what types of treatments make the most sense for which locations, which produced water types and qualities, and how can we maximize our ability to utilize that water for our best uses and improve the socioeconomic opportunities for the State of New Mexico, whether for industrial economic development or other applications. That is a summary of where I see the consortium moving and the interest we have in treatment over the next couple of years. Thank you.

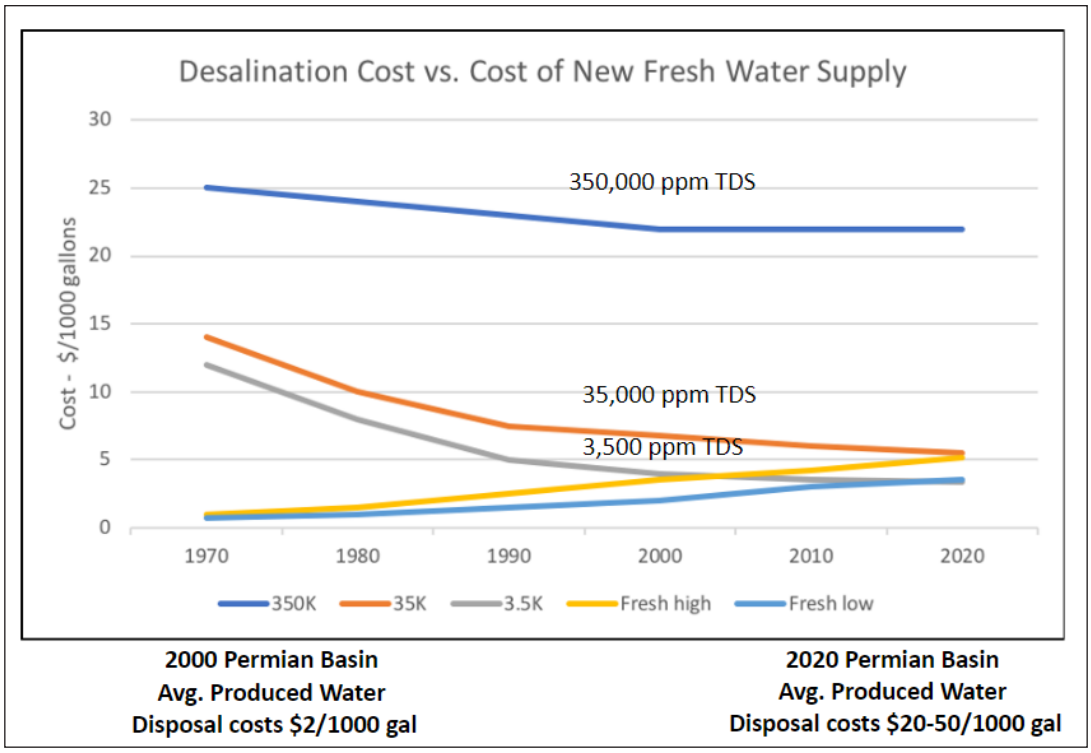


Figure 3. Changing desalination and produced water disposal costs.

Element	Value
Oil production value	$6-8 B
Gas production value	$5-7 B
General Fund direct revenues	$2 B
General Fund	$1B
Capital Outlay	$.4-.5 B
Taxes to local government	$.5 B
Percent of Budget from Oil and Gas Revenues	30%

(NM LFC Finance Facts, 2018)

Benefits for state economic development and industrial growth and societal benefits

Cost/Benefit	Range of Values
Price of Oil (WTI)	$55.00
Price of Recycled Water per barrel	$0.50 - $7.00
Marginal Cost of Production & Taxes	$20 - $25
Marginal Cost of Water Disposal per barrel	$0.50 - $2.25
Marginal Cost of Transportation	$0.00 - $9.00
Marginal Cost of Recycling	$1.00 - $16.00
Marginal Private Value of Recycled Water	$0.25 - $1.75
Marginal Social Value of Recycled Water	$0.48 - $51.24

(UNM - Chermak & Patrick, 2018)

Figure 4. Socioeconomic benefits of produced water reuse.

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65th Annual New Mexico Water Conference Poster Abstracts and Presented Posters

Ordered From Earliest to Latest Submission

*****Denotes Poster is Not Available in the Following Section*

1) Evaluation of Heavy Metal Adsorption onto Microplastics

Presenter: Jasmine Anne Quiambao, Civil Engineering, UNM, jannequiambao@unm.edu
Co-authors: Jorge Gonzalez-Estrella (Civil & Environmental Engineering, OSU), Kerry Howe (Civil Engineering, UNM)

This project evaluates the association of microplastics and heavy metals in freshwater systems. Microplastics are ubiquitous across aquatic environments. However, the studies on occurrences of microplastics in marine ecosystems are well-established compared to freshwater. Microplastics are defined as synthetic polymers with a diameter of <5mm. Microplastics with a diameter of <150 µm are of particular concern given their small size and their potential to be ingested. Microplastics could enter freshwater systems by recreational activities, solid waste dumping, wastewater treatment effluents, or other sources. The interaction of microplastics with other contaminants could enhance toxicity and threaten human health and the environment. Freshwater systems in New Mexico near abandoned mine sites have concentrations of heavy metals above the EPA maximum contaminant levels. This project aims to assess the adsorption of heavy metals onto microplastics in contaminated freshwater systems.

This research is divided into two main tasks: (1) detection and characterization of microplastics in freshwater systems containing elevated concentrations of heavy metals; and (2) evaluation of heavy metal adsorption onto microplastics in laboratory experiments. Water samples from Tingley Beach, the Rio Grande, and Laguna Pueblo, NM were collected and analyzed for this research. This project provides information about the occurrence of microplastics in freshwater systems in New Mexico and the potential adsorption of heavy metals onto them. The accumulation of heavy metals and microplastics in aquatic ecosystems may increase the potential toxicity to various living organisms. **(Pg. 141)**

2) Understanding Water Contamination by Household Chemicals: A Guide to Stop Polluting Taos Water

Presenter: Peggy De'Scoville, UNM-Taos, pde@unm.edu

A case study on common household chemicals with adverse effects on the water ecosystem. Chemicals discussed include bleach and chlorine, per- and polyfluoroalkyl substances (PFAS), polytetrafluoroethylene, benzophenone, triclosan, and synthetic musks. Each chemical is described, along with its effect on the environment, human health, and where to find it. The intention is to inform the reader and empower action.

This case-study was the assignment of Dr. Brooke Zanetell, FORS-2120-800. **(Pg. 142)**

3) Juvenile Drift of an Invasive Crayfish in the Pecos River, New Mexico

Presenter: Sara A. Ricklefs, Biology, ENMU, ara.ricklefs@enmu.edu
Co-author: Jesse E. Filbrun (Biology, ENMU)

Invasive crayfish disrupt ecosystem functions by competing and hybridizing with native species, altering physical habitats, and impacting water quality. In 2019 and 2020, we collected drifting juvenile crayfish in the Pecos River as part of our long-term Drifting Egg and Larval Fish Survey (DELFS). While downstream drift is a well-documented dispersal mechanism for early life stages of many marine and aquatic crustaceans, this behavior has not been reported for crayfish. Our study fulfilled two key objectives: 1) identify the drifting juvenile crayfish to species level using DNA barcoding and 2) report the timing and extent of drifting behavior relative to environmental variation. We collected 98 juvenile crayfish in 2019 and 59 juvenile crayfish in 2020. We confirmed that drift occurred at night from April through June. Collections occurred in relatively clear (5–64 NTU), warm water (15–23°C), and at low flows (41–152 cfs). We randomly selected 24 specimens from each field season for species-level identifications using the barcoding region of the cytochrome c oxidase I (COI) gene. We identified nearly all drifting juveniles as virile crayfish (*Faxonius virilis*). Collections of this invasive species have been recorded throughout the Rio Grande, but not in the middle Pecos River. Documenting this dispersal mechanism of an invasive crayfish species will be a valuable contribution to our understanding of crayfish invasion ecology. We believe educating the public on best practices to prevent further crayfish translocations within New Mexico should be a priority of watershed managers. **(Pg. 143)**

4) Coupling Winter Anoxia and Stream Metabolism within a New Mexico Montane Grassland Stream*

Presenter: Justin Nichols, Civil Engineering, UNM, justin76@unm.edu
Co-authors: Aashish Sanjay Khandelwal (Civil Engineering, UNM), Betsy Summers (Energy, Pacific Northwest National Laboratory), Peter Regier (Energy, Pacific Northwest National Laboratory), Ricardo González-Pinzón (Civil Engineering, UNM)

Historical studies have demonstrated drastic changes in a stream's biogeochemistry during seasonal ice- and snow-cover, such as observed winter dissolved oxygen (DO) depletion to hypoxic concentrations. Due to the logistical constraints of sampling DO in ice- and snow-covered streams, the sampling frequency is often sparse, which has led to multiple hypothesized DO depletion drivers. By utilizing aquatic semi-continuous sensors within the East Fork Jemez River, we observed prolonged winter DO depletion to anoxic concentrations, less than 0.2 ppm, for 57 days. By combining our aquatic data with meteorological data, we were able to find a strong temporal correlation between DO depletion

and snow depth with daily average DO declining by 8.6 ppm during five days of snow accumulation of 694.7 mm. Spectrograms indicated that diurnal cycling continued under ice-cover for both water temperature and DO, but cycling ceased during periods of prolonged snow cover. Principle component analysis verified a negative relationship between DO and snow depth, while DO recovery was correlated to increased stage attributed to spring snowmelt. The coupling between snow cover and DO depletion suggests that snow cover blocks solar radiation from reaching benthic autotrophic communities, thus stopping gross primary production (GPP) from occurring. DO rebounds when spring snowmelt scours enough ice and snow from the water column to revitalize reaeration and promote GPP by allowing solar radiation to reach the stream's benthos. Thus, our novel data demonstrates coupling between winter surface water quality, meteorological conditions, and stream metabolism.

5) Improving Fertigation Applications in a Flood-Irrigated Pecan Orchard*

Presenter: Esmaiil Mokarighahroodi, Plant and Environmental Science, NMSU, emokari@nmsu.edu

New Mexico is the largest producer of pecan in the USA with 43.8 million kilograms of in-shell nuts produced in 2019. The objective of this study is to investigate the soil nitrogen (N) distribution and root N uptake in a flood-irrigated pecan orchard located at the New Mexico State University Plant Science Research Center (PSRC). To measure soil N, loose soil samples were collected 5 times in three different distances (under canopy, dripline, and outside of dripline) from a tree trunk in six different depths. To determine the amount N in the pecan tree, plant samples including branch, leaf, stem, and nuts were collected 5 times. Results showed that considerable amounts of N were leached below rooting zone (approximately 60 cm) for all different distances in all months. As more root N uptake happens within rooting zone, N below the rooting zone can leach and contaminate the groundwater resources. No specific patterns were observed among soil N concentrations in different distances from the tree trunk for each month. Also, findings showed the NO_3 uptake increased sharply in the early growing season and declined gradually to the end of the growing season. The maximum NO_3 uptake occurred in May which was around 144 PPM. The results showed there was no increase in root NO_3 uptake after the peak root NO_3 uptake while two more fertigation applications were applied. Thus, findings showed that N fertilizer applications should be managed properly and should be applied any time before May.

Keywords: Nitrogen application; Nitrogen leaching; Root nitrogen uptake; Soil nitrogen

6) Recovery of Rare Earth Elements and Potable Water from Produced Water*

Presenter: Lin Chen, Civil Engineering, NMSU, chenlin@nmsu.edu
Co-authors: Frank Ramos (Geological Sciences, NMSU), Pei Xu (Civil Engineering, NMSU)

Produced water (PW) is the largest waste stream generated during oil and gas production. Recovery of potable-quality water and valuable metals such as rare earth elements (REEs) from PW could play a key role in reducing volumes of PW for disposal and mitigating the risks of conventional disposal processes. In PW, REEs such as lanthanum (La), neodymium (Nd), and europium (Eu), have been detected. However, present treatment technologies for PW is energy- intensive and high cost. Therefore, it is imperative to develop innovative low-cost and energy efficient technologies for clean water recovery and vital element recovery. Energy-efficient treatment of PW for clean water generation and for recovery of REEs provides an environmentally responsible and economically attractive solution to addressing the challenges of water scarcity, reducing the cost of PW disposal, and producing strategic elemental commodities. In this study, we developed an energy efficient and low-cost process for REEs recovery and production of clean potable water. Single slope, single basin solar stills (SSSS) are used for both generating of clean water and concentrating REEs for subsequent recovery. Multi-stage extraction of REEs using CYANEX572 extractant and ion exchange columns for separation of REEs can be applied. Results show that solar evaporation using SSSS can achieve 12.8-14.9% clean water recovery. Removal efficiencies of all metals in the distillate was higher than 96%, while the highest removal efficiency of 99.99% was achieved for Na, Mg, P, Ca, V, Mn, Fe, Ni, Se, and Sr. Recovery of Eu, La, and Nd are 88.7%, 21.1%, and 81.6%, respectively; recovery efficiency of REEs increased with increasing extraction reaction time during the baseline tests.

7) Flow Connectivity and Sediment Transport Modeling in Flashy Ephemeral Channel Networks

Presenter: Sandra Glasgo, Earth and Environmental Science, NMT, sandra.glasgo@student.nmt.edu
Co-authors: Daniel Cadol (Earth and Environmental Science, NMT), Madeline Richards (Ben Gurion University of the Negev) Jonathan Laronne (Ben Gurion University of the Negev), Kyle Stark (Ben Gurion University of the Negev)

In large river systems such as the Rio Grande, sediment influx and water delivery from ephemeral streams is difficult to quantify and track. Yet is has major management implications to such diverse issues as reservoir sedimentation, sediment plugs and avulsions, flooding, and additions to streamflow. In the Arroyo de los Piños, one such ephemeral system, we have been monitoring discharge at 18 different points for two years in an effort to quantify water and sediment delivery from the ephemeral channels. The data collected in the past, present, and future will allow for a better understanding of how the network connects across a range of precipitation intensities and magnitudes, and how these interactions control water and sediment delivery to the watershed outlet. Initial data support the prevailing understanding that the primary controls on local runoff generation are rainfall intensity, lithology, and sub-basin size.

To investigate how these flow events influence sediment discharge, future work will focus on building open channel flow models with sediment transport capability. First, we will focus on the outlet reach, where discharge and bedload data collected primarily during the 2018 monsoon season will be used to evaluate the quality of the sediment transport modules within the Army Corp of Engineers models HEC-RAS 1D/2D and ADH. If successful, we will then be able to model sediment transport in other reaches upstream in the channel network. Combined with our flow connectivity data, this would enable an unprecedented quantification of sediment transport connectivity within ephemeral fluvial systems. **(Pg. 144)**

8) Patch Mosaic Paradigms in Algae Turf Scrubber Substrate*

Presenter: Bert Siville, Plant and Environmental Sciences, NMSU, bsiville@nmsu.edu
Co-authors: Jessica Castro (Plant and Environmental Sciences, NMSU), Michaela Buenemann (Geological Sciences, NMSU), Wiebke J. Boeing (Fish, Wildlife & Conservation Ecology, NMSU)

Algae turf scrubbers (ATS) are increasingly utilized to grow benthic macroalgae on substrate to remediate aquatic ecosystems and wastewater while simultaneously growing beneficial biomass. Efficient estimation of algal biomass growth and composition are essential for economic management and may be achievable through spectral evaluation. ATS substrates across treatments were imaged and then digitized using ENVI visual analysis software, R studio statistical analysis software, and ArcGIS. Fragstats was then used to generate landscape, class and patch metric analysis. Analysis of correlations provided evidence of a negative correlation in percent land cover between two pairs of "class types." Spectral analyses were efficient at distinguishing among different health states of alga *Oscillatoria*.

9) Quantifying Patterns of Drifting Fish Eggs and Larvae in the Middle Pecos River

Presenter: Jesse E. Filbrun, Biology, ENMU, jesse.filbrun@enmu.edu
Co-authors: Richard M. Raymondi (Biology, ENMU), Sara A. Ricklefs (Biology, ENMU)

Native fishes of the American Southwest are increasingly imperiled by habitat fragmentation from dam construction and intense regional drying. To monitor fish assemblage responses to environmental change, we recently established a long-term Drifting Egg and Larval Fish Survey (DELFS) in the Pecos River near Fort Sumner, New Mexico. Herein, we present survey results for April through August 2020. Fish eggs and larvae were collected using 500 µm drift nets equipped with flow meters. Larvae were also collected using quatrefoil light traps. We surveyed the river on 15 occasions, during which we collected 105 samples. We sorted 4,385 fish eggs and 10,184 fish larvae from our samples. Most eggs and larvae were collected in drift nets shortly after sunset. Total densities of drifting eggs and larvae decreased dramatically after a two-week reservoir block release (sustained at 1260 cfs) during June, but rapidly increased within days after returning to base flows (about 57 cfs). Although we have yet to complete larval identifications, the general successional pattern we observed in 2019 and 2020 consisted of early pulses of several species of minnows, then river carpsucker, and lastly channel and flathead catfishes. Currently, we are working to identify fish eggs and cryptic larvae using the barcoding region of the cytochrome *c* oxidase I (COI) mitochondrial gene. Our goal for this study is to provide water release recommendations to Pecos River managers that reduce extinction risk of native fishes in the face of rapid climate change and other habitat disturbances. **(Pg. 145)**

10) The Environmental Legacy of Uranium Mining and Milling in New Mexico

Presenter: Bruce Thomson, Civil Engineering, UNM, bthomson@unm.edu

Between 1951 and 1989, the Grants mining district of northwestern New Mexico produced more uranium than any other district in the United States. Almost 250 mines were located in New Mexico consisting of both open pit and underground mines. Open pit mines, especially the large Jackpile-Paguate mine on the eastern flank of Mt. Taylor, left a large area of open pits and exposed strata that remains largely un-remediated and it is now a Superfund site. Dewatering of underground mines had a large impact on regional aquifers. Eight mills processed uranium ore at one time or another in the state by leaching with a strong acid (seven mills in NM) or alkaline solution (one mill), and then recovering the dissolved U from solution. The tailings were disposed of as a slurry in unlined tailings piles. Tailings wastewater was of very poor quality characterized by either low pH (acid leach mills) or high pH (alkaline leach mill), high total dissolved solids, and high concentrations of metals and radionuclides. Most mills were located in remote locations, have been remediated, and therefore present little threat to human health or the environment, but two of the mill sites have been declared Superfund sites. Though no mining or milling has occurred for nearly 20 years, it is important to understand the legacy of uranium production to develop effective remediation strategies and minimize risks to health and the environment if production resumes in the future.

Note: This poster is largely based on a chapter in the forthcoming New Mexico Geological Society Guidebook, 71st Field Conference, Geology of the Mount Taylor Area, 2020 published by the New Mexico Bureau of Geologic and Mineral Resources, New Mexico Institute for Mining and Technology. **(Pg. 146)**

11) Developing an Effective Monitoring Strategy Using Photogrammetry and 3D Mapping to Measure the Impact of a Plug and Spread Composite Treatment in a Degraded Alluvial Fan in the Semi-Arid Grasslands of the Southwest

Presenter: Meagen Larson, Forestry, NMHU, mlarson2@live.nmhu.edu
Co-authors: Blanca Céspedes (Forestry, NMHU), Julie Tsatsaros (Forestry, NMHU), Craig Conley (NMHU; USFS, Rocky Mountain Research Station), Sara Amina Sena (Hermit's Peak Watershed Alliance)

The degradation of alluvial fans in semi-arid grasslands of the Southwest is often the result of channel incision and has been shown to contribute to a loss of hydrologic connectivity between montane areas and lowland grassland areas. Anthropogenic activities including agriculture and human settlement have contributed to the degradation of fluvial systems through channel formation. Functionally intact alluvial fans are depositional areas that contain nutrient-rich, permeable soils that support forage and habitat suitable for livestock and wildlife as well as represent important recharge zones for groundwater and shallow aquifers. In this study, we examine the impact of a Plug and Spread composite restoration treatment in improving the hydrologic function of an alluvial fan system in northern New Mexico by restoring sheet flow to the alluvial fan floodplain. The response to

the restoration treatment will be evaluated using photogrammetry and 3D mapping to measure changes in sediment height and volume throughout the study site. Drone imagery is collected post restoration, both before and after the 2020 monsoon season (June-November 2020) and is being processed using Pix4D Mapper software. The software will create an accurate 3D model of the site through a generated orthoimage and digital elevation model in which sediment height and volume measurements can be taken. The goal of this study is to develop a replicable methodology for processing drone imagery using Pix4D Mapper as well as developing an effective monitoring strategy using these technologies to measure the impact of restoration treatments in precipitation-driven, semi-arid grassland ecosystems. **(Pg. 147)**

12) Isotopic Niche Overlap Among Freshwater Turtles in the Pecos River System, USA

Presenter: Thanchira Suriyamongkol, Biology, ENMU, thanchira.suriyamongkol@enmu.edu
Co-authors: Vinicius Ortega-Berno (Biology, ENMU), Laramie B. Mahan (Biology, ENMU), Ivana Mali (Biology, ENMU)

Aquatic turtles represent important biotic components of freshwater ecosystems. The Pecos River system is inhabited by six freshwater turtle species, including a widespread *Trachemys scripta* (Red-eared Slider) and a species of conservation concern *Pseudemys gorzugi* (Rio Grande Cooter). Here, we assessed isotopic niche widths and niche overlap of these two sympatric riverine turtles in the Pecos River tributaries, New Mexico, USA. In 2017 and 2019, we collected freshwater turtles using hoop net traps and snorkel methods. We used carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope analyses from three different tissue types: blood, nail, and carapace. We analyzed the data using the package SIBER in R. Our results showed niche partitioning among *P. gorzugi* populations, but little partitioning among sex classes within a population. At the sites where both species occur, we documented niche overlap, especially for $\delta^{15}N$ values. Stable isotopes showed similar ellipse area overlap (SEA_B) of *T. scripta* and *P. gorzugi* among populations (~20‰²), but little to no overlap of standard ellipse areas for small sample sizes (SEA_C). At the study sites where *P. gorzugi* co-occurred with *T. scripta*, it is likely that the species are competing for similar resources although *T. scripta* generally showed wider ranges for $\delta^{13}C$ and $\delta^{15}N$. Our study aids in understanding the ecology and natural history of *P. gorzugi*, one of the least studied freshwater turtles of USA. Moreover, this study provides insights to interspecific relations of *T. scripta*, one of the most invasive turtle species, in their native range. **(Pg. 148)**

13) Analysis of the Relationship Between Water, Oil and Gas in New Mexico: Past and Future Trends

Presenter: Bruce Thomson, Civil Engineering, UNM, bthomson@unm.edu
Co-authors: Janie Chermak (Economics, UNM), Katie Zemlick (NMOSE)

The relationship between oil & gas (O&G) production and water in NM is complicated. Large volumes of water are used for hydrofracturing (HF or fracking). The number of wells hydrofracked increased from 623 in 2015 to 1076 in 2019, while the volume of water used increased from 8,700 AF/yr to 40,000 AF/yr. Although this is a large volume, it constitutes less than 25% of groundwater withdrawn for agricultural use in Eddy and Lea counties in 2015 alone.

Far greater volumes of wastewater, or produced water (PW), result from O&G production. The volumes of PW increased by 20% between 2015 and 2019, from 115,000 to 160,000 AF/yr. More than 95% of PW is generated in southeastern NM. While the number of wells and O&G production continues to increase, the PW-to-oil ratio has steadily decreased from 10 bbls PW/bbl oil in 2008 to 3.1 bbls PW/bbl oil in 2019.

PW has an average salinity greater than three times that of seawater making re-use difficult. Roughly half of PW is used for secondary recovery of oil and the rest is disposed of by injection into salt-water disposal (SWD) wells. Some PW is used for HF, however, the amount is not known. No desalination of PW is done in NM and, due to its costs and complexity, large-scale desalination is not anticipated in the foreseeable future.

Decisions on future management of water by the O&G industry are primarily driven by private economic considerations, demonstrating the need for improved understanding between water and O&G production. **(Pg. 149)**

14) Environmental Flow Analysis for Rio Grande Silvery Minnow Recruitment

Presenter: Michael D. Porter, U.S. Army Corps of Engineers, michael.d.porter@usace.army.mil
Co-author: Aubrey Harris (U.S. Army Corps of Engineers)

Rio Grande Silvery Minnow (*Hybognathus amarus*, Silvery Minnow) reproduction in response to spring runoff is the focus of an analysis to improve our understanding environmental flow requirements. Water management on the Rio Grande over the past 100 years has changed the hydrology and channel geomorphology. Determination of appropriate flow parameters supporting floodplain inundation provides important information for fish nursery habitat, including Silvery Minnows. Water management and drought have reduced the magnitude of the spring snowmelt hydrograph, while channelization and in-stream structures have reduced the connectivity between the river and the floodplain. The availability of inundated floodplain habitat can have important implications for Silvery Minnow reproduction, recruitment, and population viability.

The objective of this study to better understand annual Silvery Minnow spawning and production in response to environmental flow parameters. Metrics describing juvenile production and other population parameters were calculated from Silvery Minnow population monitoring data. A functional analysis approach with HEC-Ecosytem Functions Model and R statistical software is used to evaluate the relationships of seasonal hydrology (magnitude, duration), seasonal hydrology paired with hydraulic analyses (1-D and 2-D hydraulics on various scales, habitat suitability indices), and Silvery Minnow life history metrics (seasonal recruitment trends and population indices). This method supports adaptive management by identifying environmental flow parameters that benefit recruitment, which may inform water management strategies and restoration design criteria. **(Pg. 150)**

15) Establishing Methods to Artificially Spawn Pecos River Minnows

Presenter: Richard M. Raymondi, Biology, ENMU, richard.raymondi@enmu.edu
Co-author: Jesse E. Filbrun (Biology, ENMU)

The Pecos River provides critical ecosystem services and water to support agricultural activities and human population centers. Unfortunately, dam construction, water extraction, and intense regional warming increasingly fragment the river and threaten its native ichthyofauna. Current hydrological regimens are causing collapses of native pelagic-spawning minnows and replacement by invasive fishes. In 2020, we were awarded a NM WRRI Student Research Grant to investigate the effects of streamflow on growth and survival of larval pelagic-spawning minnows. The first step of this project was to establish methods to induce laboratory spawning and hatching of captive minnows. We collected adults in spawning condition of target species (*Cyprinella lutrensis, Hybognathus placitus, Macrhybopsis aestivalis, Notropis stramineus*) from the Pecos River using backpack electrofishers. Fish were transported to ENMU, acclimated in aerated aquaria, and maintained on high-protein diets. Males and females were anesthetized with MS-222 and checked for spawning readiness. Gravid females and ripe males were injected with Ovaprim®, a spawning agent used to induce reproduction, and placed in aquaria with different environmental variables to determine optimal conditions for spawning. In total, we performed 438 injections from June to August resulting in four spawning events: one *H. placitus* released eggs that were not fertilized, and *C. lutrensis* successfully spawned on three occasions. As native fish populations continue to decline, conservation aquaculture may be necessary for species preservation. Our results will fill critical gaps on the efficacy of Ovaprim® on pelagic-spawning minnows for future spawning trials. **(Pg. 151)**

16) Investigating Channel Infiltration and Groundwater Recharge in the Jornada Experimental Range Using Chloride Profile Analysis*

Presenter: Sarah Reuter, Earth and Environmental Science, NMT, sarah.reuter@student.nmt.edu
Co-authors: Daniel Cadol (Earth and Environmental Science, NMT), Talon Newton (NM Bureau of Mines and Geology, NMT) Fred M. Phillips (Earth and Environmental Science, NMT)

Determination of the rate and distribution of groundwater recharge is essential to understanding the water budget of New Mexico and to making informed water plans. A study in the Jornada Experimental Range (*On the Sensitivity of Hillslope Runoff and Channel Transmission Losses in Arid Piedmont Slopes*) inspired us to look for evidence of percolation past the root zone in small, first order piedmont watersheds in the JER. Two cores were extracted from small streams of the same magnitude as the one in the afore-mentioned study, and one core was taken from a flat area near a drainage divide of one of the streams. The cores were divided into samples of ~10 cm depth. Water potential, gravimetric water content, and chloride concentration were measured for each. Water content was much higher in the fluvial cores than in the interfluvial core, indicating increased infiltration beneath channels. However, chloride profiles from each core showed a chloride bulge. This persistent chloride indicates that appreciable focused recharge has not passed through the vadose zone to the water table in modern times. The chloride bulges below the channels were lower in the profiles than the bulges in the interfluvial core, again indicating greater infiltration in the channels. Vegetation is also denser around the channels, which supports the interpretation that the increased infiltration becomes increased evapotranspiration. The depth at which decreases in water potential data were found, closely correlated with where increases in chloride content, and decreases in gravimetric water content occurred.

17) Exploring Surface Water as the Reservoir of CRE Infecting Patients in SE New Mexico*

Presenter: Kasandra Velarde, Biology, NMT, kasandra.velarde@student.nmt.edu
Co-author: Linda DeVeaux (Biology, NMT)

Many infections by formerly treatable pathogens are acquired during routine medical visits or prolonged hospital stays. Once the antibiotic resistance is established in the pathogen population, human activities can lead to the transfer of antibiotic resistance genes (ARGs) throughout the environment, including reservoirs such as surface waters. Recently, four cases of CRE (*carbapenem-resistant Enterobacteriaceae*), an emerging antibiotic resistant infection, have been found in three adjacent counties of SE New Mexico. The New Mexico Department of Health could find no identifiable health-care source; the only commonality was the Pecos River that traverses these counties. We sampled river water at five different locations in the affected counties, and screened the bacterial population for the presence of CRE-related genes, particularly the VIM gene common to the four patients. We found no carbapenem-resistance genes within five different bacterial communities. However, understanding the role of the environment as a reservoir of antibiotic resistance could give insight on the evolution of emerging pathogens in surface water to predict and control potential outbreaks.

18) Poly- and Perfluoroalkyl Substances (PFAS) Adsorption at the Air-Water Interface*

Presenter: Zahra Abbasian Chaleshtari, Chemical and Materials Engineering, NMSU, abbasian@nmsu.edu
Co-authors: Reza Foudazi (Chemical and Materials Engineering, NMSU)

Poly- and perfluoroalkyl substances (PFAS) are a group of manmade chemicals with each or more than one hydrogen atom on the alkyl chain replaced by a fluorine atom. PFAS have been recognized as contaminants of emerging concern (CECs) due to toxicity, bioaccumulation, and environmental persistence. Therefore, PFAS properties and remediation methods are being widely investigated in recent studies. Study of interfacial properties of PFAS is of great importance as the air-water interface is a retention source for PFAS transport in atmosphere, soil, and groundwater. In the present study, PFAS adsorption at the air-water interface is investigated. PFAS adsorption kinetics and equilibrium at the air-water interface are studied by measuring the dynamic surface tension. We evaluate the effect of perfluoroalkyl chain length, PFAS concentration, and composition of PFAS contaminants on their adsorption at the interface. The results of the present study have environmental implications for proper understanding of PFAS fate and transport.

19) Evaluation of Polychlorinated Biphenyls (PCBs) in Albuquerque Urbanized Area Stormwater*

Presenter: Zach Shepard, U.S. Geological Survey, zshepard@usgs.gov
Co-author: Kali Bronson (Bernalillo County)

The watershed-based MS4 permit for the Middle Rio Grande, New Mexico requires Bernalillo County to develop a strategy to identify and eliminate controllable sources of polychlorinated biphenyls (PCBs) that may cause or contribute to the exceedance of applicable surface water quality standards. Manufacturing of PCBs began around 1929 for use in industrial and commercial applications until their ban in 1979 due to their varying toxicity. Although legacy PCBs are no longer directly used, they do not readily break down and are therefore persistent in the environment. Additionally, some PCBs may still be made indirectly through various manufacturing processes. The U.S. Geological Survey, in cooperation with Bernalillo County, characterized PCB concentrations from four watersheds in the urban Albuquerque area. PCBs were detected in 34 of 36 stormwater samples and in 12 of 13 bed sediment samples collected during wet and dry seasons in 2017-18. Six of the 36 water samples exceeded the New Mexico surface-water quality standard of 14 nanograms per liter for the protection of wildlife habitat and aquatic life for PCBs. However, none of the water samples exceeded the permit level limit of 200 nanograms per liter for PCBs in stormwater systems discharging into the Rio Grande. The PCB congener profiles (contribution to total PCB concentration from each of the 209 distinct PCBs) indicate that sources to stormwater drainage basins in Bernalillo County originate both from legacy Aroclors, and from current-use sources, such as yellow pigments (for example, in printed materials and packaging in urban litter or refuse).

20) Biomineralization of Hypersaline Produced Water Using Microbially Induced Calcite Precipitation*

Presenter: Lei Hu, Civil Engineering, NMSU, leihu@nmsu.edu
Co-authors: Huiyao Wang (Civil Engineering, NMSU), Pei Xu (Civil Engineering, NMSU), Yanyan Zhang (Civil Engineering, NMSU)

Reusing produced water (PW) as the subsequent hydraulic fracturing fluid is currently the most economic and dominant practice in shale oil and gas industry. However, prior to the reuse, high $Ca2^{+}$ present in PW needs to be removed in order to minimize the potential for well clogging and formation damage. In this study, microbially induced calcite precipitation (MICP), as an emerging biomineralization technique mediated by ureolytic bacteria, was employed to remove $Ca2^{+}$ and toxic contaminants from hypersaline PW for the first time. Batch and continuous studies have demonstrated the feasibility of MICP for $Ca2^{+}$ removal from hypersaline PW under low urea and nutrient conditions. Throughout the operation of the continuous biofiltration system with biochar as the media, high removal efficiencies of $Ca2^{+}$ (~96%), organic contaminants (~100%) and heavy metals (~100% for As, Cd, Mn and Ni, 92.2% for Ba, 94.2% for Sr) were achieved when PW co-treated with synthetic domestic wastewater (SDW) under the condition of PW:SDW = 1:1 & urea 4 g/L. Metagenomic sequencing analysis showed that a stable ureolytic bacterial consortium (containing *Sporosarcina* and *Arthrobacter* at the genus level) was constructed in the continuous biofiltration system under hypersaline conditions, which may play a crucial role during the biomineralization process. Moreover, the combination of the MICP and ammonium recovery could significantly reduce the acute toxicity of PW towards *Vibrio fischeri* by 72%. This research provides a novel insight into the biomineralization of calcium and heavy metals from hypersaline PW through MICP technique. Considering the low cost and excellent treatment performance, the proposed process has the potential to be used for both hydraulic fracturing reuse and desalination pretreatment on a large scale.

21) Repeat Post-Wildfire Geomorphic Surveys of North Fork Eagle Creek, New Mexico, 2017 to 2021

Presenter: Alexander P. Graziano, U.S. Geological Survey, agraziano@usgs.gov

About one-quarter of the water supply for the Village of Ruidoso, New Mexico, is from groundwater pumped from wells located along North Fork Eagle Creek in the mountains of the Lincoln National Forest. Concerns regarding the effects of groundwater pumping on surface-water hydrology in the North Fork Eagle Creek Basin and the effects of the 2012 Little Bear Fire, which resulted in substantial losses of vegetation in the basin, led the U.S. Department of Agriculture Forest Service, Lincoln National Forest, to require monitoring of North Fork Eagle Creek for short-term geomorphic change as part of the permitting decision that allows for continued pumping of the production wells. To address the monitoring requirements, annual geomorphic surveys of North Fork Eagle Creek along a 1.89-mile-long study reach between two U.S. Geological Survey streamflow-gaging stations were conducted from 2017 to 2020 (a final survey is planned for the summer of 2021).

Geomorphic monitoring has included annual topographic surveys of 14 select cross sections and annual surveys of all woody debris accumulations and pools in the study reach channel. Preliminary results from the 2018 and 2019 surveys indicated that, since the 2017 survey, seasonal high-flow events have only caused minor observable geomorphic changes (aggradation or degradation of surface materials by about 1–2 feet) in parts of 3 of the 14 surveyed cross sections. However, the number of woody debris accumulations in the channel has substantially increased and some of those accumulations have appeared to influence local geomorphic changes, including the formation of pools. **(Pg. 152)**

22) Preliminary Results of Water Quality Monitoring of the Upper Pecos River*

Presenter: Letisha Mailboy, Natural Resources Management, NMHU, lmailboy@live.nmhu.edu
Co-authors: Megan Begay (Natural Resources Management, NMHU), Jennifer Lindline (Natural Resources Management, NMHU)

Since February 2020, NMHU Environmental Geology students have been collecting biweekly water quality data for the Upper Pecos River (UPR) to establish baseline conditions and assess whether waters are meeting their high quality cold-water designation. Five monitoring sites were established along a 25 km stretch at approximately equal distances to capture conditions above a historic mine site (Willow Creek), at the confluence of a tributary from the proposed exploratory hard rock drilling site (Macho Creek), and at several high-use recreation areas (Terrero Village, Dalton Canyon, and Pecos Village). The team is collecting bi-weekly in-the-field physical-chemical parameters (pH, temperature, dissolved oxygen, electrical conductivity) using

a YSI 556 Multi Probe and collecting grab water samples for turbidity analysis in the NMHU Water Resources laboratory using a Hach TL2300 turbidimeter. The majority of reported turbidity values fell below the 10 NTU threshold. Electrical conductivity increased downstream along the study stretch but remained within the 300 µS/cm threshold. Temperature increased downstream and throughout the summer months, but remained below the 25°C (77°F) segment-specific criterion. Statistical analysis and assessment of amounts and trends in these and other parameters relative to sample data, site location, and stream discharge are ongoing. Biweekly averages are being computed and trends are being assessed. Preliminary findings suggest that the Upper Pecos River is in good health and that the majority of the measured parameters are within range for its domestic water supply, fish culture, high quality cold-water aquatic life, and other designated uses.

23) Determining the Effects of Stream Restoration on Bluewater Creek, New Mexico

Presenter: Daniel Guevara, NM Environment Department, Surface Water Quality Bureau, daniel.guevara@state.nm.us

The Surface Water Quality Bureau (SWQB) of the New Mexico Environment Department (NMED) began an Effectiveness Monitoring program in 2008 to document water quality improvements from Clean Water Act §319 projects. Water quality is measured upstream and downstream of multiple stream restoration projects before and after implementation, to document the effectiveness of projects in improving impaired streams. This monitoring has focused primarily on stream temperature, which is one of the most common causes of stream impairment in New Mexico. Data loggers record stream temperature at 15-minute intervals from spring through fall, which allows for an Analysis of Covariance to quantify the effects of the projects, which primarily involve fencing, planting, and in-stream structures. Results have shown decreases in maximum stream temperatures due to restoration on Bluewater Creek, San Antonio Creek, and Comanche Creek. Other projects have not produced similar results, but monitoring is ongoing to account for the lag time of vegetation growth. These results can provide useful feedback to project managers and restoration practitioners in planning future work. **(Pg. 153)**

24) Monitoring Toxic Metal Uptake by Corn Grown in Agricultural Fields Across Animas and San Juan Rivers*

Presenter: Michael Whiting, Plant and Environmental Sciences, NMSU, mikeaid@nmsu.edu
Co-authors: Guarav Jha (Plant and Environmental Sciences, NMSU), April Ulery (Plant and Environmental Sciences, NMSU), Kevin Lombard (Plant and Environmental Sciences, NMSU)

On August 5, 2015, more than 3 million gallons of metal contaminated water from the Gold King Mine were released into Cement Creek unintentionally, leading to the contamination of the Animas and San Juan Rivers. Analysis of edible produce collected from fields irrigated with Animas River water was done in 2018 and found three corn samples with lead concentrations above the World Health Organization (WHO) guideline value of 0.05 ppm. Since then, the original samples were reanalyzed, resulting in two corn samples out of 30 still being above the WHO guidelines. The purpose of this study is to investigate these findings and to monitor the metals lead, arsenic, and aluminum in the agricultural fields.

Five fields along the Animas and San Juan Rivers were selected for the study. Samples of soil, leaf tissue, corn husk, and corn kernels were collected through the pre-growing, growing, and post-growing seasons. These samples were analyzed using ICP-MS/OES (Inductively Coupled Plasma-Mass Spectrometry/Optical Emission Spectrometry) and PXRF instrumentation, focusing on the elements Pb (lead), As (arsenic) and Al (aluminum).

25) Solar Reforming of Microplastics in Water for H_2 Production and Degradation Using Nanocomposite Photocatalysts

Presenter: E.M.N. Thiloka Edirisooriya, Civil Engineering, NMSU, thiloka@nmsu.edu
Co-authors: Huiyao Wang (Civil Engineering, NMSU), Pei Xu (Civil Engineering, NMSU)

Microplastics are considered to be the most substantial category of anthropogenic particles. Highly stable and durable plastic particles are accumulated due to the plastic debris released into water bodies. Millions of micro- and nano-sized plastics are formed as a result of photodegradation, embrittlement, and fragmentation because of wave action. The long-term presence of these particles in water and their accumulation in the food chain have severely impacted living organisms, including human beings. According to the statistical analysis using Google Scholar, studies on microplastic and nano-plastics have rapidly increased with substantive research interests in toxicity and treatment.

When categorizing the removal technologies in terms of particle size, the particles greater than 1 mm can be effectively removed using membrane bioreactors, retrofiltration, bacterial oxidation, rapid sand filter, and disc filter. Further, the coagulation process is used to remove microplastics, and Al-based coagulants are found to be the most effective. Microplastics within the size range of 10-20 µm are removed using the magnetics extraction method with Fe nanoparticles. Photo reforming of plastic waste has been identified as a much greener removal method because it could generate H_2 during the process. Platinum nanoparticles deposited on zinc oxide (ZnO) nanorods (ZnO-Pt), UV-absorbing TiO_2-Pt photocatalyst, and the toxic CdS/CdOx quantum dots have been used in photo reforming microplastics. Highly functional photocatalysts such as ZnO-Pt, TiO_2-Au, TiO_2-Pt, and graphene oxide/TiO_2/Au ternary nanocomposites prepared using atomic layer deposition and hydrothermal deposition methods are proposed to use in further studies to remove micro- and nano-plastics that can easily pass through the conventional treatment methods. **(Pg. 154)**

26) Assessment of the Cyanobacterial Harmful Algal Blooms (cHABs) and Toxins in the Blooming Water Bodies of New Mexico

Presenter: Sergei Shalygin, Plant and Environmental Sciences, NMSU, nqgood@nmsu.edu
Co-authors: F. Omar Holguin (Plant and Environmental Sciences, NMSU), Peter Cooke (Plant and Environmental Sciences, NMSU)

Desert ecosystems are usually considered terrestrial, where water algal blooms are not quite common. However, there are many water reservoirs in American deserts, and New Mexico is not an

exception. Summer 2019 brought worrisome news that several New Mexican lakes were blooming with potentially harmful cyanobacteria. This message was even televised on the news. Harmful blooms when massively developed may harm small and large animals as well as humans. Cyanobacterial species could produce various toxins belonging to different classes of the chemical compounds. Small doses of toxins such as Microcystin may cause liver damage, and Saxitoxin could stop normal function of lung muscles leading to serious health problems. The purpose of my research was to detect cyanobacterial Harmful Algal Blooms (cHAB) within blooming waters in New Mexico. Collected cyanobacterial biomass was investigated under a light microscope; all three lakes under investigation: Caballo, Snow, and Abiquiu lakes showed presence of potentially toxic cyanobacterial species. Advanced Ultra Performance Liquid Chromatography with tandem mass spectrometry were used in order to detect toxins. Mass spectral Multiple Reaction Method (MRM) was able to detect Microcystin-LR and Microcystis-LL in the water as well as cyanobacterial biomass collected in Caballo Lake in the summer of 2020. Additionally, water samples from Abiquiu Lake showed the presence of Microcystin-LR. Initial concentration estimation showed that Microcystis-LR found in Caballo Lake is present in the 100 micrograms per microliter concentration, which is 100 times higher than the World Health Organization recommendation for base level of Microcystins. Future research is needed to confirm this major finding. Next Generation Sequencing research is required to confirm species composition estimates based on microscopical observations. **(Pg. 155)**

27) The New Mexico Produced Water Database 2020

Presenter: Martha Cather, Petroleum Recovery Research Center, NMT, martha.cather@nmt.edu
Co-author: Raven Goswick (Petroleum Recovery Research Center, NMT)

Produced water management and reuse is of growing concern in New Mexico. Key to management is developing a better understanding of critical data such as volumes, locations, quality, and rates of production/injection. The primary objective of this research was to build a geospatial database of oilfield water volume information that can be linked to the existing produced water quality databases. The NMOCD provides oil, gas, and water production and injection data on a monthly basis. The data are publicly available, but in a format difficult for the average user to manipulate. We have compiled this information into a database that allows users to conduct temporospatial and stratigraphic analysis, to better visualize locations, important formations, and volumes of water production and injection and in doing so to have a better understanding of the overall "budget" for oilfield waters in New Mexico. The database is linked to two pre-existing water quality databases. A second effort of the work was to solicit information from the water management industry concerning management practices so that we could have a clearer idea of the entire budget of water including freshwater additions and recycling of produced water. The static database has been completed and will be available soon; unfortunately, little additional information was forthcoming from industry. A second phase to make the data available online and provide more frequent updates for some data is envisioned for the coming year, along with renewed efforts to engage industry in obtaining the data they say that they need. **(Pg. 156)**

28) Hydrogeochemical Analysis of Springs in the Cibola National Forest: Implication for Springs/Wetlands Sustainability & Geochemical Response to Forest Fire

Presenter: Naomi Delay, Earth and Planetary Sciences, UNM, ndelay567@unm.edu
Co-authors: Laura J. Crossey (Earth and Planetary Sciences, UNM), Livia Crowley (National Forest Service, Cibola NF)

Aridland springs of the Southwest provide habitat for many species and important resources for local communities. The Manzano Mountains of north-central New Mexico provide important sources of recharge to springs, local wetlands, and regional groundwater basins. Ojo del Rancho del Medio (RDM) and Ojo del Rancho del Medio West (RDMW) springs within the Mountainair District of the Cibola National Forest are the focus of this study. Regionally, springs are associated with the Madera Group of Pennsylvanian age, dominated by carbonate lithologies. We use a multidisciplinary approach to quantify spring sustainability and determine the sources and pathways to springs.

Water samples have and will be collected for analyses of major ion chemistry and stable isotopic analysis of deuterium and oxygen in order to determine the flow path, recharge mechanisms, and to determine the sources of soluble ions of these spring waters. Monitoring (conductivity, depth, and temperature) for selected time intervals will help connect water quality to spring discharge and documenting change across rainfall events as well as seasonally.

Preliminary analyses of isotopologues (δD and δ18O) show these springs are within the range of observed values for the nearby Sandia Mountains consistent with winter recharge mechanisms. Preliminary major ion geochemical analyses similarly show these springs are consistent with other Sandia Mountain springs issuing from the Madera Group carbonates.

Monitoring of the water quality of these springs will provide a baseline of the seasonal hydrochemistry and assist in understanding the sustainability of these springs to better inform land management decisions. **(Pg. 157)**

29) Case Study of *Acequias* and Native Bees: Connections and Solutions*

Presenter: Adrienne Rosenberg, UNM, arosenberg1@unm.edu

For hundreds of years, residents in New Mexico have distributed water across the semi-arid landscape through a network of community-controlled ditches called *acequias*. Research has shown that *acequias* provide important ecosystem services, such as recharging aquifers, improving groundwater quality, and supporting wildlife, to the surrounding community and environment. New Mexico is also recognized as hosting some of the most diverse native bee populations in the United States. These keystone and indicator species provide a variety of ecosystem services, such as crop pollination, food for wildlife, and bank stabilization for *acequias* (through riparian vegetation pollination), that are vitally important to landscape functions. Today, against the backdrop of adjudication, *acequias* are in peril of losing their capacity to function under the threats of climate change and waterscape disruption. Native bees are also experiencing precipitous declines due to similar threats of climate change and habitat fragmentation. Yet within the mutual danger to each,

there are solutions for both. This paper argues that *parciantes* can assist in preserving their water rights through the establishment of native bee habitat (and pollinator corridors) on *acequia* fed land while directly curbing the impacts of climate change, waterscape disruption, and habitat fragmentation.

30) Phycoremediation of Contaminated Groundwater with Microalgae for Simultaneous Water Treatment and Biofuel Production at a Legacy Uranium Mining Site

Presenter: Zachary DeLay, Trades, Advanced Technologies and Sustainability, SFCC, zachary.delay@sfcc.edu
Co-authors: Annie Padilla (Trades, Advanced Technologies and Sustainability, SFCC), Ondine Frauenglass (Assistant Director, SFCC), Luke Spangenburg (Biofuels, Center of Excellence, Training Center Corporation, SFCC), Stephen Gómez (Trades, Advanced Technologies and Sustainability, SFCC)

The former uranium-ore processing facility at Ambrosia Lake processed more than three million tons of uranium ore between 1958 and 1963, providing uranium for U.S. national defense programs. BHP, a global mining company, has contracted with NREL and Santa Fe Community College to determine the feasibility for simultaneous phycoremediation and biofuel production from algae grown using water at Ambrosia Lake containing elevated concentrations of radionuclides. SFCC has isolated and cultivated several strains of site-specific algae and tested growth in well water from the site. Initial results suggest algae may remove U and Ra from the groundwater. The cleaned water will be used to irrigate crops that can phytoremediate the legacy site. The biomass from these isolated algae cultures and field crops will be provided to NMSU and NREL for analysis and fuel conversion. The project is a collaboration between NREL, BHP, NMSU, Oregon State University, and SFCC to research sustainable ways to clean up legacy mining impacts and develop feedstocks for biofuels. We will present the background for this project, which can serve as a model for expanded efforts around the world and provide a new opportunity for large-scale algal biomass cultivation and reclamation of contaminated mine water. **(Pg. 158)**

31) Evaluating Soil Lead Bioavailability in Agricultural Fields Across the Animas Watershed*

Presenter: Michael Whiting, Plant and Environmental Sciences, NMSU, mikeaid@nmsu.edu
Co-authors: Bianca Wright (Plant and Environmental Sciences, NMSU), April Ulery (Plant and Environmental Sciences, NMSU)

In 2015, an incident of three million gallons of mine waste being spilt into the San Juan and Animas rivers lead to an increase of studies monitoring lead (Pb), arsenic (As) and aluminum (Al) in corn crops grown in the northern New Mexico area. A 2019-2020 study found a possible contamination of Pb in corn kernels. This study follows up on the previous investigation verifying that Pb contamination is present, and to determine if there is a possible pathway into the edible parts of corn grown in four selected fields of the watershed. Evaluating the soil lead bioavailability in agriculture fields across the Animas and San Juan Watersheds benefits several communities living in this region, including members of the Navajo Nation, local growers, and consumers in and around the Farmington and Aztec area.

32) A Critical Review of Reclamation's Yield Modeling for the New Mexico Unit of the Central Arizona Project

Presenter: Norm Gaume, P.E., retired, water resources engineer/manager/consultant; normgaume@gmail.com
Co-author: Peter Coha (retired, Intel; peter.coha@gmail.com)

It's important in these times when important government decisions are made without regard to the pertinent facts and science to note publicly when public water development reports and developed water yield analyses overstate the scientific data upon which they are based.

During the June 2020 review period for the draft Environmental Impact Statement (EIS) for the Gila River Diversion and Storage Project, Norm Gaume and Peter Coha obtained from the Bureau of Reclamation and operated the Excel spreadsheet models of the yield of the proposed water development project and the downstream impacts of diversions. They found the presentations of the yield model results and the associated economics in the draft EIS and technical memoranda substantially overstated the modeled yield and understated the developed water cost.[1]

- Annual unit costs of developed water are calculated by dividing total annual costs by mean annual net yield. The draft EIS used the term "applied water." The model and Reclamation's written answers to questions revealed that "applied water" included evaporation losses from the project storage ponds. The unit costs were for water diverted into storage, not the cost of water delivered to farms.

- The project benefits were based on a crop mix including 25% pecans. The draft EIS failed to mention the model showed no stored water available for release for 396 consecutive days in 2012 and 2013 and daily irrigation releases of stored water as low as 0.07 cfs in order to provide continuous daily releases.

- The draft EIS contained a literature review of evaporation loss rates from shallow storage ponds without documenting regarding rates that were used. The model contained computed evaporation rates for the Cliff-Gila Valley with annual averages substantially lower than the annual rates used by the New Mexico Interstate Stream Commission for Arizona v. California annual decree accounting and a negative slope from 1967 to 2017.

The poster will show a comparison of the representations and conclusions of the draft EIS with graphically presented modeling data.

The Gila Diversion and Storage Project was allowed to die after $16 million was spent for its planning because the draft EIS showed it was unfeasible. The draft EIS narratives and high-level performance representations made by the draft EIS are falsely superior to the underlying modeling basis of the project's performance.

[1] Gaume, Norm, and Peter Coha, "Comments of Norm Gaume, P.E. (ret.) and Peter Coha pertaining to the Draft Environmental Impact Statement (DEIS) dated April 2020 for the New Mexico Unit of the Central Arizona Project (NM Unit)", June 8, 2020, 27 pages plus attachments **(Pg. 159)**

33) Characterization of Metal Uptake in Corn Grown in a Variety of Soil Types*

Presenter: Mckayla Gilbert, Farmington High School, kaylagilbert02@gmail.com

Farmers along the San Juan River in the Four Corners Region in New Mexico and the Navajo Nation struggle with continual contamination to their irrigation water source and food crop from an abandoned mine spill in 2015, the Gold King Mine (GKM) Spill. Abandoned mines containing toxic waste in southwest Colorado, including GKM, are upstream of New Mexico and the Navajo Nation. Long-term exposure to metals and metalloids such as uranium (U), cadmium (Cd), lead (Pb), and arsenic (As) can have an adverse effect on development of the human body, and the cognitive development of children (Chang et al., 2014). Contaminated *Zea Mays* (Naadą́ą́) samples and control were collected and analyzed, to characterize metal uptake in corn grown in a variety of soil types. Concentration levels of U, Cd, Pb, and As in corn were measured by the Inductively Coupled-Plasma Mass Spectrometer (ICP-MS). The mean concentration for U, Cd, Pb, As were 0.040628 ppb, 5.789 ppb, and 1.296 ppb, respectively. Arsenic results were below detection levels of the spectrometer.

34) Naïve Occupancy of the Rio Grande Cooter (*Pseudemys gorzugi*) Across 16 Survey Sites on the Pecos River in New Mexico and Texas*

Presenter: Laramie B. Mahan, Biology, ENMU, laramie.mahan@enmu.edu
Co-authors: Lawrence G. Bassett (Biology, TXST), Thanchira Suriyamongkol (Biology, ENMU), Michael R. J. Forstner (Biology, TXST), Ivana Mali (Biology, ENMU)

The Rio Grande Cooter (*Pseudemys gorzugi*) is a large riverine turtle that is considered threatened in New Mexico and Mexico, and a species of greatest conservation need in Texas. The species occurs in the Rio Grande drainages in southeast New Mexico, southwest Texas, and northeast Mexico. In the US, the majority of survey efforts have been focused on the smaller tributaries of the Rio Grande watershed including the Black River (NM), Delaware River (NM), and Devils River (TX). The Pecos River itself has not been properly surveyed for the species in over a decade. Yet, the Pecos River is one of most anthropogenically altered rivers in the US, potentially threatening the persistence of the species. During the summer of 2020, we surveyed the Pecos River using hoopnet traps across 16 sites in New Mexico and Texas. We marked each *P. gorzugi* captured and took standard measurements. We collected water-quality parameters such as pH, conductivity, temperature, flow, depth, and turbidity. Overall, we captured *P. gorzugi* at 5 of the 16 sampling sites (4 in NM, 1 in TX), with a naïve occupancy of 31.25%. We captured 11 *P. gorzugi* including 4 females, 6 males, and 1 juvenile. In the summer of 2021, we will repeat our efforts at 16 new localities to develop a single season, single species occupancy model. Determining where *P. gorzugi* occurs along the Pecos River system is important for examining which environmental factors affect species presence/absence, which will aid the assessment of the species' conservation status.

35) A Comparison of Methods to Estimate Water Use for Irrigated Agriculture Near Fort Sumner, New Mexico*

Presenter: Amy E. Galanter, New Mexico Water Science Center, U.S. Geological Survey, agalanter@usgs.gov
Co-authors: Allison Flickinger, Jeb Brown (New Mexico Water Science Center, U.S. Geological Survey), Julie Valdez, Charles Lawler, Matt Nelson (Water Use and Conservation Program, NM OSE)

Irrigated agriculture accounts for most of the water used in New Mexico, yet there is a lack of reliable and readily available data for irrigated agriculture water use. The New Mexico Office of the State Engineer estimates water use for irrigated agriculture using the Blaney Criddle (BC) method which calculates the evapotranspiration (ET) for a given crop type, region, growing season, and meteorological condition and then applies that number to the irrigated acreage. The BC method is time consuming and requires knowledge of the crop type, which is often sparsely available. Remote-sensing methods for crop ET estimation are attractive due to readily accessible data, availability of data for areas of interest, and the potential for quick and frequent output of ET estimates. The USGS completed a comparative analysis between the BC method and a remote-sensing based estimation method (Operational Simplified Surface Energy Balance [SSEBop]) for 5,476 irrigated acres in the Fort Sumner Irrigation District. The SSEBop method estimated 5% less ET (523 acre-ft) than the BC ET estimation, which could be related to the fact that the BC method estimates ET under ideal conditions while the SSEBop method estimates actual ET. This localized case study shows that the SSEBop method was comparable to the BC method and more investigation is merited on a statewide comparison for various scales, topographic settings, and crop types.

36) Estimates of Water Use Associated with Continuous Oil and Gas Development in the Permian Basin, Texas and New Mexico, 2010–2019*

Presenter: Amy E. Galanter, New Mexico Water Science Center, U.S. Geological Survey, agalanter@usgs.gov
Co-authors: Grady P. Ball, Joshua F. Valder, Ryan R. McShane, Joanna N. Thamke, Jeremy S. McDowell, Natalie A. Houston (U.S. Geological Survey)

The Permian Basin, located in west Texas and southeastern New Mexico, is one of the largest conventional oil and gas reservoirs in the United States and is becoming one of the world's largest continuous oil and gas (COG) producing reservoirs. Continuous, or horizontal well drilling techniques, extract oil and gas by directionally drilling and hydraulically fracturing the reservoir rock surrounding the borehole. The extraction of oil and gas from COG reservoirs using hydraulic fracturing requires large volumes of water, yet a comprehensive assessment is needed to estimate the total volume of water. The USGS is conducting a project to assess the entire life cycle of water use in areas of COG development. A framework of scripts and regression analyses were used to estimate direct, indirect, and ancillary water use associated with COG development in the Permian Basin from 2010 to 2019. The framework used to develop the scripts and regression analyses is presented as a method to model and analyze water use in multiple areas of COG development, where water-use data often are lacking. This analysis in the Permian Basin uses a similar

analytical framework to one used to analyze Williston Basin COG development in North Dakota and Montana.

37) Abatement of Lead and Uranium by Fired Natural Clays to Produce Potable Water

Presenter: Jeremy Jones, Chemistry and Biochemistry, NMSU, odinseye@nmsu.edu
Co-authors: Sarah Bockisch, Moticha Franklin, Antonio Lara (Chemistry and Biochemistry, NMSU)

Two of the most dangerous heavy metal contaminates found in drinking water are lead and uranium, both of which cause serious detrimental life threating effects. Modern technologies that combat these toxins in water are generally expensive and difficult to maintain. Most people affected by this problem do not have the means to implement these types of technologies. Clays offer an appropriate solution due to their cation exchange capabilities, but when clays become wet, they are difficult to manage. Alternatively, solid phase fired clay pellets are easy to manage, implement, maintain, and are cost effective. The main objective of this study is to determine the efficacy of fired clay pellets for the abatement of uranium and lead in aqueous solutions. Two clays were chosen, one from New Mexico and one from Arizona. Each fired clay material has been exposed non-competitively and competitively to 250 ppb solution of uranium and lead for seven days. To keep the chemical sorption potential similar between exposures, each metal contributes 125 ppb to the solution in the competitive study. All samples were tested in triplicate and agitated for the duration of the experiment to minimize concentration gradient potential. The supernatant of the exposed samples was analyzed with ICP-MS. All samples exposed to the clay pellets exhibited concentrations below the EPA MCL, 30 ppb for uranium and 15 ppb for lead. Based on this analysis, it can be determined that both clay materials provide an efficacious method in the removal of aqueous uranium and lead. **(Pg. 160)**

38) The Solution to Pollution is Diminution: Use Only Enough

Presenter: Cecilia V. López, Advanced Technology and Sustainability, SFCC, cecilopez20@hotmail.com

Algae blooms are photosynthesising, microscopic bacteria that live in slow moving waters like lakes, rivers, and ponds creating toxins harmful to humans, pets, fish, and ecosystems. Algal blooms are caused by hot temperatures, climate change, upstream pollution, waste water from treatment plants, and runoff from farms.

Solutions

It isn't realistic to kill off bacteria in lakes and reservoirs as treatments can kill fish and harm the ecosystem. We can, however, reduce nutrients like phosphorus and nitrogen from getting into rivers and runoffs that feed into the lakes by working with New Mexican farmers and educating them on what they can do to help prevent harmful algal blooms, HABs.

Only use what you need.

- Nitrogen and phosphorus are the nutrients found in fertilizers that cause harmful algal blooms. Educating farmers on the benefits of only using the amount of fertilizer needed for optimum crop growth and a quality product would decrease the amount of nutrients found in runoff.
- Giving farmers incentives to use alternative farming methods could also directly affect the amount of nutrients found in runoff. Dry farming is a farming method that requires little to no irrigation for crop growth and would completely dissolve the issue of having nutrient rich runoff that creates HABs. Though New Mexico has a rugged landscape and rainfall is scarce, studies show dry farming to be a successful, alternative farming method. It has been used by New Mexican pueblos for many years, and can be adopted by many New Mexican farmers if given governmental incentives. **(Pg. 161)**

39) Comparison of Water Movement in Pecan Fields Under Different Irrigation Scenarios; Implications to the Water Cycle

Presenter: Jorge Preciado, NM WRRI, NMSU, preciado@nmsu.edu
Co-authors: Alexander "Sam" Fernald (NM WRRI), Richard Hereema (Plant and Environmental Sciences, NMSU), Salim Bawazir (Civil Engineering, NMSU), Manoj Shukla (Plant and Environmental Sciences, NMSU), Curt Pierce (Plant and Environmental Sciecnes)

Water balance is important to provide information and to conserve water: the flow of water in the system can be used to help manage the water supply, and changes in management can increase water productivity in arid regions. For this study, the soil-water content was measured from one soil column within orchards using time domain reflectometry probes (CS655 12cm, Campbell scientific) installed at different depths in the root zone of pecans and stored measurements in a Campbell Scientific data logger CR300. Water that passes the root zone was considered deep percolation. This study estimates recharge and models water flow through the soil in drip and flood irrigated pecan orchards to better understand surface water/groundwater interactions for improved river basin water management and quantifies water stored in the soil and lost through evapotranspiration.

This research is expected to provide a better estimate of the water consumed by pecans, and the amount of water that percolates. Thereby, we will have a better quantification of the water that is used in agriculture and water that percolates to recharge the basin. The project will evaluate the best irrigation scenario for the Mesilla Valley, and make projections of the different irrigation methods to grow sustainable pecans in the valley. It will add to our understanding of the implications to the water cycle. This will help lead to better agricultural practices in order to achieve crop sustainability in the area. **(Pg. 162)**

40) Acoustic Pipe Microphone Calibration in a Sand-rich New Mexican Ephemeral Channel*

Presenter: Kyle Stark, Earth and Environmental Science, NMT, kyle.stark@student.nmt.edu
Co-authors: Daniel Cadol (Earth and Environmental Science, NMT), Jonathan B. Laronne (Geography and Environmental Development, Ben Gurion University of the Negev), David Varyu (Technical Service Center, Bureau of Reclamation)

Monitoring the transport of bedload sediment (the fraction of sediment transported via traction along the bed of a river) is notoriously difficult, time-consuming, and expensive. Transport rates are usually estimated between flood events using sediment traps, scour chains, or through geomorphic analysis. Very few experiments attempt to monitor directly and continuously. One such location is the sediment monitoring and research facility in the Arroyo de los Pinos watershed, an ephemeral tributary of the Rio Grande. Samplers emplaced in the channel bed operate at near 100% efficiency (i.e., they capture bedload at rates equal to its transport downstream) but have a limited capacity. In ephemeral channels such as the Pinos, their capacity is often reached less than 20% through the duration of the flow.

One solution to this problem is to install instruments that measure bedload indirectly. At the Pinos, we have chosen to use acoustic pipe microphones, which record the acoustic response from the impact of sediment on a hollow pipe. These instruments can monitor the channel continuously, even after the samplers reach capacity. The data presented here is an initial calibration of these instruments from the Pinos, a sand-rich channel. We present two methods of calibration; only one improves the correlation between measured bedload flux and acoustic pipe microphone response above the base model. With careful calibration of these instruments, river channels can be monitored for bedload transport at a fraction of the cost.

41) Sustainability in a Human-Dominated Region: Agricultural Use of Natural Capital

Presenter: Yining Bai, New Mexico Water Resources Research Institute (NM WRRI), NMSU, ynb@nmsu.edu
Co-authors: Saeed P. Langarudi (NM WRRI, NMSU), Alexander "Sam" Fernald (NM WRRI, NMSU)

Irrigation, drainage, and conservation assets, as forms of natural resources serving US agriculture, amount to billions. Natural resource capital could be depreciable and not considered as one of the operational aspects of policymaking. However, the approach to compiling water into traditional forms of capital is elusive. To agriculture in the arid or semi-arid area, the value of water determines agriculture's future sustainability. Based on summarizing the quantitative framework, a model was built on the system dynamics platform and integrated with economic development dynamics, population growth, land uses, and climate change. The use of water and irrigated land as critical natural capital in the Lower Rio Grande (LRG), a southwest region in the US, was investigated by bringing together the ecological footprint (EF), water footprint (WF), and corresponding capacity indicators into an improved three-dimensional model. Results showed that the LRG has long been operating in a state of overshoot due to a shortage of annual natural capital flows and accumulated depletion of stocks. From 2010 to 2015, an EF depth of 5.9 was accumulated. Concerning water use, the LRG is a debtor.

Overall, LRG's economic growth did not show signs of decoupling from the EF and WF. These findings highlight the employment of valuing natural capital in the form of water reveals that the integration of natural capital value links into a socio-hydrology system may change the implications of agriculture policy analysis. This integrated model provided deep insight into the structural and characteristic dynamics of both flows and stocks while avoiding unexpected consequences of policies across various components within single forms of natural capital from a healthy sustainability perspective. Our study enhances understanding of the critical role of natural capital in ensuring regional sustainability and improving human welfare. **(Pg. 163)**

42) ZiaMet, the New Mexico Mesonet

Presenter: David Dubois, Plant and Environmental Sciences, NMSU, dwdubois@nmsu.edu
Co-author: Stan Engle (Plant and Environmental Sciences, NMSU)

Our current ZiaMet weather observational network consists of 26 stations, with 10 being configured as agricultural weather stations. These 10 stations consist of 3-meter wind and direction, 2-meter air temperature and relative humidity, solar radiation, rain gauge, and soil temperature at 10-cm depth. These agricultural stations routinely are used to calculate evapotranspiration that farmers can use for crop irrigation scheduling. The remaining 16 station are former NOAA US Regional Climate Reference Network weather stations, with triple redundant 1.5-meter air temperature sensors and one precipitation gauge, using triple redundant vibrating wire sensors. The data supports numerous programs including agriculture, water management, industry, emergency management, transportation, federal and state government, education, and the media. All of the data is telemetered to the NM Climate Center's data center in real time and available online: http://weather.nmsu.edu. Data is also sent nationwide to Mesowest so that anyone can use the real-time data, https://mesowest.utah.edu/. We are part of the National Mesonet Program that provides the National Weather Service (NWS) with data from approximately 35,000 real-time weather stations, including surface and upper-air data. Our goal is to expand the current ZiaMet network across the state to provide New Mexicans with a high quality source of weather information. More high-quality data leads to more accurate forecasts and more well-informed decision-making during critical weather situations. The ZiaMet network helps fill both temporal and spatial gaps that the federally owned programs such as the Automated Surface Observing System stations do not cover. **(Pg. 164)**

43) Nitrogen, Carbon Dioxide and Argon Adsorption for Surface Area of an Unknown New Mexico Clay in Order to Elucidate Uranium Abatement

Presenter: Moticha M. Franklin, Chemistry and Biochemistry, NMSU, moticha@nmsu.edu
Co-authors: Jeremy Jones (Chemistry and Biochemistry, NMSU), Antonio Lara (Chemistry and Biochemistry, NMSU)

Uranium contaminated drinking water on the Navajo Nation has been extremely detrimental to the surrounding Four Corners region. Technologies to purify water, such as reverse osmosis, are not appropriate for the region. An appropriate solution is needed - inexpensive, simple to implement, and requiring readily available materials. Clays are the answer. Due to their cation exchange capabilities, clays bind and sequester heavy metals in water. However, muddy suspensions, upon adding water to the clay in its powder form are difficult to manage. For this reason, we fabricated clay pellets. A Gallup, New Mexico soil was used because it is found juxtaposed to the uranium affected area. The capacity for clays to sorb heavy metals is directly related to the surface area of the clay. The ASAP 2050 Extended Pressure Adsorption Analyzer was used with nitrogen (N_2), carbon dioxide (CO_2) and argon (Ar) sorbates to determine the surface area of the Gallup clay in its different forms. We hypothesize that fabrication of clay

pellets will decrease the available surface area, relative to clay powder. Brunauer–Emmett–Teller isotherm sorption measurements follow: N_2 sorbate (powder 67 m²/g; pellets 41 m²/g); CO_2 sorbate (powder 42 m²/g; pellet 31 m²/g) and Ar sorbate (powder 63 m²/g: pellet 38 m²/g). The reduction of surface area on pellet fabrication verified the hypothesis. Despite the loss of surface area, pellet manageability, relative to the muddy clay suspension, is a desirable trade-off.

This research was supported by funds from the New Mexico State Legislature (NMWRRI2018-19), administered by the New Mexico Water Resources Research Institute and Water Resources Research Institute FY19 Student Water Research Grant NMWRRI-SG-2019. **(Pg. 165)**

44) Aquaponics Cuts Path Toward Water-Neutral Agriculture in New Mexico

Presenter: R. Charlie Shultz, Controlled Environment Agriculture, SFCC, richard.shultz@sfcc.edu
Co-author: Nate Downey (Lettuce Etc LLC, SFCC)

The Santa Fe Community College's Controlled Environment Agriculture (CEA) program teaches food-production using a range of closed-loop, water-recirculating systems including conventional hydroponics, aquaponics, and hybrid systems. Along with their exceptionally efficient use of nutrients and little-to-no effluent discharge, many of these systems grow fish and plants while recycling 98% of their water daily. Theoretically, crops could grow using roof-water catchment alone (given 12" precipitation/year) and be primarily "water neutral."

Since margins in farming are thin and aquaponics systems require significant up-front expenditures, two often-insurmountable hurdles for commercial aquaponics are:

- The low (wholesale) prices farmers get from grocery stores, restaurants, and institutions
- The time it takes to work a busy day at a competitively priced farmers market

A recent internship project by an SFCC student tested how a subscription-based, farm-to-home delivery model would function in Santa Fe.

What if farmers could sell to their neighbors? What would the costs and logistics of a farm-to-home delivery-model look like? How would the packaging and delivery-routing work? How much would people appreciate the flavor of exceptionally fresh aquaponics produce?

This poster will show that 88% of 170 survey respondents chose "Loved it!" in the multiple-choice "flavor" question, that substantial majorities appreciated our packaging and delivery service, and that 73% said they would pay more than grocery-store prices for such a highly ecological product. After analyzing about 8,000 survey-question responses, we conclude that such a business model represents a clear path to a primarily water-neutral form of agriculture in New Mexico. **(Pg. 166)**

45) Effect of Chloride Salt Solutions on the Unconfined Compressive Strength of Heat-Treated Clay Pellets Made for the Abatement of Uranium in Contaminated Water

Presenter: Joshua Herrera, Chemistry and Biochemistry, NMSU, josherr@nmsu.edu
Co-authors: Jeremy Jones (Chemistry and Biochemistry), Antonio Lara (Chemistry and Biochemistry)

Uranium contamination in drinking water is an ongoing crisis for citizens of the Navajo Nation. This problem can be mitigated with locally produced clay pellets known to abate uranium, but parameters that effect the robustness of these pellets must be understood before they are utilized. It is known that chloride salt solutions affect the plasticity and liquid limit of clays, but there is little study on how these solutions alter the robustness of a clay, especially after heat-treatment. This is surprising given how cations affect clay platelet coordination, such as with potassium in illite clays. To better understand this effect, chloride salt solutions were mixed into two clays, a sodium-bentonite clay and a local illite-smectite clay, at specific weight ratios during the pellet fabrication process. The chloride salt solutions used were LiCl, NaCl, and KCl with each at a concentration of 0.8M. The robustness of each set of pellets was quantified by the maximum compressive force (MCF) measured during unconfined compression testing. The addition of NaCl had little to no effect on the pellet robustness. The bentonite pellets maintained a MCF of 700±100 ftlb (n=15) while the illite-smectite pellets' MCF slightly decreased from 2300±200 ftlb (n=15) to 2000±300 ftlb (n=15). The addition of the other chloride salts, however, has preliminarily shown to increase pellet robustness. The bentonite pellets' MCF increased to 900±100 ftlb (n=5) when using LiCl and 1300±300 ftlb (n=5) when using KCl. This finding suggests that externally added cations can have a significant effect on heat-treated pellet robustness. **(Pg. 167)**

46.) Multilevel Assessments of Contribution of Livestock Manure to Nitrogen Budget in Arid-land Ecosystems: The Case of Dairies in New Mexico

Presenter: Suraj Ghimire, Economics, UNM, ghimires@unm.edu
Co-author: Jingjing Wang (Economics, UNM)

The livestock industry is one of the major contributors of nitrogen pollution. Nearly one-third of the global human-induced nitrogen emissions is contributed by this sector. The intensification of dairy farms has resulted in an oversupply of nitrogen in smaller land pockets causing degradation of environmental and human health. New Mexico leads the country in terms of the average number of cows per large dairy farms and has held this position since 2002. A study by Johnson et al. (2003) indicates that nearly two-thirds of the New Mexican dairies have improper management of manure leading to groundwater pollution. This study aims to quantify the contribution of large dairy farms towards the nitrogen budget of the arid land ecosystem and recommend optimal abatement strategies. First, we modeled the spatial distribution of large dairy farms in New Mexico based on herd and land sizes and identified four hotspot watersheds. Then, we performed a watershed level assessment of the nitrogen balance by comparing the amount of excreted nitrogen with the assimilative capacity of croplands using remote sensing data. This assessment showed that there is an excess of nitrogen and the croplands alone cannot

assimilate it. Therefore, we suggested including rangelands as a possible nitrogen sink and recalculated the nitrogen budget. After the inclusion, the assimilative capacity of the system exceeded the amount of excreted nitrogen. This strategy was deemed economically viable in our cost-benefit analysis. Therefore, we recommend including rangelands as a possible abatement strategy to contain nitrogen pollution. **(Pg. 168)**

47) Influence of Saline Irrigation Water on Soil Chemistry and *Atriplex* sp. Growth*

Presenter: Sarah M. Cerra, Plant and Envrionmental Sciences, NMSU, scerra@nmsu.edu
Co-author: Manoj K. Shukla (Plant and Envrionmental Sciences, NMSU)

Increased temperatures and decreased precipitation in the southwestern United States has prompted growers to use brackish groundwater for agriculture. The objectives of the study are to determine the impacts of ions in brackish groundwater irrigation on soil chemistry and the growth of *Atriplex canescens* and *A. lentiformis*. We hypothesized that ions from the concentrate will accumulate in the soil in a bell pattern from the drip source as the wetting front moves away from the source. Soil samples were collected from three distances from the drip source in two directions. At each distance, samples were collected from two depths. Using the soil paste extract method, sodium, calcium, magnesium, and chloride ions were collected. Growth of six plants was observed over three years and plant ion concentrations were determined at the end of year 1 and year 3. Evapotranspiration rates were obtained using the Hargreaves and the Blaney Criddle Equations. Plant growth and biomass stayed nearly the same over time. Ions accumulated along the wetting front of the drip irrigation creating a favorable environment for root growth. Plant growth over the study supports continued research of *A. canescens* and *A. lentiformis* for cattle fodder.

48) Improving Green Water Use Proportion in a Center Pivot Irrigation System by Using Circular Grass Buffer Strips

Presenter: Paramveer Singh, Plant and Environmnetal Sciences, NMSU, param@nmsu.edu
Co-authors: Sangu Angadi (Agriculture Science Center, NMSU), Robert Lascano (Wind Erosion & Water Conservation, USDA-ARS), Sultan Begna (USDA-ARS), Dave Dubois (Plant and Environmental Sciences, NMSU), Rajan Ghimire (Agriculture Science Center, NMSU), John Idowu (Plant and Environmental Sciences)

Circular Grass Buffer System (CBS) is a simple, elegant and cost-effective strategy that involves rearranging the dryland portion of partial pivots into circular buffer strips of native perennial grasses alternating with crop strips to offer several benefits including improving efficiency of the water cycle. To explore and gauge the benefit of CBS in enhancement of rainwater capture and use by irrigated center pivot circles, a set of observations were made around a 44 mm rainfall event at NMSU ASC Clovis, NM. With CBS, there was an 11.7 mm increase in soil moisture as compared to 7.8 mm without it (Control-CT) after rainfall. Over four days from the rain event, corn in CBS extracted 1.1 mm more water than CT. Although the amount seems small, it was enough to reduce water stress as corn leaf water potential in CBS was -13.2 as compared to -15.1 bar in CT. Attributing to these favorable conditions, CBS reported a 1426 kg ha^{-1} increase in biomass, while in CT it was 1150 kg ha^{-1}. Results indicates that with CBS, storage and use of rainwater by irrigated agriculture increased, which alleviated water stress and improved crop growth. Therefore, CBS may prove effective in sustaining dwindling groundwater reserves of the Ogallala Aquifer (OA) by reducing irrigation inputs without hampering crop growth. **(Pg. 169)**

49) Sedimentology and Topography of a Confluence Outlet of an Ephemeral Tributary to the Mid Rio Grande – Arroyo de los Pinos

Presenter: Sharllyn Pimentel, Earth and Environmental Science, NMT, sharllyn.pimentel@student.nmt.edu
Co-authors: Daniel Cadol (Earth and Environmental Science, NMT), Jonathan B. Laronne (Geography and Environmental Development, Ben-Gurion University of the Negev), Kyle Stark (Earth and Environmental Science, NMT)

Ephemeral streams contribute to the dynamic fluvial geomorphology in perennial streams. The river confluences are point sources of sediment and water delivery downstream. Previous confluence studies have concentrated on the hydrodynamics, topography, and sedimentology downstream of the confluence in the main stem, with limited information on the tributary proper. Focusing on semi-arid ephemeral outlets is important because the sediment and hydraulic regime of the tributary contrasts strongly with the main stem. These tributaries infrequently flow after localized high intensity rainfall events and the sediment delivered to main trunk rivers is often much coarser than the mainstem bedload. Our aim is to quantify confluence characteristics of planform geometry, discharge ratios, bed discordance, and sediment stratification at the confluence of a novel bedload research station, the Arroyo del los Pinos, into the Rio Grande.

Structure from Motion (SfM) photogrammetry is used to generate Digital Elevation Models (DEMs), and then the DEMs of Difference (DoD) were analyzed to compare multi-temporal topographic and volumetric changes after every flood event of the Pinos. Stratification based on trenching of the tributary bed sediments details the hydrodynamic conditions during deposition of the morphological units at the tributary.

Deposition of an asymmetrical tributary mouth bar occurred because the Rio Grande basin experienced an abnormally high flow stage related to above average snowmelt in the spring of 2019. Cross-stratification of the deposits indicated flow separation along the tributary mouth and the development of a recirculating eddy within the tributary during high flows on the Rio Grande. **(Pg. 170)**

50) The Relationship Between Firing Temperature and the Sorption Effectiveness of Fired Clay Pellets

Presenter: Sarah Bockisch, Chemistry and Biochemistry, NMSU, bockisch@nmsu.edu
Co-authors: Jeremy Jones (Chemistry and Biochemistry), Antonio Lara (Chemistry and Biochemistry)

Uranium contamination in drinking water is prevalent in the Four Corners area of the Southwest. Ingesting aqueous concentrations of heavy metal uranium greater than 30 ppb has long been known to cause a variety of serious health effects as per the

EPA. Traditional methods for uranium removal are often too expensive and complex to be a viable option for lay persons suffering from this contamination and require utilities that many do not have access to. Fired clay pellets offer a good alternative to these removal methods. However, a means to measure the concentration of uranium in the water is essential, and enhanced fluorimetry is an instrumental method with several advantages over other analysis methods. Firing the clay powder into a pellet gives it a manageable structure while still retaining its sorption properties, and the firing temperature affects its relative ability to sequester uranium. Upon abatement, the uranium concentration can be analyzed using fluorimetry. To this end, low, medium, and high firing temperatures for the clay were tested. These fired clay pellets were subsequently exposed to a 125 ppb uranium solution for 24-, 48-, and 72-hour periods. The resulting solutions were analyzed using polyphosphate enhanced fluorimetry and ICP-MS, an orthogonal analytical method, for comparison. Analysis showed similar sorption by both low-temperature fired clay and mid-temperature fired clay, and almost no uranium sequestration by the high-temperature fired clay. Additionally, similar trends between data obtained by fluorimetry and data obtained by ICP-MS could also be seen. **(Pg. 171)**

51) Biodegradable Porous Hydrogels Designed for Soil Water Retention

Presenter: Ryan Zowada, Chemical and Materials Engineering, NMSU, rzowada@nmsu.edu
Co-authors: Catherine Brewer (Chemical and Materials Engineering, NMSU), Reza Foudazi (Chemical and Materials Engineering, NMSU)

Arid regions have difficulty retaining water in soil due to climate effects as well as poor soil properties. Sandy soils have low water holding capacity allowing high levels of water loss from evaporation and gravity (i.e., drainage). We are developing a foam-templated biodegradable porous hydrogel as a soil additive that will better retain water in the soil and act as a water reservoir for plant life. The interconnected porosity of the hydrogel will both increase the affordability of a soil additive (50 – 80% porosity), and increase water availability by holding water in macroporous channels rather than the polymer matrix. **(Pg. 172)**

52) Electrical Resistivity Mapping of Rio Grande River-Groundwater Interactions

Presenter: Autumn Pearson, Plant and Environmental Sciences, NMSU, autumnpe@nmsu.edu
Co-authors: Dale Rucker (HydroGEOPHYSICS, Inc.), Chia-Hsing Tsai (Plant and Envrionmental Sciences, NMSU), Erek H. Fuchs (Elephant Butte Irrigation District), Kenneth C. Carroll (Plant and Environmental Sciences, NMSU)

Surface-groundwater interactions including connectivity remain a challenge to characterize, especially for ephemeral rivers such as the lower Rio Grande. This investigation used a noninvasive and spatially distributed geophysical method (i.e., time-lapse electrical resistivity) for mapping the water table below and adjacent to the Rio Grande, which has been validated using groundwater table monitoring well data. Time-lapse monitoring of electrical resistivity (i.e., inversely related to electrical conductivity and also water saturation) before, during, and after the irrigation season has been used to characterize the transient and spatial connectivity of the water table with the base of the Rio Grande from disconnection, to connection, and back to disconnection. Results have shown resistivity impacts due to a coupling of both variations in water saturation and an aqueous electrical conductivity (i.e., salinity) difference between resident groundwater from the previous irrigation season and the infiltrating surface water. The relationships between bulk resistivity versus aqueous salinity and bulk resistivity versus water saturation have been developed using laboratory experiments to evaluate the time-lapse resistivity data and characterization of surface-groundwater connectivity. This type of spatiotemporal groundwater level assessment advances our disconnection process characterization capabilities, and will support the sustainable conjunctive use of surface water and groundwater especially for ephemeral systems. **(Pg. 173)**

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Evaluation of Heavy Metal Adsorption onto Microplastics

Jasmine Anne Quiambao

Department of Civil, Construction & Environmental Engineering, University of New Mexico, Albuquerque, New Mexico, 87131, United States

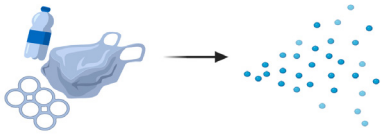
Co-Authors: Jorge Gonzalez-Estrella and Kerry Howe

OBJECTIVE

To evaluate the adsorption of heavy metals onto microplastics in contaminated freshwater systems.

INTRODUCTION

Microplastics



Plastics
- Light-weight
- Durable
- Versatile
- Low-cost production
- Non-biodegradable

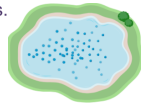
Microplastics (MPs)
- Water-insoluble; polymer particles with diameter of < 5 mm.
- **Primary source:** Personal care products manufactured with < 5mm (e.g. body wash, toothpaste, etc.).
- **Secondary source:** Fragmentation of plastic bags, bottles, fishing nets, etc.

Environmental Effects
- Improper disposal leads to polluting the environment.
- MPs accumulate in aquatic ecosystems.



- **Physical impact**: entanglement & ingestion (diameter of < 150 µm).
- **Chemical impact:** release of additives, pesticides, and pollutants from MPs.
- **Biological impacts:** microorganisms colonizing the surface of MPs.

Microplastics in Freshwater Systems
- Source: anthropogenic activities.
- **MP studies:** < 4% of MPs in freshwaters & ~ 96% in seawater.

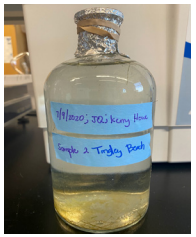


Synergy with other Contaminants
- The **main concern:** heavy metal can adsorb onto MPs surface.
- The physicochemical properties of MPs and heavy metals and environmental characteristics drive the adsorption.

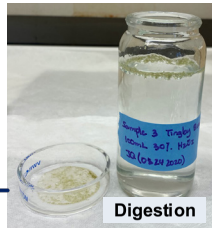
MATERIALS AND METHODS

Task 1: Detection of Microplastics in Freshwater

Sampling Locations:
- Paguate River
- Freshwater reservoirs near the Jackpile mine of Laguna Pueblo
- The Rio Grande
- Tingley Beach
- Field control (1L)



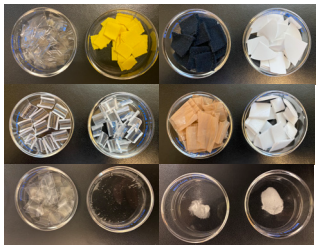




To assure the quality of **visual inspection** and subsequent **polymer identification**.

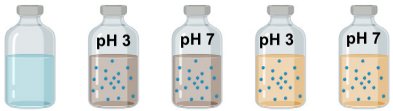
- Digestion: 100 mL of 30% (v/v) H_2O_2 in oscillation incubator at 50°C and 80 rpm for 48h.

Microplastics Characterization



- Nine (~1 cm^2) plastic materials and three commercial microspheres for characterization.
- ZETA potential and BET analyses

Task 2: Adsorption Kinetic Experiment

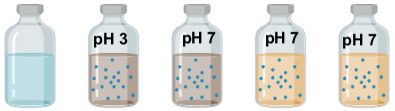


Control | 10 $mg\ L^{-1}$ **As** | 10 $mg\ L^{-1}$ **U**

Three microplastics: 0.1 g of polyethylene (PE), polystyrene (PS), and polymethyl methacrylate (PMMA) commercial microspheres.

Two heavy metals: Arsenic (As) and Uranium (U)
- Ultra-pure water (18 MΩ) ~ pH 3 and pH 7 (±0.2)
- 50 mL samples (triplicate) and agitated at 150 rpm for 7 days at 25°C.

Task 2: Adsorption of Heavy Metal onto Microplastic



Control | Arsenic (As) | Uranium (U)

Three microplastics: 0.02 g of PE, PS, and PMMA.

Two heavy metals: 10, 20, 30, 40, and 50 $mg\ L^{-1}$ of As and 2, 5, 10, 15, 20 $mg\ L^{-1}$ of U
- Ultra-pure water (18 MΩ) ~ pH 3 and pH 7 (±0.2)
- 20 mL samples (triplicate) and agitate at 150 rpm for 48 hr at at 25°C.

Analyses
- Attenuated total reflection fourier-transform infrared (ATIR-FTIR) spectroscopy
- Energy Dispersive X-Ray Spectroscopy (EDS)
- Scanning electron microscopy (SEM)
- X Ray Photoelectric Spectroscopy (XPS)
- Inductively coupled plasma optical emission spectroscopy (ICP-OES)

Expected Outcomes

- MPs in static freshwater systems used for recreational activities.
- MPs found in freshwater near mine sites will likely contain higher metal concentrations on their surface.
- U and As adsorption onto microplastics depend on the type of polymer and pH.

Environmental Implications

The synergy of these pollutants may increase potential toxic effects on human health and the environment.

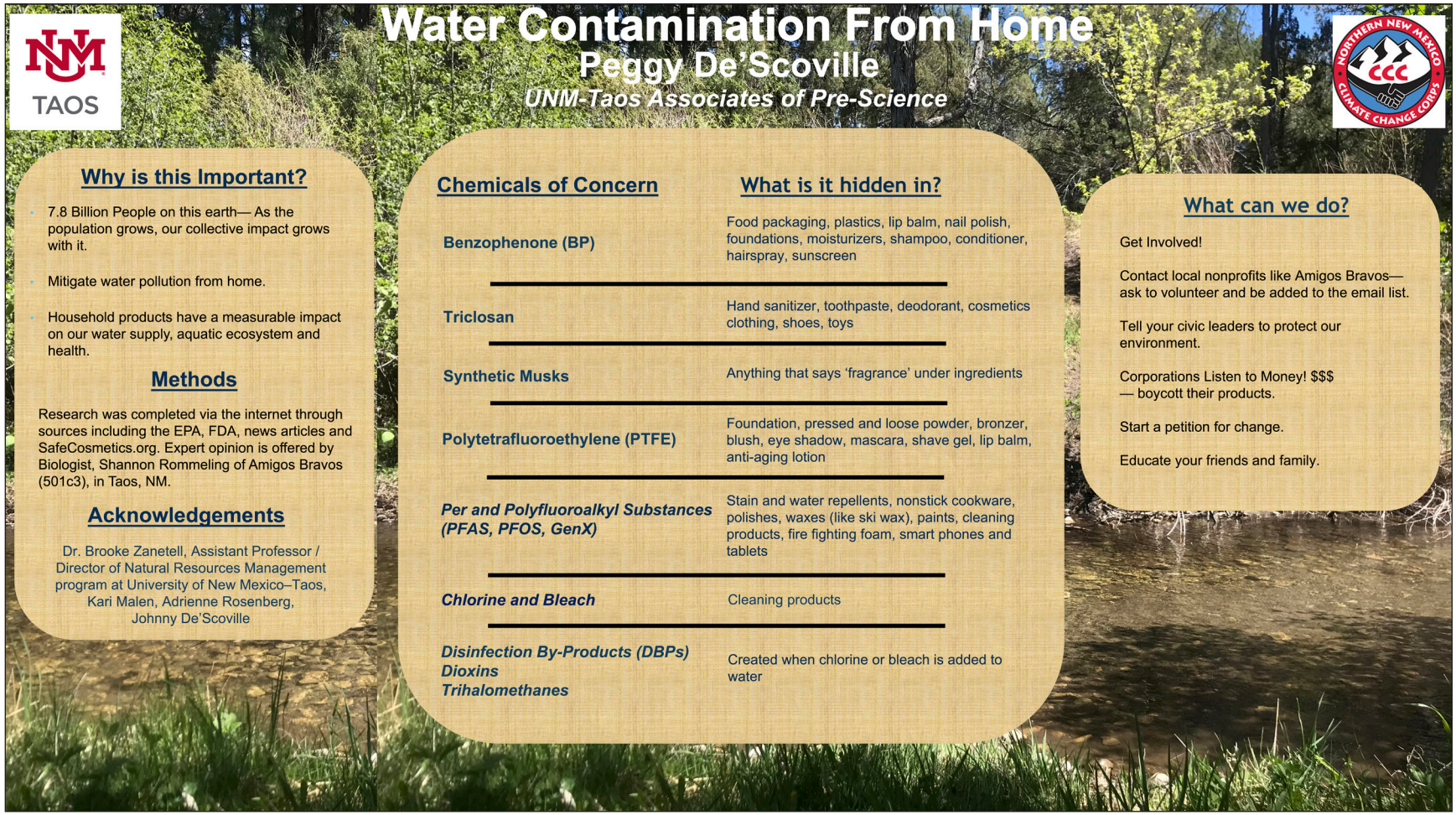
Future Work

- Spectroscopy analyses on task 1 methodology.
- Adsorption kinetic and adsorption isotherm experiments.

Acknowledgements

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Abstract 1) Evaluation of Heavy Metal Adsorption onto Microplastics (Pg. 125)



Abstract 2) Understanding Water Contamination by Household Chemicals: A Guide to Stop Polluting Taos Water (Pg. 125)

Juvenile drift of an invasive crayfish in the Pecos River, NM

Sara A. Ricklefs and Jesse E. Filbrun
Dept. of Biology, Eastern New Mexico University, Portales, NM

Background and Research Objectives

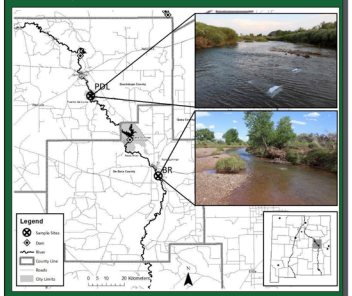
Background

- In 2019 and 2020, we passively collected drifting juvenile crayfish in the Pecos River as part of an ongoing Drifting Egg and Larval Fish Survey (DELFS). We found no peer-reviewed literature describing juvenile crayfish drift.
- Juvenile crayfish are morphologically ambiguous and, therefore, difficult to identify taxonomically.

Research Objectives

1. Identify the juvenile crayfish drifting to species level using DNA barcoding.
2. Report the timing and extent of drifting behavior of juvenile crayfish relative to environmental conditions.

Study Sites



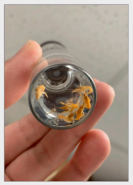
Sara Ricklefs
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Methods

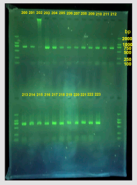



- Juvenile crayfish were collected in drift nets (500 µm) deployed in 30-minute sets with flow meters.
- Adult vouchers were collected, identified using gonopod morphology, and barcoded alongside juveniles.





- Specimens were sorted by organism, preserved in 90% ethanol, and stored at -20°C.
- Each specimen was photographed; CLs were measured and recorded via ImageJ software.

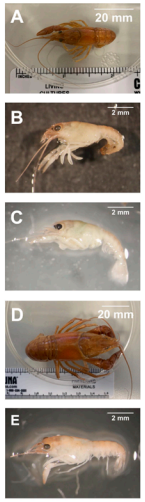



- Genomic DNA was extracted from tail muscle of adults and whole juveniles.
- Mitochondrial cytochrome *c* oxidase I (COI) DNA barcode was amplified by PCR using universal arthropod primers.

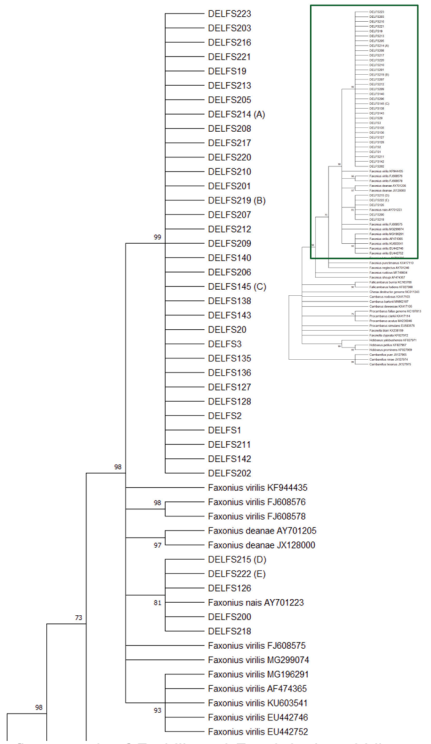
Environmental Conditions and Juvenile Drift

Date	Juveniles Collected (#)	Water Temperature (°C)	Discharge (cfs)	Turbidity (NTU)
Puerto De Luna				
4/6/2019	7	17.7	83	5
4/7/2019	2	17.7	81.2	5
5/9/2019	5	15.3	91.9	14
Bosque Redondo				
4/27/2019	59	20.8	68.8	64
4/28/2019	23	20.8	56.8	64
5/28/2019	2	19.1	152	42
4/16/2020	14	17.6	43.5	6
4/27/2020	21	21	51.3	10
4/29/2020	3	21.3	41.1	8
5/11/2020	10	18.8	66.4	16
5/14/2020	6	21.1	57.4	12
5/20/2020	2	23.4	49	12
5/28/2020	1	24.6	70.9	11
6/2/2020	2	26.6	65.2	15
	Average:	**20.4**	**69.9**	**20.3**

COI Barcoding Results



Above: Photographs of samples are provided with their respective labels.
Right: Bootstrap Consensus tree of GenBank references and DELFS specimens by sample ID.



Discussion

- Our study includes the first records of *F. virilis* and *F. nais* in the middle reach of the Pecos River.
- Invasions of *F. virilis* have caused hybridization with and depletion of native species. Drift dispersal could impact the rate of watershed invasion.
- Educating the general public about how crayfish introductions commonly occur is a worthwhile endeavor not only in New Mexico, but worldwide.

Acknowledgments

This study is funded by internal Faculty Research Grants awarded to Jesse Filbrun. Field collections were approved by NMDGF (Permit # 3678) and ENMU (IACUC # 2019-0301-03). We thank Rick Raymondi for assistance in the field and with DNA extraction and PCR analysis. We thank Dr. Chris Taylor for assistance with adult voucher species confirmation.

Abstract 3) Juvenile Drift of an Invasive Crayfish in the Pecos River, New Mexico (Pg. 125)

Flow Connectivity and Sediment Transport Modeling in Flashy Ephemeral Channel Networks

Sandra Glasgo[1], Daniel Cadol[1], Madeline Richards[2], Jonathan Laronne[2], Kyle Stark[2]

1 New Mexico Institute of Mining and Technology, Socorro, NM ‖2 Ben Gurion University of the Negev

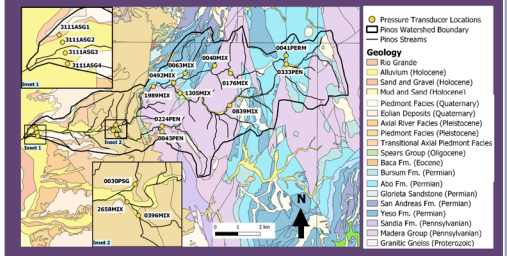
Abstract

In large river systems such as the Rio Grande, sediment influx and water delivery from ephemeral streams is difficult to quantify and track. Yet is has major management implications to such diverse issues as reservoir sedimentation, sediment plugs and avulsions, flooding, and additions to streamflow. In the Arroyo de los Piños, one such ephemeral system, we have been monitoring discharge at 18 different points for two years in an effort to quantify water and sediment delivery from the ephemeral channels. The data collected in the past, present, and future will allow for a better understanding of how the network connects across a range of precipitation intensities and magnitudes, and how these interactions control water and sediment delivery to the watershed outlet. Initial data support the prevailing understanding that the primary controls on local runoff generation are rainfall intensity, lithology, and sub-basin size.

To investigate how these flow events influence sediment discharge, future work will focus on building open channel flow models with sediment transport capability. First, we will focus on the outlet reach, where discharge and bedload data collected primarily during the 2018 monsoon season will be used to evaluate the quality of the sediment transport modules within the Army Corp of Engineers models HEC-RAS 1D/2D and ADH. If successful, we will then be able to model sediment transport in other reaches upstream in the channel network. Combined with our flow connectivity data, this would enable an unprecedented quantification of sediment transport connectivity within ephemeral fluvial systems.



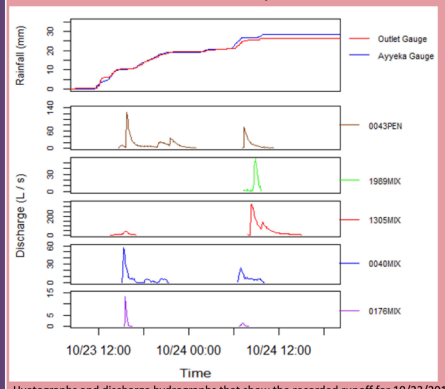
Location map of basins of interest and the planform geometry of the confluence. The arrows indicate flow.



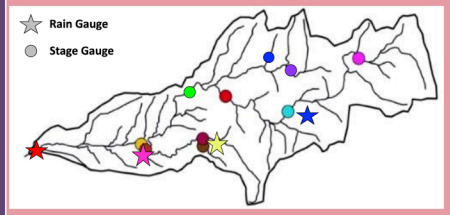
Location map of Arroyo de Los Pinos streams and pressure transducer sites

Flood Events

Small Event: October 23-24, 2018

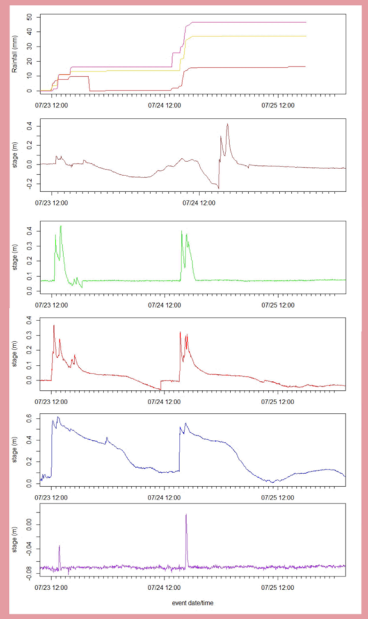


Hyetographs and discharge hydrographs that show the recorded runoff for 10/23/2018.



Schematic of watershed with locations of transducers

Larger Event: July 23-24, 2020



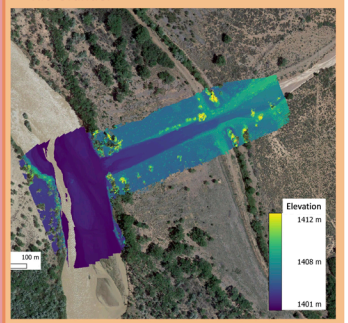
Stage hydrographs from loggers that recorded the flood events on 7/23/20 and 7/24/20.

Discussion

- Greater integration of flow from downstream sites in the large watershed.
- Small sub-watersheds produced larger runoff ratios
- Large watersheds have higher rainfall threshold to produced runoff
- Storms with greater rainfall depth are more likely to produce flow in large sub-basins but have similar probabilities of missing small sub-basins
- Comparison of downstream gauging sites shows significant channel transmission losses (bed seepage)

Future Work

Discharge, bedload, and topographic data collected during the monsoon season of 2018 will be used to build open channel flow models with sediment transport capability. These models will be used to evaluate the quality of the sediment transport simulation capabilities within the Army Corp of Engineers models HEC-RAS 1D/2D and ADH. Modeled sediment flux will be compared against monitored sediment flux near the confluence of the Pinos and Rio Grande.



References

Richards,M. (2020). RAINFALL-RUNOFF RELATIONSHIPS IN THE ARROYO DE LOS PINOS SOCORRO NEW MEXICO. MS Thesis, New Mexico Institute of Mining and Technology, Socorro New Mexico.

Acknowledgements

Support for this research is being provided by:
- Water Resources Research Institute
- US Army Corps of Engineers
- US Bureau of Reclamation

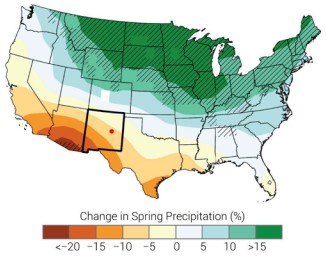
Abstract 7) Flow Connectivity and Sediment Transport Modeling in Flashy Ephemeral Channel Networks (Pg. 126)

Quantifying patterns of drifting fish eggs and larvae in the middle Pecos River

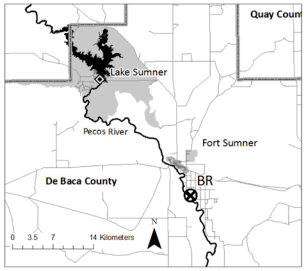
Jesse E. Filbrun, Richard M. Raymondi, and Sara A. Ricklefs,
Department of Biology, Eastern New Mexico University, Portales, NM

Rationale

- Native fishes of NM are collapsing because of habitat fragmentation.
- We established a long-term survey of fish eggs and larvae in the Pecos River to quantify reproductive effort relative to environmental drivers.
- Water managers may use survey results to inform best practices that reduce threats to native fishes.



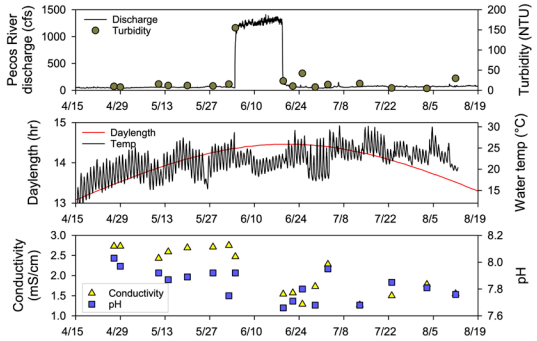
Predicted change in spring precipitation (%) for the middle 21st century (versus mid 20th century) under a higher emissions scenario (NOAA Technical Report NESDIS 149-NM).



Location of our survey site in the Pecos River near Bosque Redondo Park (BR).

Jesse E. Filbrun, Ph.D.
Assistant Professor of Biology
Eastern New Mexico University
Email: jesse.filbrun@enmu.edu
Website: filbrunlab.weebly.com

Environmental conditions



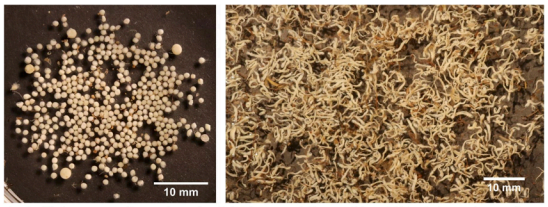
Environmental variation at the BR site during 2020. Top: discharge and turbidity; middle: daylength and water temp.; bottom: conductivity and pH.

Fish collections

- Fish eggs and larvae were sampled from April–August 2020 using drift nets (500 µm mesh) set for 30 min and equipped with flow meters.
- Fish larvae were also collected using light traps baited with glow sticks.
- Samples were rapidly chilled to euthanize fish eggs and larvae, then preserved in 90% ethanol.
- Environmental and water quality variables were recorded, plus USGS gage station stream discharge.

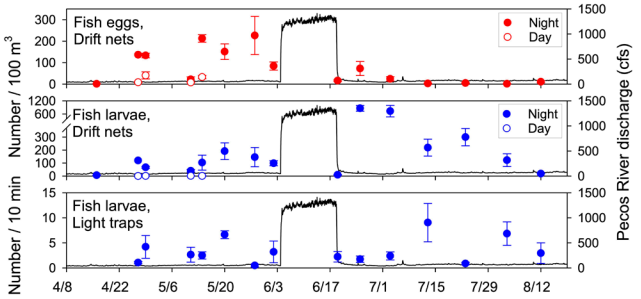


Top: Quatrefoil light traps; bottom: Drift net



Left: Fish eggs collected on April 27 in one drift net (N = 448); right: subset of fish larvae collected on July 3 in one drift net (N = 2,518 in total)

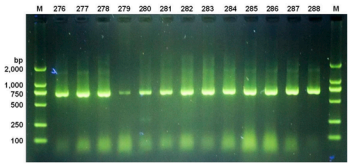
Fish egg and larval catch rates



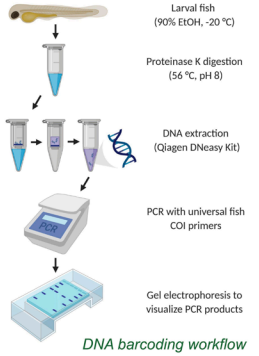
Catch rates of fish eggs and larvae at the BR site during 2020.

DNA barcoding

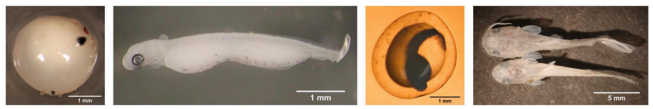
- Fish eggs and larvae representing unique morphotypes were identified to species level using the COI barcode.
- Barcoded specimens were photographed to construct a digital reference library.



Electrophoresis gel of larval fish specimens (276–288) showing the COI barcode product (~650 bp).



DNA barcoding workflow



Left to right: River Carpsucker egg, River Carpsucker larva, Speckled Chub egg, and Flathead Catfish (top) with Channel Catfish (bottom).

Acknowledgments

This survey was funded by a NM WRRI Faculty Water Research Grant, internal grants awarded by ENMU, and grants awarded by the Western Division and Arizona/New Mexico Chapter of the AFS. Collections were approved by New Mexico Department of Game and Fish (Permit # 3678) and ENMU (IACUC # 2019-0301-03).

Abstract 9) Quantifying Patterns of Drifting Fish Eggs and Larvae in the Middle Pecos River (Pg. 127)

The Environmental Legacy of Uranium Mining & Milling in New Mexico

Bruce Thomson
Civil, Construction & Environmental Engineering
University of New Mexico
(bthomson@unm.edu)



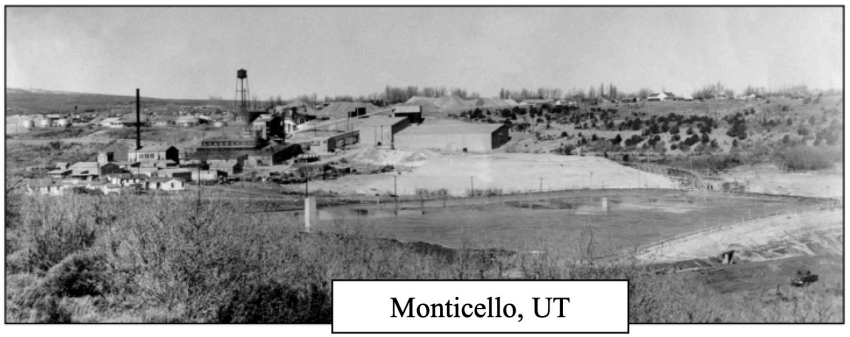
Fiestaware

Early Uses & Source of U for Manhattan Project

- Uranium (U) was discovered in 1789 by Klaproth (German chemist) from mineral pitchblende (UO_2)
- Prior to discovery of fission of heavy elements demand for U was small. Used for color in glass & glaze in ceramics (No. Food placed on Fiestaware won't cook itself!!)
- Discovery of fission in 1938/1939 led to explosion in U demand and consequent development of U resources around the world.
- Manhattan project used 6,000 tons of U ore
  - 67% from Shinkolobwe Mine – Belgian Congo, now DRC (up to 65% U_3O_8)
  - 17% from Canada
  - 14% from western CO
- Domestic U came from mines in western CO which mined carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 1\text{-}3H_2O$)
  - Originally mined for Ra, price was then $70 K/g - $120 K/g ($3.0 M/g in 2020)
  - Mines switched to V for steel alloy, including re-processing of tailings
  - Mines switched to U ~1942, including re-processing of tailings

- Stunningly ironic that world class U reserves were found <150 miles from Los Alamos, NM

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Monticello, UT

Developing an Effective Monitoring Strategy Using Photogrammetry and 3D Mapping to Measure the Impact of a Plug and Spread Composite Treatment in a Degraded Alluvial Fan in the Semi-Arid Grasslands of the Southwest

Meagen Larson[1*], Dr. Blanca Céspedes[1], Dr. Julie Tsatsaros[1], Dr. Craig Conley[1,2], Sara Amina Sena[3]
[1] Forestry Department, New Mexico Highlands University, P.O. Box 9000, Las Vegas, NM, 87701
[2] Human Performance & Innovation and Organizational Learning Group, USFS, Rocky Mountain Research Station, Missoula, MT
[3] Hermit's Peak Watershed Alliance, 289 County Road A2, Sapello, NM, 87745

INTRODUCTION

The degradation of alluvial fans in semi-arid grasslands of the Southwest is often the result of channel incision and has been shown to contribute to a loss of hydrologic connectivity between montane areas and lowland grassland areas. In this study we examine the impact of the Plug and Spread (Figure 1) composite restoration treatment (Zeedyk, 2015) by measuring sediment aggradation as an indicator of restored sheet flow to the fan surface using photogrammetry and 3D mapping. Understanding the impact of restoration in degraded alluvial fan systems can be applied to land management strategies to increase water availability, forage production and groundwater recharge potential in increasingly warmer, less predictable climatic conditions.

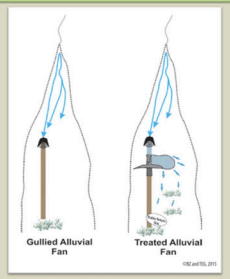


Figure 1. Illustration of Plug & Spread treatment in alluvial fan system (Zeedyk, 2015)

METHODS & OBJECTIVES

- **March – June 2020** Plug and Spread composite treatment to reroute runoff back to alluvial fan floodplain, ancillary structures to stabilize sheet flow and prevent future channelization (Figure 2)
- **June 2020** Post-restoration, pre-monsoon season unmanned aerial vehicle (UAV) flight with New Mexico Forest & Watershed Restoration Institute (NMFWRI) to capture pre-monsoon season imagery for baseline analysis (Figure 4)
- **August – December 2020** Develop methodology using Pix4D, ArcMap, and ArcGIS Pro software for image synthesis and to determine accuracy of digital elevation model (DEM) products and 3D model generation, develop analytical analysis to quantitatively determine effectiveness of treatment
- **November 2020** Post-restoration, post-monsoon season UAV flight with New Mexico Forest & Watershed Restoration Institute to capture post-monsoon imagery used to calculate differences in elevation height and sediment volume before/after the monsoon season as an indicator of restored sheet flow to the fan floodplain

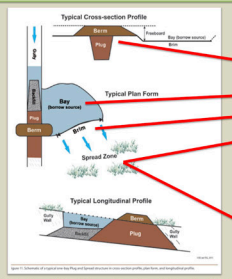




Figure 2. Profile illustration of Plug & Spread treatment (Zeedyk, 2015) and associated restoration structures within study site

ANTICIPATED OUTCOMES

This study aims at developing a methodology using UAV imagery, photogrammetry, and 3D mapping as an effective monitoring tool to determine the impact of a Plug and Spread composite restoration treatment. If the research objectives are met, we expect to see the following:

- Pix4D Mapper synthesis of UAV collected imagery (Figure 5) will generate accurate DEMs (Figure 7) of pre- and post-monsoon season flyovers in which elevation height differences will be detected as a result of sediment aggradation
- Lidar generated point clouds (Figure 8) in conjunction with 2D orthophotos (Figure 6) will construct accurate 3D models pre- and post-monsoon season in which changes in sediment volume will be detected a result of sediment aggradation
- Multiple Pairwise Comparison statistical analysis will provide quantifiable, measurable evidence into the effectiveness of a Plug and Spread composite treatment as a viable technique for restoring hydrologic connectivity in this particular alluvial fan in a semi-arid grassland ecosystem
- Photo monitoring will provide qualitative evidence into the effectiveness of a Plug and Spread composite treatment by tracking increases in vegetative cover and decreases in % bare ground

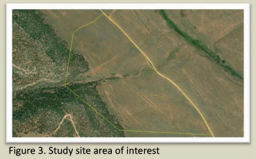


Figure 3. Study site area of interest



Figure 4. NMFWRI UAV flight path, pre-monsoon flight

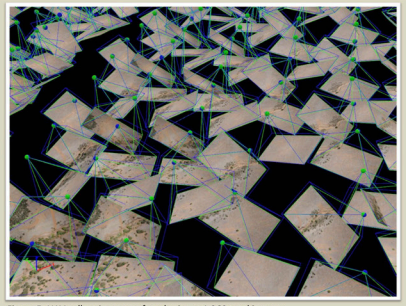


Figure 5. UAV collect imagery of study site - ~1,360 total images



Figure 6. Pix4D generated 2D orthophoto

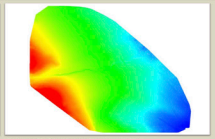


Figure 7. Pix4D generated DEM

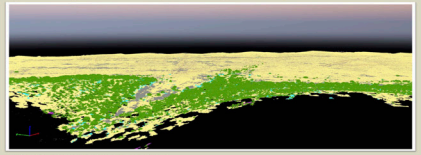


Figure 8. Lidar generated point cloud

SUMMARY

This research project combines traditional ecological knowledge, site-specific restoration treatments, and GIS technology to develop an effective monitoring strategy to measure the impact of a Plug and Spread composite treatment. Changes in sediment height and volume will be measured as indicators of restored sheet flow through 2D and 3D digital modeling between two UAV flights, before and after the 2020 monsoon season. In precipitation driven systems, the amount, frequency, and duration of precipitation events will determine the impact of the Plug and Spread composite treatment and the anticipated outcomes of this study. Despite the lack the predictability, by plugging the incised channel, we are effectively capturing and rerouting any amount of water back on to the fan floodplain that would otherwise be accelerated out of the alluvial fan system.

REFERENCES & ACKNOWLEDGMENTS

Thank you to Dr. Blanca Cespedes, Dr. Julie Tsatsaros, Dr. Craig Conley, Sara Amina Sena, Bill Zeedyk, Joe Zebrowski, Patti Dappen, Katie Withnall, Josh Miner, & Sol Ranch
For more information, please contact Meagen Larson at mlarson2@live.nmhu.edu

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Abstract 11) Developing an Effective Monitoring Strategy Using Photogrammetry and 3D Mapping to Measure the Impact of a Plug and Spread Composite Treatment in a Degraded Alluvial Fan in the Semi-Arid Grasslands of the Southwest (Pg.127)

Isotopic niche overlap among freshwater turtles in the Pecos River system, USA

Thanchira Suriyamongkol, Vinicius Ortega-Berno, Laramie B. Mahan, and Ivana Mali
Department of Biology, Eastern New Mexico University. Portales NM 88130

Introduction and Objectives

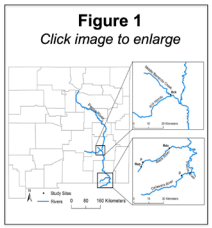
- The Pecos River system (PRS) is one of the most antropogenically altered river systems in the US. It is home to six freshwater turtle species, including a species of conservation concern *Pseudemys gorzugi* (Rio Grande Cooter)
- Although native to PRS, *Trachemys scripta* (Red-eared slider) has been widely spread throughout the world. Where introduced, *T. scripta* is known to compete for resources with native freshwater turtles
- Assessing dietary habits and resource competition is fundamental for understanding species ecology and their roles in the ecosystem
- Stable isotope analyses of carbon and nitrogen examines diet on a longer time span, and can be used to determine niche overlap among turle species inhabiting the same locality

Objective: To quantify isotopic signatures of *P. gorzugi*, and determine the extent of niche overlap of *P. gorzugi* and *T. scripta* across different habitats in the Pecos River tributaries

Study sites and Methods

- Our study was conducted at 5 locations across three Pecos River tributaries in New Mexico (Fig.1)
- We captured turtles from May to September of 2019 using hoop net traps; samples from site P were taken in 2017 via snorkeling
- For each turlte captured, we collected at least one of the three tissue samples: nail, blood, and carapace for stable isotope analyses
- Stable Isotope analyses of $\delta^{15}N$ *or* $\delta^{13}C$ were done by UC Davis Stable Isotope Facility
- Isotopic compositions were determined using the formula: $\delta^{15}N$ *or* $\delta^{13}C$ *= [(Rsample – Rstandard)/ Rstandard] x 1000*, and all results were expressed in delta notation (δ) in parts per thousands (‰)
- We used Stable Isotope Bayesian Ellipses (SIBER) package in R to estimate Bayesian Layman's isotope metrics
- We calculated the Bayesian standard ellipse areas (SEA_B) and standard ellipses corrected for the small samples size (SEA_c) as a measure of isotopic niche for *P. gorzugi* across all habitats and *T. scripta* where it co-occurs with *P. gorzugi*

Figure 1
Click image to enlarge



Results

Click figures to enlarge





Trachemys scripta ***Pseudemys gorzugi***

Figure 2

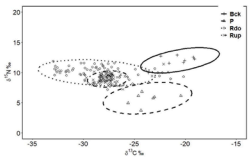


Figure 3

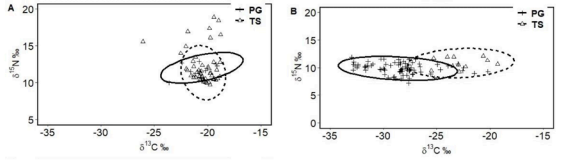
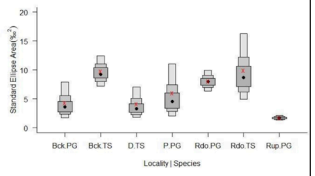


Figure 4



Discussion

- This study is the first to compare isotopic niches of two naturally occurring freshwater turtle species of the PRS
- Our study shows that local resource availability may influence *P. gorzugi* niche width. We speculate that isotopic partition of *P. gorzugi* among surveyed sites reflects the local availability of resources and their isotopic signatures
- At the sites where both species occur, we documented niche overlap, especially for $\delta^{15}N$ values. it is likely that the species are competing for similar resources although *T. scripta* generally showed wider ranges for $\delta^{13}C$ and $\delta^{15}N$
- Isotopic similarity does not necessarily represent ecological or dietary similarity; different food resources could contain identical isotopic compositions
- Future studies should focus on expanding surveyed locations across *P. gorzugi* range (i.e., Texas) and conducting a thorough assessment of site-specific food sources in order to construct mixing models of prey item distribution in *P. gorzugi* diets



Acknowledgments

We thank New Mexico Water Resources Research Institute for funding. We also thank undergraduate and graduate students from ENMU for their help with tissue collection. This project was approved by NMDGF authorization #3621 and ENMU IACUC (03-02/2016; 2019-0226-01A1)

Abstract 12) Isotopic Niche Overlap Among Freshwater Turtles in the Pecos River System, USA (Pg. 128)

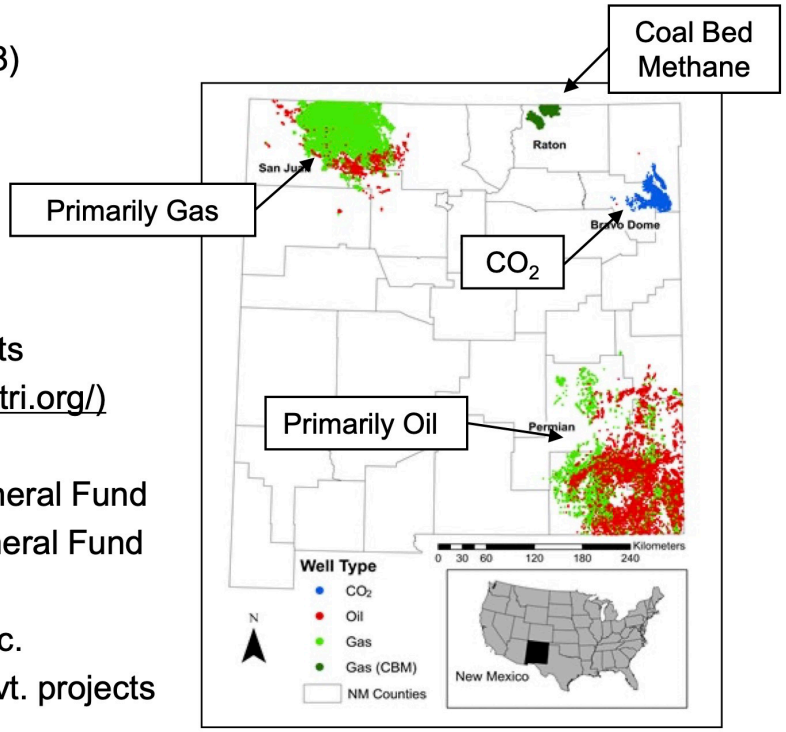
Analysis of the Relationship Between Water, Oil and Gas in New Mexico: Past and Future Trends

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- Contribution to NM's economy (LFC Finance Facts, 2018)
  - Oil production value: $6 - $8 B
  - Gas production value: $5 - $7 B
- ~$2 B in direct revenues to NM
  - ~$1B to General Fund
  - $400 - $500 M for Capital Outlay
  - Property & gross receipts taxes to local governments
  - > 30% of General Fund revenues in 2018 (www.nmtri.org/)
- General rule of thumb
  - $1/bbl increase in oil price produces $9.5 M for General Fund
  - 10% increase in gas price produces $6.5 M for General Fund
- 21 beneficiaries
  - Land grant permanent fund – Schools, hospitals, etc.
  - Severance tax permanent fund – Retire debt for govt. projects
- But O&G development has a large water footprint for:
  - Well development by hydraulic fracturing (HF or fracking)
  - Wastewater from production (produced water)



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Environmental Flow Analysis for Rio Grande Silvery Minnow Recruitment

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Aubrey Harris, PE
U.S. Army Corps of Engineers, Albuquerque, NM, USA

Introduction

- Environmental flow parameters for Rio Grande Silvery Minnow
- Functional analysis evaluated the relationships of metrics
- Fish population metrics calculated from monitoring data
  - Spring-summer recruitment
  - Fall population index
- Environmental metrics
  - Seasonal hydrology (magnitude, duration),
  - Habitat suitability based on hydraulic analyses
- Environmental flow parameters supports adaptive management
- Inform water management strategies
- Inform restoration design criteria.

Functional Analysis Methods

- Functional analysis evaluates the relationships of fish and environmental metrics
- **Fish metrics were derived from population monitoring data**
  - Recruitment slope measures reproductive success from May through July
  - October Index estimates fish population at the end of irrigation season
- **Environmental metrics (100+) were derived to characterize spring runoff**
  - Flow data was from the USGS Gage at Central Bridge in Albuquerque
  - Hydrologic metrics were derived using the Ecosystem Function Model (EFM) from the Hydrologic Engineering Center (HEC)
  - Hydraulic metrics were derived using HEC River Analysis System (RAS) based on EFM flow metrics
- **R software** used to generate linear models of fish and environmental metric pairs
- Higher correlation (r^2) with smaller **AIC** score of fish metric with environmental metric indicates the strength of interaction
- Evaluate the ecological and biological relevance of metric interactions

Fish Metric	Formula	Date
Recruit Slope	lm(fish/area*100)	May 1 - Aug 9
October Index	fish/area*100	October

Results

Functional analysis suggests the **14-21 day maximum-minimum flow** is important for silvery minnow production

- Good flow is correlated with higher Silvery Minnow Recruitment and the subsequent October Index
- Poor flow is correlated with low Recruitment and October Index
- Threshold flow represents flow magnitude between 1130-2100 cfs for 14-21 days duration that warrant additional analysis to identify useful minimum spring runoff

Environmental flow (Spring runoff)	21-day maximum-minimum flow range		14-day maximum-minimum flow range		Recruitment (slope)		October Index (CPUE)	
	Min	Max	Min	Max	Min	Max	Min	Max
Good flow	2460	5610	2630	5780	0.26	1.15	0.42	36.83
Threshold flow	1130	1870	1400	2100	0.06	0.07	0.15	0.79
Poor flow	426	759	499	1040	0.00	0.07	0.01	0.55

Conclusions

Additional analyses focusing on the 1130-2100 cfs magnitude for 14-21 days duration should refine the minimum environmental flow for successful Silvery Minnow reproduction

Acknowledgements

Thanks to:
- U.S. Army Corps of Engineers Upper Rio Grande Water Operations
- U.S. Army Corps of Engineers Middle Rio Grande Endangered Species Collaborative Program
- U.S. Army Corps of Engineers Engineering Research and Design Center
- U.S. Bureau of Reclamation
- American Southwest Ichthyological Researchers

Abstract 14) Environmental Flow Analysis for Rio Grande Silvery Minnow Recruitment (Pg. 128)

Establishing methods to artificially spawn Pecos River minnows

Rick Raymondi and Jesse Filbrun

Dept. of Biology, Eastern New Mexico University, Portales, NM

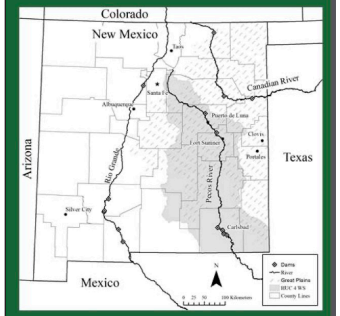
Background and Research Objectives

Background

- New Mexico is in a period of prolonged drought exacerbated by climate change.
- Fishes of the Great Plains are vulnerable to habitat fragmentation from dam construction and regional drying.
- Quantifying the effects of water management on native fishes is critical for future conservation efforts.

Research Objectives

- Establish artificial spawning methods for native fishes.
- Investigate the effects of high discharge on larvae of native fishes using an artificial stream tank.

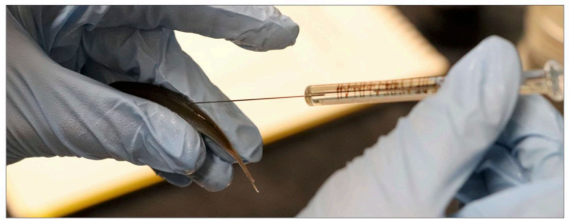


A map the Pecos River watershed (shaded area) and the Great Plains ecoregion (hatch lines).

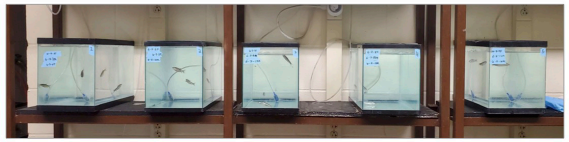
Rick Raymondi
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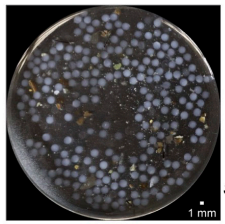
Methods

- Target species were collected from the Pecos River using backpack electrofishers and transported back to the Behavior Ecology Laboratory at ENMU.
- Fish were acclimated in species specific tanks for a minimum of 24-hours before injection trials.
- Specimens were assessed for maturity with gravid females and ripe males selected and anesthetized with MS-222 before Ovaprim® injection.
- Injected fish were placed in aquaria with different environmental variables and monitored for spawning activity.



Above: intramuscular injection with Ovaprim® behind the dorsal fin of Plains Minnow. Below: specimens in spawning aquaria post injection.





Left: unfertilized Plains Minnows eggs 12-hours after injection. Right: positive results from a successful reproduction event; Red Shiner minnow at 12 weeks.

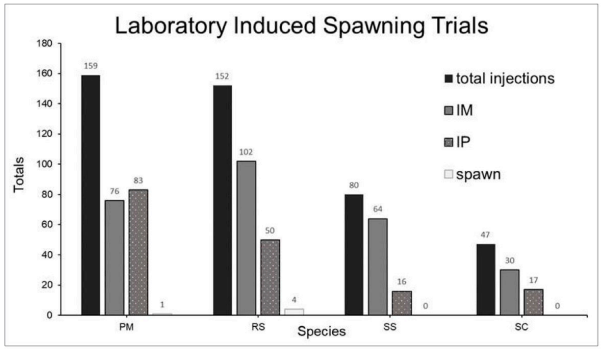


Life History Traits of Candidate Fishes

Species	Spawning Behavior	Egg Type	Status
Speckled Chub[1] *Macrhybopsis aestivalis*	pelagic broadcast	semibuoyant nonadhesive	native
Plains Minnow[1] *Hybognathus placitus*	pelagic broadcast	semibuoyant nonadhesive	non-native
Sand Shiner[1] *Notropis stramineus*	broadcast	demersal adhesive	native
Red Shiner[2] *Cyprinella lutrensis*	speleophils	demersal adhesive	native

Life histories of candidate species that represent different life histories of cyprinids in the Pecos River.

Results



Results form spawning trials. IM = intramuscular, IP = intraperitoneal, spawn = single tank event, PM=Plains Minnow, RS=Red Shiner, SS=Sand Shiner, SC=Speckled Chub.

Discussion

- We performed 438 Ovaprim® injections between June and August with only five unique spawning events occurring. One event was the release of unfertilized eggs by Plains Minnows with the four successful reproductive events by Red Shiner.
- We believe that Ovaprim® will aid in the laboratory induced spawning of Pecos River minnows but water chemistry, flow, and substrate play a critical role. Future trials should mimic Pecos River water chemistry in the lab as river chemistry changes pre- and post-reservoir release.

References

[1]Platania, S.P., Altenbach, C.S. 1998. Reproductive strategies and egg types of seven Rio Grand basin cyprinids. Copeia 3: 559–569.

[2]Simon, T. P. 1999. Assessment of Balon's reproductive guilds with application to Midwestern North American Freshwater Fishes, pp. 97-121. *In*: Simon, T.L. (ed.). Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press. Boca Raton, Florida. 671 pp.

Acknowledgments

This study is funded by internal Faculty Research Grants awarded to Jesse Filbrun, NM WRRI (NMWRRI-SG-2020) and the New Mexico State Legislature. Field collections were approved by NMDGF (Permit # 3678) and ENMU (IACUC # 2019-0301-03, 2020-0317-05). We thank Sara Ricklefs for assisting in specimen collection and injection trials.

Abstract 15) Establishing Methods to Artificially Spawn Pecos River Minnows (Pg. 129)

Repeat Post-Wildfire Geomorphic Surveys of North Fork Eagle Creek, New Mexico, 2017 to 2021

Alexander P. Graziano
U.S. Geological Survey, New Mexico Water Science Center

Introduction

About one-quarter of the water supply for the Village of Ruidoso, New Mexico, is from groundwater pumped from wells located along North Fork Eagle Creek in the mountains of the Lincoln National Forest (U.S. Department of Agriculture [USDA] Forest Service, 2016) (fig. 1 and fig. 2). Concerns regarding both the effects of groundwater pumping and the 2012 Little Bear Fire (fig. 3) on the surface water hydrology of North Fork Eagle Creek, led the USDA Forest Service, Lincoln National Forest, to require monitoring of North Fork Eagle Creek for short-term geomorphic change as part of the permitting decision that allows for continued pumping of the production wells (USDA Forest Service, 2016).

To address the geomorphic monitoring requirements, annual geomorphic surveys of North Fork Eagle Creek along a 1.89-mile-long study reach between the North Fork Eagle Creek near Alto, New Mexico, streamgage (U.S. Geological Survey [USGS] site 08387550) and the Eagle Creek below South Fork near Alto, New Mexico, streamgage (USGS site 08387600) (fig. 2 and fig. 4) were conducted from 2017 to 2020. (A final survey is planned for the summer of 2021).

Methods

- Annual topographic surveys of 14 select cross sections using real-time kinematic global navigation satellite systems (RTK GNSS)
- Annual surveys of all woody debris accumulations and pools in the channel of the study reach, which include:
    - Identifying and cataloguing all woody debris accumulations and pools
    - Taking photographs of all woody debris accumulations and pools
    - Classifying woody debris accumulations by their potential to form debris jams
    - Measuring all pools for residual depth
- Qualitative annual surveys of other features of geomorphic significance (for example, channel bifurcations, flood deposits, and fine-sediment accumulations)

Study area

Figure 1. Location of Study Area in New Mexico



Figure 2. Study Area in the Eagle Creek Basin (modified from Matherne and others, 2010)

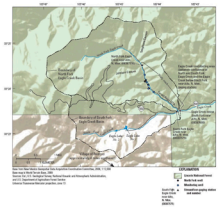
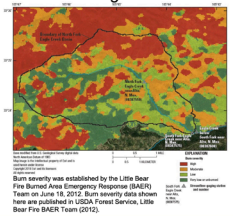
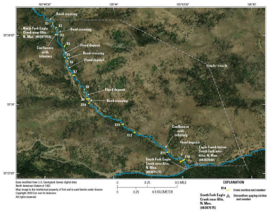


Figure 3. Burn Severity of the Little Bear Fire of 2012 in the North Fork Eagle Creek Basin



Burn severity was established by the Little Bear Fire Burned Area Emergency Response (BAER) Team on June 18, 2012. Burn severity data shown here are published in USDA Forest Service, Little Bear Fire BAER Team (2012).

Figure 4. Study Reach with Locations of Cross Sections and Other Features



Large sections of the study reach (fig. 4) are characterized by intermittent streamflow (Matherne and others, 2010). Where streamflow is normally continuous (including at the upper and lower portions of the study reach, near the streamgages), the discharge typically remains less than 2 cubic feet per second throughout the year (Graziano, 2019).

Results & Conclusions

Figure 5. Discharge at the North Fork Eagle Creek Streamgage (08387550) between the 2017 and 2019 Surveys

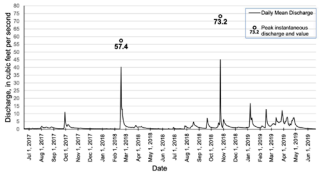
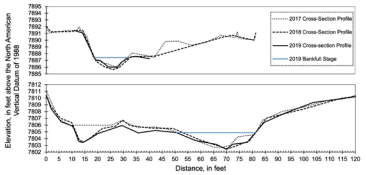


Figure 6. Example North Fork Eagle Creek Cross Sections, 2017 to 2019 (*Data are preliminary and subject to revision*)



Geomorphic change to the study reach is expected to be largely driven by seasonal high-flow events, specifically those with peak discharges greater than 50 cubic feet per second that have about a 2-year recurrence interval and tend to occur during the North American monsoon months of July, August, and September or result from snowmelt runoff in the winter and spring months (Graziano, 2019).

Preliminary results from the 2018 and 2019 surveys indicate that seasonal high-flow events (fig. 5) have only caused minor observable geomorphic changes (aggradation or degradation of surface materials by about 1–2 feet) in parts of 3 of the 14 surveyed cross sections (fig. 6). However, the number of woody debris accumulations in the channel has substantially increased and some of those accumulations have appeared to influence local geomorphic changes, including the formation of pools (fig. 7).

Figure 7. Photos of Woody Debris Accumulations from the 2019 Survey



Disclaimer: This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

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U.S. Department of Agriculture [USDA] Forest Service, 2016, Record of decision, North Fork Eagle Creek Wells Special Use Authorization: U.S. Department of Agriculture Forest Service, 28 p., accessed July 18, 2018, at https://www.fs.usda.gov/project/?project=9603.

Acknowledgements

This study is being conducted in cooperation with the Village of Ruidoso

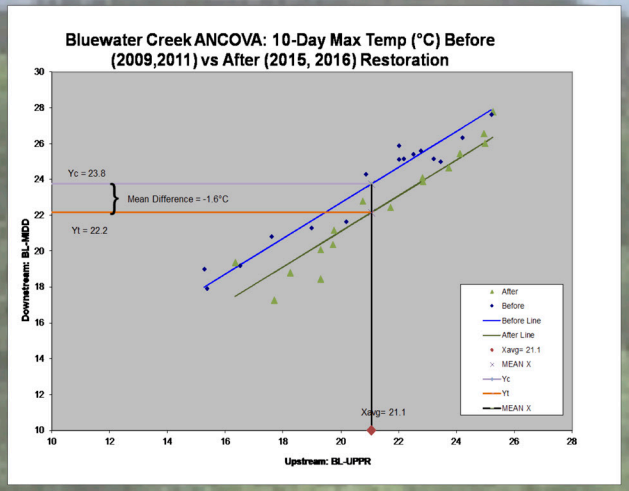
Abstract 21) Repeat Post-Wildfire Geomorphic Surveys of North Fork Eagle Creek, New Mexico, 2017 to 2021 (Pg. 130)

Determining the Effects of Stream Restoration on Bluewater Creek, New Mexico

Daniel Guevara, Watershed Scientist
NMED Surface Water Quality Bureau



Bluewater Creek project reach before restoration (2009).



ANCOVA Chart showing decrease in stream temperature on Bluewater Creek Upstream/Downstream Before/After restoration



Bluewater Creek Project Reach After Restoration (2017).



Restoration and best management practices have improved water quality on Bluewater Creek in Cibola County NM. Prior to the improvements, Bluewater creek was heavily impacted by off-road vehicle use and grazing. Staff from the Surface Water Quality Bureau (SWQB) at the New Mexico Environment Department (NMED) documented water quality problems such as high nutrients, turbidity, and temperature. Starting in 2009, Wild Earth Guardians conducted a Clean Water Act (CWA) Section 319(h) project to build fencing exclosures to restrict access for herbivores and off-road vehicles to the riparian area, and to re-plant native vegetation including cottonwood trees and willows. Additionally, the Cibola National Forest improved grazing management in the upper watershed by rounding up wild horses that were impacting the area. The results were impressive as the area was transformed from a denuded channel to a lush riparian forest in just a few years. Subsequent water quality surveys indicated that nutrient and turbidity levels had improved, and these impairments were removed from the 303(d) List of Impaired Waters. The success of this work indicates that these proven methods could be applied in other similar locations to improve steam habitat and water quality.

Methods

- Onset Hobo Water Temp Pro V2 loggers recorded stream temp on 15 minute interval
- Spherical densiometer provided percent canopy cover values
- Before/After Upstream/Downstream Study Design for statistical analysis
- Analysis of Covariance (ANCOVA) quantified the effects of restoration. (Grabow, Spooner, et al. 1998)

New Mexico Environment Department – Surface Water Quality Bureau
https://www.epa.gov/nps/nonpoint-source-success-stories-new-mexico

Abstract 23) Determining the Effects of Stream Restoration Projects on Water Quality in Northern New Mexico (Pg. 131)

Solar reforming of microplastics in water for H_2 production and degradation using nanocomposite photocatalysts

E. M. N. Thiloka Edirisooriya, Huiyao Wang, Pei Xu

Department of Civil Engineering, New Mexico State University, Las Cruces, NM

Introduction

- Microplastics are the most substantial category of anthropogenic particles.
- Highly stable and durable plastic particles are accumulated due to the plastic debris released into water bodies.
- Millions of micro- and nano-sized plastics are formed as a result of photodegradation, embrittlement, and fragmentation because of wave action.
- The long-term presence of these particles in water and their accumulation in the food chain have severely impacted living organisms, including human beings.
- The research objective is to develop efficient and sustainable methods to degrade micro- and nano-plastics from water using photocatalysis while producing hydrogen (H_2) under solar reforming.

Classification, Sources, and Properties of Microplastics

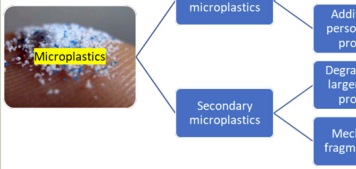


Figure 1: Classification of microplastics

Table 1: Properties of micro and nano plastics

Property	Nanoplastics	Microplastics
Composition	Mixture of polymers, highly weathered	Different polymers
Size	1 nm-1 µm	Lower limit 1 to 20 µm Upper limit 1 -5 mm
Size distribution	Polydisperse (continuum of size)	Polydisperse
Shape	Asymmetrical	Pellets, fragments and fibres or irregular
Surface charge	Uncontrolled with the presence of different species	

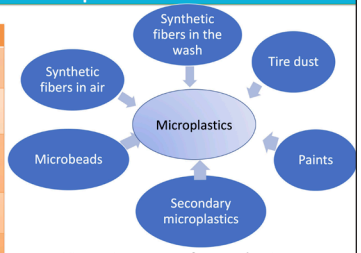


Figure 2: Sources of microplastics

Toxicity

- MPs may be toxic due to their inherent ability to induce intestinal blockage or tissue abrasion.
- In earthworms (*Eisenia andrei*), fibrosis, congestion and inflammatory infiltrates were observed after exposure to MPs (from 62 to 1000 mg/kg of polyethelene).
- In sea bass (*Dicentrarchus labrax*), moderate to severe histopathological alterations of the intestine were measured, after 30-90 days of exposure to poly vinyl chloride MP through ingestion.
- limited absorption (0.2%) of polylactide-co-glycolide microparticles (3 mm) was measured in human mucosal colon tissue. The mucosal colon tissue of patients with inflammatory bowel disease, showed increased transport (0.45% as compared to 0.2% in healthy controls) in relation to greater gut permeability. (Table 3)

Removal technologies

Table 2: Summary of removal technologies of micro and nano plastics

Size range of plastics	Method	Remarks
Microplastics (1 mm – 5 mm)	Membrane bioreactor	Removal efficiency 99.9%
	Rapid sand filter	Removal efficiency 97%
	Disc filter	Removal efficiency 95%
	Coagulation process	Removal efficiency below 40%
	Ultrafiltration process	Higher removal efficiency than that of coagulation process
Microplastics (10-20 µm)	Magnetic Polyoxometalate-Supported Ionic Liquid Phases (magPOM-SILPs)	Removal efficiency over 90%
Nanoplastics	Advanced oxidation process	Much greener approach
	ballasted flocculation	Removal efficiency 88% (Lab scale)
	Filtration with a 0.22 µm filter	Removal efficiency 92 % (Lab scale)
	centrifugation at 10,000 rpm	Removal efficiency 99% (Lab scale)

Advanced oxidation & Photo reforming

- Advanced oxidation includes homogeneous or heterogeneous photocatalysis.
- In photocatalysis many pollutants in the water are breakdown at the room temperature by oxidation.
- Either sunlight or artificial light can be used as energy source.
- Owing to its low production cost and good chemical stability, it has been widely employed in photo-degradation of organic compounds (Table 4)

- Application of photocatalysis to H_2 production from organic substrates is usually called photo reforming, makes use of semiconductors to promote redox reactions, namely, the oxidation of organic molecules and the reduction of H+ to H_2 (Table 4)

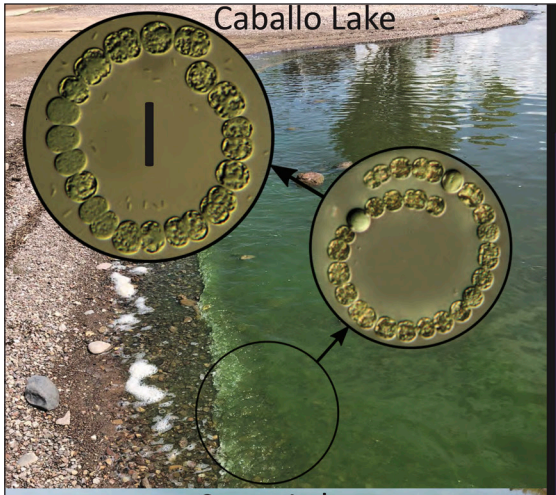
Conclusions

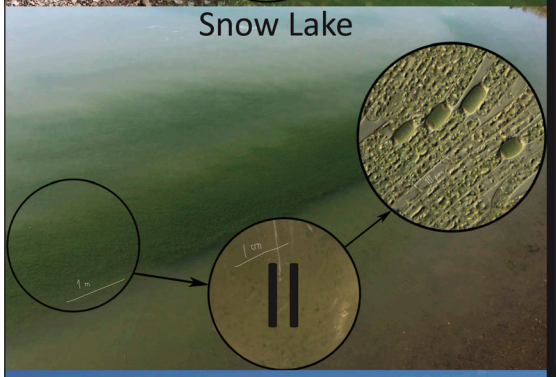
Highly functional photocatalysts such as ZnO-Pt, TiO_2-Au, TiO_2-Pt, and graphene oxide/TiO_2/Au ternary nanocomposites are proposed to use in further studies to remove micro- and nano-plastics that can easily pass through the conventional treatment methods. Development of highly functional nanocomposite photocatalysts to clean water and convert microplastics from a waste to H_2 energy is proposed as an environmental remediation of microplastic pollution

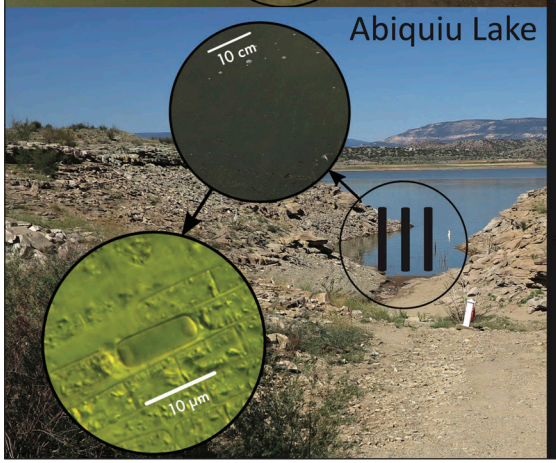
Acknowledgements

Funded by the 2020-2021 Student Water Research Grant Program of the New Mexico Water Resources Research Institute (NM WRRI).

Abstract 25) Solar Reforming of Microplastics in Water for H_2 Production and Degradation Using Nanocomposite Photocatalysts (Pg. 131)







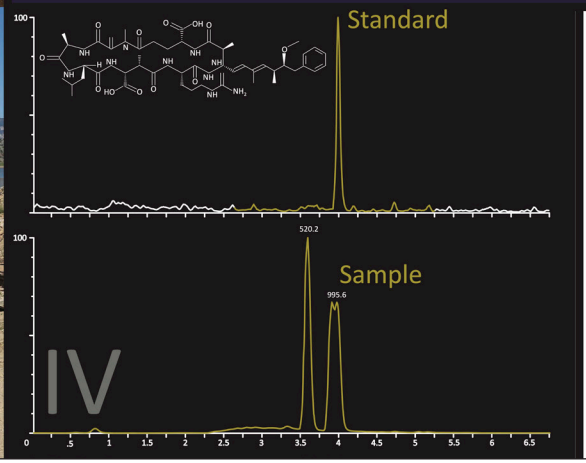
Assessment of the cyanobacterial Harmful Algal Blooms (cHABs) and toxins in the blooming water bodies of New Mexico

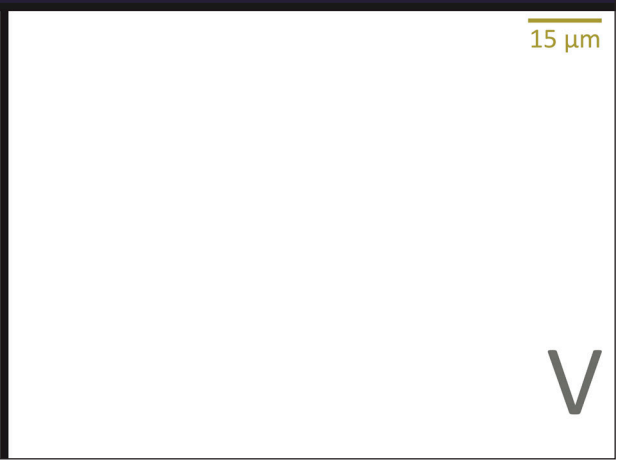
Sergei Shalygin, F. Omar Holguin, and Peter Cooke

Cyanobacterial Harmful Algal Blooms (cHABs) are the cause of many environmental problems World Wide. Once established in the water body, cHABs persist for many years. Many cyanobacterial species form and release dreadful toxins into the water. CHABs are progressing in the world and in USA due to nitrogen/phosphorus pollution and climate change/tempreture increase. Some cyanobacterial species have specific nitrogen fixing cells, making them independent from inorganic nitrogen. Prior to this research there were only disintegrated information about cHABs on the territory of New Mexico.

In the attemt to assess cHABs, several scientific methodics were implemented. To determine taxomonic affiliation of the major bloom taxa, LIGHT MICROSCOPY was used. In order to confirm viability and pigments distribution in the cells CONFOCAL MICROSCOPY was applied. TANDEM MASS SPECTROMETRY coupled with ULTRA PERFORMANCE LIQUID CHROMATOGRAPHY was used to identify 10 major cyanobacterial toxins. Standard solution of Microcystin-LR was run with the toxin samples extracted from water and biomass. MRM (Multiple Reaction Method) with two daughter fragments was used for reliable identification of the toxins. Due to COVID-19 quarantine quantification of the toxins was postoned.

According to the morphological analysis, species composition of 3 lakes under study (I, II, III) was quite diverse. Caballo Lake had *Dolichospermum spiroides* (I) as a major bloom contributor. In contrary, *Aphanizomenon flos-aquae* (II, III) was a dominant species in Snow Lake and Abiquiu Lake. There was transition in species composition from summer to fall, to the communities with multiple *Microcystis* species in Snow Lake and Abiquiu. Caballo Lake did not sustain massive bloom in the fall season. In order, to evaluate community structure, Next-Generation sequencing will be applied in future. Confocal imaging showed clear Chlorophyll distribution within the *Aphanizomenon flos-aquae* cells (V), indicating viability of populations. It also showed empty volume in the terminal cells which promotes efficient buoyancy of a population. Mass spectrometry identified 3 cyanobacterial toxins in the summer waters of 2 lakes: Caballo and Abiquiu (IV). In the fall, major toxins were found in the Snow Lake only, where community structure shifted to the *Microcystis* spp. dominated. Similar trend was observed in the Abiquiu Lake, however MRM did not find any substantial toxins neither in water nor in the living biomass. This research may serve as a template for monitoring program of water bodies of New Mexico, which is missing at the time.





Abstract 26) Assessment of the Cyanobacterial Harmful Algal Blooms (cHABs) and Toxins in the Blooming Water Bodies of New Mexico (Pg.131)

The New Mexico Produced Water Database 2020

Martha Cather and Raven Goswick

Petroleum Recovery Research Center, a division of New Mexico Tech

The Challenge

How can we do a better job of managing produced water if we don't know much about it?

- Do we know where the water comes from, how much of it is there, how much is brought in from outside the system, how much is disposed or recycled, and how much quantity or quality can vary in time and/or space?
- The primary objective of this research was to build a geospatial database of oilfield water volume information that can be linked to the existing produced water quality databases.
- A second objective was to survey people involved in produced water management in the industry to get more information on usage practices.
- Data from several sources was compiled into a database that allows users to conduct temporospatial and stratigraphic analysis, to better visualize locations, important formations, and volumes of water production and injection and in doing so to have a better understanding of the overall "budget" for oilfield waters in New Mexico. The database is linked to two pre-existing water quality databases.

It's *hard* to make a database look **EXCITING!!!!**



But with this database, we've answered some of our most frequent user requests. We have:

- Combined volume data for water, oil, and gas production along with injection data for 1995 to midway through 2020
- Kept granularity - Volume data is on the level of well and pool by month and year
- Provided aggregations of data such as annual cumulative totals, totals by well, and information to allow aggregation by pool, formation, county, or other parameters
- Added produced water quality data from both the 2016 NM Produced water database and the USGS produced water database
- Combined the best of the NM OCD well information with some of our legacy data for better identification of historical wells, added some
- Cleaned up well identifications, locations, and formations for the USGS produced water database
- Database is in Microsoft Access, but has spatial data and identifiers to allow use with GIS programs

So What?

Our next panels will show you how our database can be used to answer typical questions such as:

- How much water is produced or injected in New Mexico?
- What region (county, township, well) has the most production? Injection?
- Can we distinguish water production or injection versus water that is recycled through EOR projects?
- What formations or pools produce the most water? Which take the most disposed water?
- Where's the highest quality produced water in the state? How about the worst?
- How do water/oil ratios change through time?

Abstract 27) The New Mexico Produced Water Database 2020 (Pg. 132)

Hydrogeochemical Analysis of Springs in the Cibola National Forest: Implications for Springs/Wetlands Sustainability & Geochemical Response to Forest Fire

[1]Naomi T. DeLay, [1]Laura J. Crossey, and [2]Livia Crowley

[1]Dept. of Earth & Planetary Sciences, University of New Mexico, Albuquerque, NM 87131

[2]National Forest Service, Cibola National Forest, 2113 Osuna Rd NE, Albuquerque, NM 87113

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Introduction

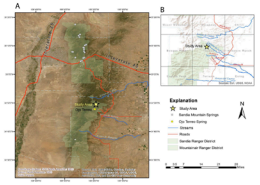


Figure 1: A- Larger map with aerial imagery shows Ranger Districts, major hydrology, roads, and location of the study area that includes Ojo del Rancho del Medio and Ojo del Rancho del Medio West. B- Close-up terrain map shows important roads and hydrology as well as USGS quadrangles of the study area. The star indicates the location of the focus study springs.

Aridland springs of the Southwest provide habitat for many species and important resources for local communities. Ojo del Rancho del Medio (RDM) and Ojo del Rancho del Medio West (RDMW) springs within the Mountainair District of the Cibola National Forest located in the Manzano Mountains are the focus of this study (shown in Fig 1). This work builds on recent regional springs assessments in the Cibola National Forest by the USFS. During this study, seasonal monitoring is proposed to continue beginning in summer of 2019 until spring/summer of 2021.

Research goals of the study:

(i) use geochemical tools to characterize water quality and understand sustainability in selected springs of the Manzano Mountains

(ii) characterize the hydrologic flow paths and spring-flow regions of the Manzano spring waters

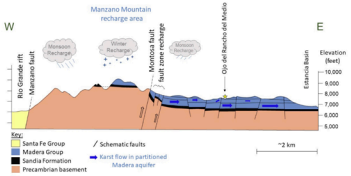


Figure 2: Local schematic cross section of the Manzano Mountains. Modified from Kietzstron et al. (1999) and Allen (2002). Schematic cross section shows the major faults and stratigraphy of the USGS Tajique and Bosque Peak and quadrangles through the study area (Ojo del Rancho del Medio Spring). Includes blue arrows showing karst flow through the Madera Group and recharge mechanisms through monsoonal and winter recharge.

Methods





Figure 3 & 4: Top image- Photo of Confluence of Ojo del Rancho del Medio and Ojo del Rancho del Medio West. Bottom image- Installation of CDT sensor downstream of springs.

Monitoring of springs: By collecting the seasonal physico-chemical parameters, water samples, and additionally the deployment of continuous sensors (CDT- Conductance Depth Temperature sensors and barometer) from August to November of 2020 (shown in Fig 4)

Sample Water Analysis:
Major and trace ion chemistry analysis using Ion Chromatography (IC), Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES), and Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) (Analytical Geochemistry Laboratory at UNM EPS)

Isotope Analysis: Analyze water samples for the isotopic values of deuterium and oxygen (δD and $\delta^{18}O$) using Picarro cavity ring-down spectroscopy (Center for Stable Isotopes at UNM)

Results & Conclusions

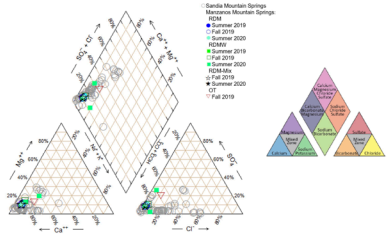


Figure 5: Major-ion chemistry analyses are shown using a Piper Diagram (Tumejag). Piper includes previous samples of Sandia Mountain springs and pdata from this study's sampling sites including Ojo del Rancho del Medio Spring (RDM), Ojo del Rancho del Medio West Spring (RDMW), Ojo Ternes Spring (OT), and the Confluence of Ojo del Rancho del Medio and Ojo del Rancho del Medio West Springs (RDM-Mixed) for different seasons between 2019 and 2020. The hydrochemical facies in right hand Piper diagram from Frus (2016).

- Major ion geochemical analyses show these springs are consistent with other Sandia mountain springs issuing from the Madera Group carbonates.
- These waters plot in the calcium, bicarbonate, and the calcium bicarbonate magnesium dominant hydrochemical facies (Frus, 2016) of the Piper diagram (Fig 5) indicating the similar major chemistry.

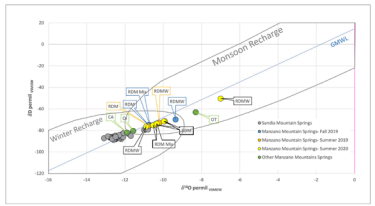


Figure 6: The stable isotope values of O and H are plotted relative to the Global Meteoric Water Line. The GMWL shows the linear relationship (slope of 8) of surface waters across the globe (Craig, 1961). Parabolas show the different recharge mechanisms (monsoonal and winter recharge) based on the work by Sharp, 2017 and Frus, 2016. This plot includes results from this study in the Manzano Mountains and previous analyses in the Sandia Mountains (Griego et al., 2018). Spring acronyms: OT-Ojo Ternes, OI-Ojo del Indio, CA-Capilla Spring. See Fig 5 for remaining acronyms.

- Analyses in show isotopologues (δD and $\delta^{18}O$) of the study springs are within the range of observed values for the nearby Sandia mountains consistent with winter recharge mechanisms (shown in Fig 6).
- Isotopologues of these waters indicate recharge from high elevation in the mountains.

Future Work & Broader Implications

Future Work:
- Tritium water sampling
- Analysis of continuous sensor data

Broader Implications:
- This study will provide the first baseline of the seasonal hydrochemistry in the Manzano Mountains.
- Based on the outcome of this study, understanding the dynamics and interactions of the springs will help us to better understand the sustainability of these springs to aid in management decisions.
- Monitoring of the water quality of these springs will assist in understanding how these springs are being affected by land management decisions.
  - For example, the conclusion of the survey by the Springs Stewardship Institute in the summer of 2019 confirmed that livestock are affecting the springs.
  - This study may bolster those recommendations.

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Acknowledgements

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Abstract 28) Hydrogeochemical Analysis of Springs in the Cibola National Forest: Implications For Springs/Wetlands Sustainability & Geochemical Response to Forest Fire (Pg. 132)

Phycoremediation of Contaminated Groundwater With Microalgae for Simultaneous Water Treatment and Biofuel Production at a Legacy Uranium Mining Site.

Zachary DeLay1, Annie Padilla2, Ondine Frauenglass3, Luke Spangenburg4, Stephen Gómez5

History of site

- From 1958 to 1963 3 million tons of uranium ore were processed at the Ambrosia lake facility.
- Philips petroleum built original mill in 1957 and operated the site until 1963.
- United Nuclear Corporation operated the mill from 1970 to 1982 operating an Ion exchange system to extract uranium from mine water.

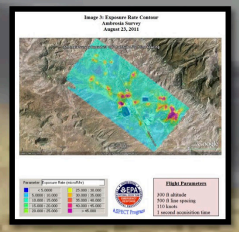




SFCC Technicians growing algae collected from Ambrosia Lake site

Current scope of work



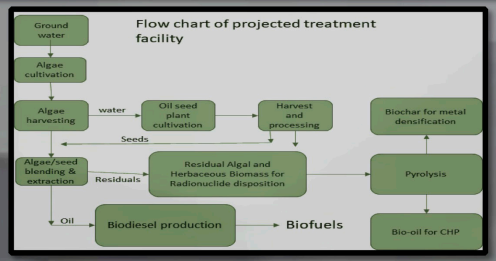


- Site now considered a legacy/superfund site owned by BHP



Multiple polyculture samples were cultured and scaled up into 2L PBRs which were used as inoculant for later experiments.

Phytoremediation and Biomass production



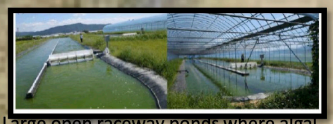
- Phytoremediation of water sources has been implemented in various methods to remediate multiple sources.
- Heavy metal removal can be accomplished with microalgae polycultures which utilize a variety of algal species which are used to increase absorption rates and target specific metals.
- The use of microalgae in wastewater treatment to eliminate excess nutrients within solution has been practiced for many years.
- Biomass will be collected from algae and crops to create biofuels which can then be used to power a process within the system.

Collaborators

- New Mexico State University(NMSU) is researching terrestrial plants which absorb contaminants and heavy metals still present in the soil.
- Remediated water produced from phytoremediation through SFCC processes will be used to grow crops and further clean water and soil.
- Oregon State University is researching phytoremediation properties of native grasses and potential uses
- National Renewable Energy Laboratory (NREL) has been offering oversight, data research/analysis and leadership.

Future

- BHP owns the site currently and will be operating Greenhouses that will be constructed on site to create and grow algae polycultures used to remediate water.



- Large open raceway ponds where algal biomass can be harvested after reaching desired density.



Abstract 30) Phycoremediation of Contaminated Groundwater with Microalgae for Simultaneous Water Treatment and Biofuel Production at a Legacy Uranium Mining Site (Pg. 133)

A Critical Review of Reclamation's Water Yield Modeling for the New Mexico Unit of the Central Arizona Project

Norm Gaume, P.E. (ret.) and Peter Coha

Retired water engineer/manager/consultant for public water agencies and retired Intel principal engineer

Problem Statement

Determine Reclamation's water yield model simulation bases for Reclamation's project performance summary metrics published in the draft Environmental Impact Statement (DEIS) for the New Mexico Unit of the Central Arizona Project, aka **Gila Diversion and Storage Project**, 2004 Arizona Water Settlements Act.

- Net yield of project water
- Reliability of project water yield
- Cost of project water
- Losses
- Impacts of the lowest seniority on the river of the NM Unit's Gila River diversion right

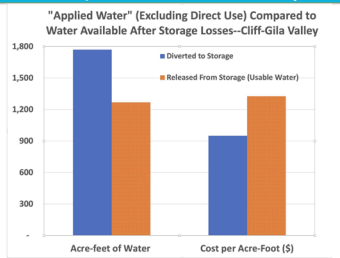
Objective & Methods

Objective: Provide Informed public comment regarding draft Environmental Impact Statement

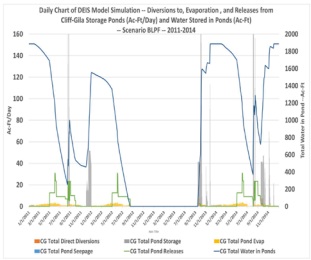
- Reviewed DEIS including appendices and associated technical memoranda
- Identified Reclamation project performance descriptions and conclusions that seemed wrong and which were unsupported by information in the DEIS and technical memoranda
- Obtained Reclamation's Excel workbook yield model from Reclamation
- Asked questions of Reclamation and received written responses
- Determined the details of model structure and operation, including macros that generated scenario simulations. One scenario matched the DEIS preferred alternative "BLPF" (Alternative B, low ditch losses, pecans in crop mix, flood irrigation)
- Compared model simulations with DEIS representations by generating daily, annual, and overall mean and median simulation graphics and data using Excel PivotTable functionality



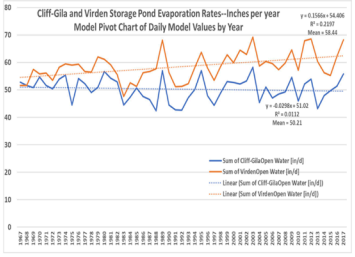
Results (details on subsequent pages) and conclusions



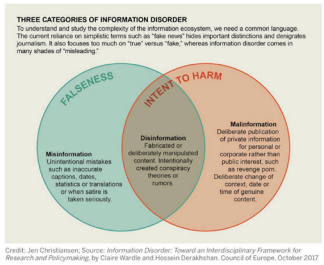
Project water yield and unit costs described in the DEIS as "applied water" included evaporation losses, overstating the yield and understating farm delivery water cost



Reclamation model shows 396 consecutive dry days 2012-13, indicating project unsuited to irrigate pecan orchards



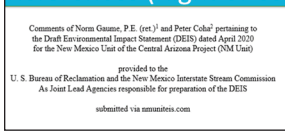
Project evaluation disregarded climate change; model simulations improperly calculated evaporation rates (note negative annual trend)



The DEIS and its water yield model are an example of information disorder.
Graphic from *Scientific American* Sept. 2019

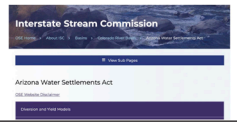
Conclusion:
Reclamation's draft EIS and technical memoranda withheld or misrepresented pertinent modeling results, violating scientific integrity and information integrity essential to democracy and NEPA compliance.

References (Right or control click for hyperlinked documents or websites)















Acknowledgements

GILA CONSERVATION COALITION

NEW MEXICO OPEN MEETINGS ACT

NEW MEXICO INSPECTION OF PUBLIC RECORDS ACT COMPLIANCE GUIDE

nmfog FOUNDATION FOR OPEN GOVERNMENT

Abatement of Lead and Uranium by Fired Natural Clays to Produce Potable Water

Author: Jeremy Jones, Sarah Bockisch, Moticha Franklin, Dr. Antonio S. Lara
Department of Chemistry and Biochemistry, New Mexico State University, Las Cruces, NM, 88003,

Abstract

- Lead and uranium in drinking water are serious threats to human health
- Modern technology is not viable for most people affected
- Clay is a viable option but is difficult to manage
- Fired clay pellets offer an appropriate solution
- Pellets from New Mexico and Arizona reduced the concentration of uranium and lead below EPA MCL

Introduction

- Drinking water contaminated by uranium and/or lead is a serious issue affecting many parts of the world
  - Examples: Navajo Nation, Flint, MI
- Uranium (U) & Lead (Pb)
  - Toxic Heavy Metals (in trace quantities)
  - EPA MCL; U – 30 ppb, Pb – 15 ppb
  - Renal failure, liver damage, & PNS damage
  - U – Cancer
  - Pb – Developmental disorders
- Need an expeditious and economically viable solution
  - Water treatment, reverse osmosis, ultrafiltration, etc.
- Clay economically viable solution
  - Ubiquitous
  - Readily available
  - Abates uranium and lead from aqueous environments
- Clay drawback
  - Clay is difficult to manage when wet
- Solution to mud manageability
  - Fired Clay Pellets
- Two Clay were chosen for this study
  - New Mexico (NM) & Arizona (AZ)
    - Adjacent to the Navajo Nation



Hypothesis

- Both NM and AZ fired clay pellets can abate ppb concentrations of U and Pb to below EPA MCL.
  - Objective
    - Determine the efficacy of fired clay pellet in the sequestration of uranium and lead from aqueous environments.

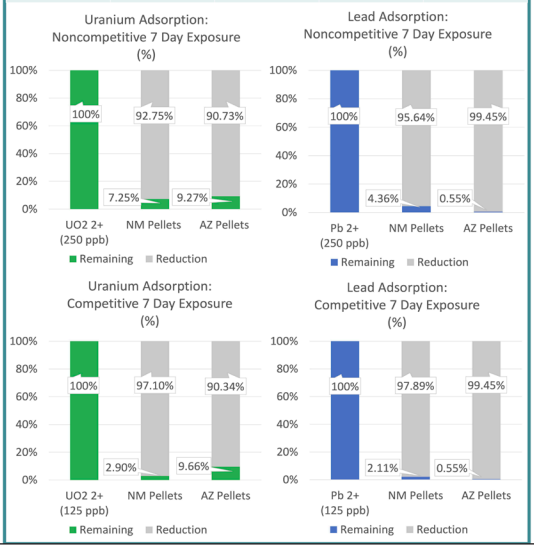
Methods

Non-Competitive & Competitive

- All samples (experimental controls in place)
  - In triplicate; n = 3
  - Five Pellets exposed for seven days with agitation
- Non-competitive
  - Separately, each clay was exposed to 50 mL of 250 ppb U or Pb
- Competitive
  - Simultaneously, each clay was exposed to a 50 mL mixture of 125 ppb U & 125 ppb Pb
  - Chemical adsorption potential
- Sample analysis; ICP-MS; EPA Method 200.8
- Data analysis software: Microsoft Excel

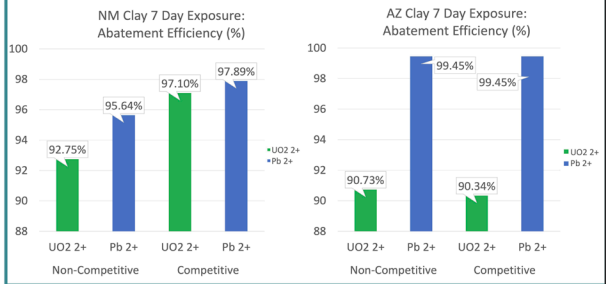
Results

Type of Clay	Non-Competitive (250 ppb)		Competitive (125 ppb)	
	Uranium (ppb)	Lead (ppb)	Uranium (ppb)	Lead (ppb)
NM Pellets (5)	18.12 ± 7.25	10.90 ± 2.73	3.62 ± 0.45	2.64 ± 0.34
AZ Pellets (5)	23.17 ± 0.76	1.37 ± 0.76	12.07 ± 0.86	1.13 ± 0.31



Results

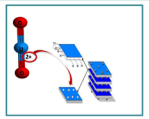
Heavy Metal Cation	NM Clay Pellets (5 ea)		AZ Clay Pellets (5 ea)	
	Non-Competitive (250 ppb)	Competitive (125 ppb)	Non-Competitive (250 ppb)	Competitive (125 ppb)
Uranium (ppb)	18.12 ± 7.25	3.62 ± 0.45	23.17 ± 0.76	12.07 ± 0.86
Lead (ppb)	10.90 ± 2.73	2.64 ± 0.34	1.37 ± 0.76	1.13 ± 0.31



Conclusion

- Results discussion
  - Change in concentration
    - (%) Remaining and Reduction
  - Abatement efficiency
    - Clays
      - Heavy metals
- Both fired clay pellets, NM & AZ, reduced U and Pb to below EPA MCL
- Both clays appear to have a higher affinity for lead
  - AZ abates more lead than NM
  - NM abates more uranium than AZ
- Fired clay pellets offer a prompt and viable solution







Future Directions

- Capacity, kinetics, and thermodynamics
- Compare 3 other clays

Acknowledgements

- New Mexico State Legislature NMWRRI2017-18, administered by the New Mexico Water Resources Research Institute
- National Institutes of General Medical Health MBRS R25GM061222 **R**esearch **I**nitiative for **S**cientific **E**nhancement
- College of Engineering New Mexico State University
  Freeport-McMoRan Water Quality Lab
  Mark Chidester



Contact Info: Jeremy Jones; odinseye@nmsu.edu

Abstract 37) Abatement of Lead and Uranium by Fired Natural Clays to Produce Potable Water (Pg. 135)

The Solution to Pollution is Diminution: Use Only Enough

Cecilia V. López

SFCC WTR 111 Prof. Rodke

Introduction

- Algae blooms (HABs) are photosynthesizing, microscopic bacteria that live in slow-moving waters.
- They create toxins harmful to humans, pets, fish and ecosystems.
- Algal blooms are cause by hot temperatures, climate change, upstream pollution, waste water from treatment plants, and **runoff from farms**.

Methods & Objectives

- Not realistic to kill off bacteria in lakes and reservoirs as treatments can kill fish and harm the ecosystem.
- Reduce nutrients like phosphorus and nitrogen from getting into rivers and runoffs that feed into lakes by working with New Mexican farmers and educating them on what they can do to help prevent HABs.
  - Only use what you need: Nutrients found in fertilizers (nitrogen and phosphorus) cause HABs. Educate farmers on the cost effectiveness of only using what they need for fertilizing crops.
  - More doesn't mean better: Educate farmers on the negative impacts of over-fertilizing i.e. crop tissue and soil nutrients.
  - Dry Farming: Dry farming has existed in NM Pueblos for centuries. Teach NM farmers alternative farming methods and give them tax incentives when implementing said methods to help prevent HABs.

Less Fertilizer

- leads to less nutrient rich runoff feeding into lakes and reservoirs causing HABs.
- more money in farmers' pockets.
- less over-fertilized/diseased crops and soils.

Dry Farming

- Ancestral Pueblo people successfully grew crops with dry farming. Giving farmers tax incentives to implement the same methods will directly impact HABs by using little to no water with dry farming.

Did you know?

- Pumice Soil and Farming in the Jemez Mountains—archeological findings have shown that dry farming was used and relied on only precipitation and pumice soil for successful harvests.

Conclusions

Cleaner runoffs:
1.Reduce the amount of fertilizer used on crops.
2. Implementing alternative farming methods that use little to no water.

References & Acknowledgements

New Mexico Geological Society
New Mexico National Park Service
Maria López, Environmental Scientist, Idaho EPA

Abstract 38) The Solution to Pollution is Diminution: Only Use Enough (Pg. 135)

Comparison of Water Movement in Pecan Fields Under Different Irrigation Scenarios; Implications to the Water Cycle

United States Department of Agriculture | National Institute of Food and Agriculture

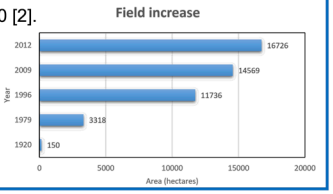
Jorge Preciado, Alexander "Sam" Fernald, Richard Heerema, Salim Bawazir, Manoj Shukla, Curt Pierce

NM Water Resources Research Institute

New Mexico State University, Las Cruces, NM 88003

Introduction

- Agriculture in arid and semi-arid regions can consume more than 80% of the available water [1].
- Pecan production in New Mexico has increase since 1920 [2].
- As of 2017, 13,888 ha of pecans have been planted in Doña Ana County [4].
- Compared with other crops grown in the Lower Rio Grande Basin, pecan trees have the highest consumptive water use [3].



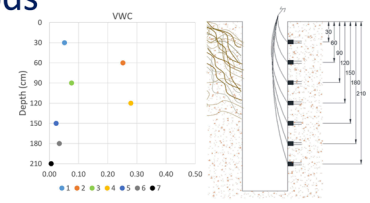
Objectives

1. Estimate recharge and model water flow through the soil in a drip irrigated pecan orchard to better understand surface water/groundwater interactions for improved river basin water management.
2. Quantify water stored in the soil and lost through evapotranspiration.
3. Monitor water table to assess groundwater level fluctuations and quantify water consumption.

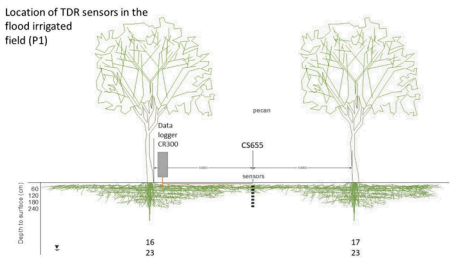
Methods

The study site is located at Leyendecker Plant Science Center, 14 km south of Las Cruces, New Mexico. The field area is 0.04 km^2, with approximately 460 trees with a square spacing of 9 m, trees are approximately 10 years old with an average trunk diameter of 0.20 m.

The soil water content is measure at three different locations using time domain reflectometry (TDR) probes (CS655 12 cm. Campbell Scientific) installed at different depths intervals (30, 60, 90, 120, 150, 180, 210 cm). And the data are stored in a Campbell Scientific data logger CR300.



Volumetric water content at different depths.



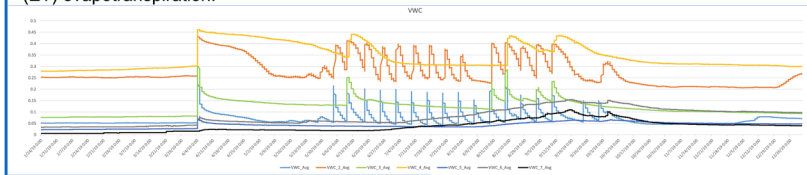
Results

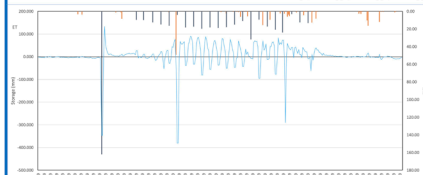
This study is estimating the amount of deep percolation in drip irrigated pecan orchard in the Mesilla Valley, using the commonly used water balance equation [5]

$$DP = IR + R - \Delta S - RO - ET$$

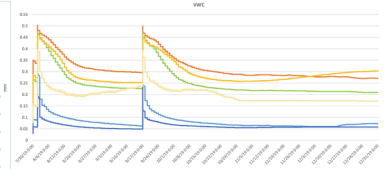
IR: Flow meter (Bigfoot); R: Rain gage; ΔS: CS 655; RO: —; ET: Leyendecker weather station

Where, (DP) deep percolation, (IR) irrigation, (R) precipitation, (ΔS) change in storage, (RO) runoff, (ET) evapotranspiration.

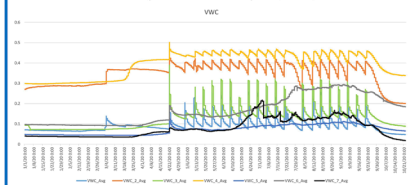




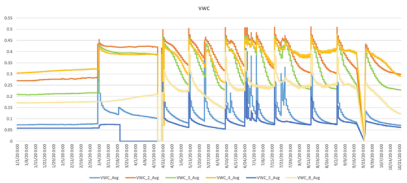
Estimated recharge and water lost through evapotranspiration.



Change in volumetric water content at different depths, highest water content 30% at 1.20 m followed by 25% at .60 m, with an increase in water table in June.



Change in volumetric water content in the drip field.



Change in volumetric water content in the flood field.

Conclusions

The amount of water in 2019 below the root zone was 2659 mm this water is mainly coming from the Rio Grande river, Irrigation amount in the drip field was 492 mm and rainfall was 126 mm in 2019 show that may be some capillary rise in the field that may affect the water movement down in the field.

References:

1. Olivera-Guerra, Merlin, Er-Raki, Khabba, & Escorihuela, 2018
2. Sammis, Shukla, Mexal, Wang, & Miller, 2013
3. Kallestad, Mexal, Sammis, & Heerema, 2008
4. USDA 2017. Census of Agriculture Las Cruces. National Agricultural Statistics Service
5. Shukla, 2014

Funding for this project is provided by USDA to Project No. 2017-68007-26318, through the National Institute for Food and Agricultural's Agriculture and Food Research Initiative, Water for Agricultural Challenge Area

Sustainability in a human-dominated region: the agricultural use of natural capital

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What is Natural Capital ?

Natural capital is a stock that yields a flow of ecosystem service and valuable goods for supporting human activities into the future based on the traditional definition of capital. Sustainability depends on the maintenance of the total stock of capital, including natural capital, out of various parts of the total stock of capital, is non-substitutable.

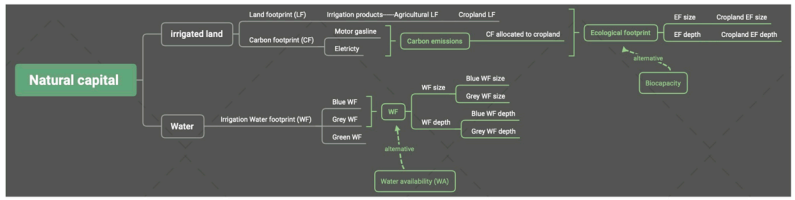
Lighten policy through natural capital

In order to fully deliver nature valuing, the ecological footprint (EF) model is a mature approach for quantitatively measuring the effect of human occupation on natural capital. The 3D ecological footprint (3D EF) model not only depicts stock consumption but also flow occupancy. A System Dynamic model using the STELLA platform is built to simulate how complex systems change over time and to capture realistic dynamic behavior between variables, including feedback loops, delays, and nonlinear relations. This model is appropriate for modeling complex relations among social, economic, and physical components coupled with interdependencies between natural capital and water system.

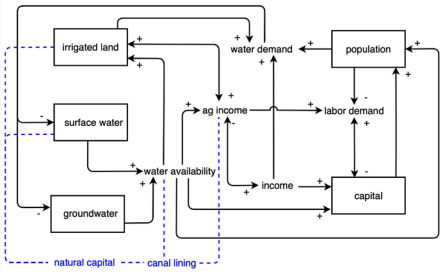
- clarify the value of natural capital
- how the value served in the sustainable management of agricultural water

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Accounting Natural capital in form of irrigated land and water

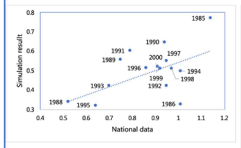


Causal structure of the model

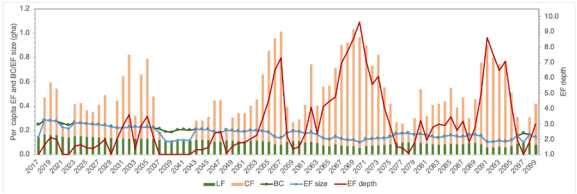


- Irrigated land contributes land footprint
- Groundwater pumping for irrigation contributes carbon footprint
- Blue WF and Grey WF contributes natural capital flow
- The cost of canal lining impacts water supply and agricultural income
- Depletion of natural capital affect the pace of canal lining

Sustainability in the light of natural capital

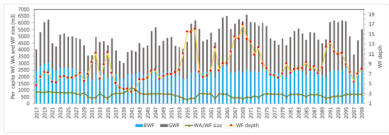


Correlation coefficient is 0.51



- CF dominates EF in the future
- BC declines as irrigated land shrinks in the future
- BC is less than the sum of CF and LF indicating the depletion of productivity in irrigated land
- EF depth accumulates to 9.6 until 2069 implying number of years to generate land sources consumed

Sustainability in the light of natural capital cont.

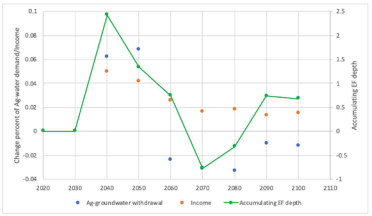


- WA < WF size: limited water availability
- The proportion of GWF increases over time
- Overdraft groundwater increases the risk of pollution
- WF depth climbs

Natural capital as indicator in policy implementation

Decoupling Index (DI) : the declining quantity of natural capital for producing per capita of income

- DI ≥ 1 (strong decoupling): natural capital consumption decrease as income grows.
- 0 < DI < 1 (weak decoupling): natural capital consumption grows simultaneously with income, with the income growing at a faster rate.
- DI ≤ 0 (coupling): natural capital consumption grows together with income, but natural capital consumption grows faster.



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Abstract 41) Sustainability in a Human-dominated Region: Agricultural use of Natural Capital (Pg. 136)

ZiaMet, The New Mexico Mesonet

David DuBois[1], Stanley Engle[1]
Deptartment of Plant and Environmental Sciences, NMSU[1]

Presented at the 65th Annual New Mexico Water Conference October 28th, 2020

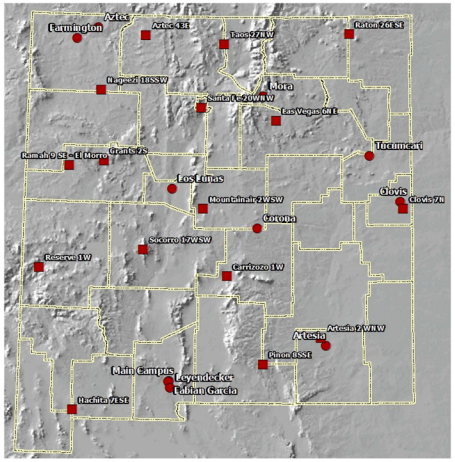
Introduction

The New Mexico Climate Center (NMCC), through New Mexico State University (NMSU), has been maintaining a modest mesonet since 1985 which has provided weather data for agricultural research as well as for dissemination of data to the general public. Since 2015, this mesonet has been re-branded the ZiaMet Network and the network is a member of the National Mesonet Program, providing data via http://weather.nmsu.edu and http://mesowest.utah.edu.

ZiaMet currently operates 10 automated agricultural weather stations usually located at NMSU science centers and 16 former federal climate reference automated stations installed in remote locations across New Mexico. ZiaMet continues to help support agricultural research while also providing data points that fill in temporal and spatial gaps that are not provided by other weather station networks such as the federally-owned Automated Surface Observing System. By working to fill these gaps, ZiaMet is helping to provide decision support to economic sectors, both public and private.

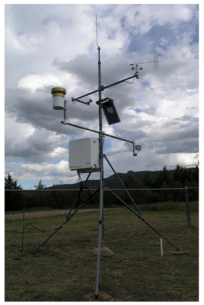
This paper will discuss the current operational status of ZiaMet, the data provided by the program, and plans for future growth.

Weather Station Locations



Agricultural Stations

- Sensors
  - Wind speed/direction at 3 meters above ground (AG)
  - Solar Radiation between 2 to 3 meters AG
  - Tipping-bucket rain gauge between 2 to 3 meters AG
  - Air Temperature/RH sensor at 2 meters AG
  - Soil temperature at 10 cm below ground
- Data Collection/Transmission
  - Collects data at 5 minute intervals
  - Transmits at near-real time via short range radio + NMSU network

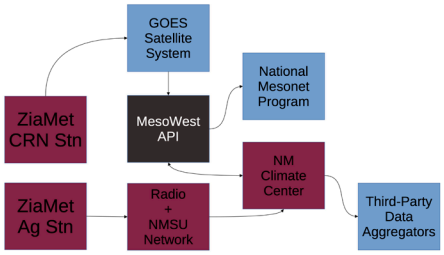




Climate Stations

- Sensors
  - Triple redundant air temperature sensors enclosed in an aspirating solar radiation shield mounted at 1.5 meters AG
  - Weighing rain gauge using triple redundant vibrating wire sensors
- Data Collection/Transmission
  - Data is collected at 5 minute intervals
  - Transmits hourly via GOES satellite data channel

Flow of Data



Operational Assets

Aside from the physical weather station infrastructure, the ZiaMet network consists of personnel and computational assets that maintain the infrastructure and provide data access.

- Personnel
  - Two full time employees
  - One undergraduate student
- Computational assets
  - Main website server accessed via http://weather.nmsu.edu
  - Multiple fully replicated database servers
  - Multiple data acquisition and processing servers

Data Products

Most ZiaMet data is provided through the NM Climate Center website. Custom data requests are handled manually. Data collection external to the ZiaMet network is available and the NMCC can also help provide weather data collection for external projects.

- Penman-Monteith Short/Tall canopy reference ET
- Hargreaves-Samani reference ET
- Pecan ET
- Growing Degree Days
- Data Summaries

Database Statistics

- 4.2 GB of data
- Since 2013, 4.35 million data reports from ZiaMet agricultural stations
- Since 2018, 2.25 million data reports from ZiaMet climate stations
- From 1985 to 2019, 1.6 million hourly data reports from the original ZiaMet agricultural weather stations

Future Work

- Currently only one Ag station has multiple soil temperature sensors. Add soil temperature and soil moisture sensors at multiple depths.
- Add 10 meter wind speed/direction sensors to assist in forecasting.
- Supplement precipitation monitoring by adding weighing precipitation gauges at every site.
- Expand network so that every NM county contains at least one station. 13 counties do not.

Contact Info

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NM Climate Center
http://weather.nmsu.edu

Abstract 42) ZiaMet, the New Mexico Mesonet (Pg. 136)

Nitrogen, Carbon Dioxide and Argon Adsorption for Surface Area of an Unknown New Mexico Clay in order to Elucidate Uranium Abatement

Moticha M. Franklin , Jeremy Jones, Dr. Antonio S. Lara
Department of Chemistry and Biochemistry, New Mexico State University, Las Cruces, NM, 88003

Introduction:

- Heavy metals, especially Uranium, contaminate the Navajo Nations water source (Figure 3)
  - Health problems, sometimes death, occur from drinking contaminated water
- **Uranium abatement** occurs for all regional and reference clays that have been tested (Figure 2)
- Muddy suspensions are difficult to manage
  - Dirt ceramic pellets fabricated from clays to sorb uranium
- **Surface area is directly related to uranium abatement**

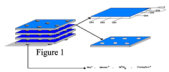
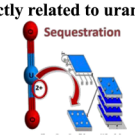


Figure 1
Clay: aluminophylosilicate sorbent, cation exchange





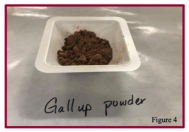
Justification/Objective:

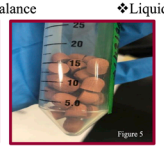
Hypothesis: Clay pellets, relative to clay powder decreases available surface area.

- Analyze surface area of clay powder and clay pellet (benchmark)
  - Compare surface area between powder and pellet
- Compare surface area between the different sorbates
  - N_2 is a standard, Ar is spherical and CO_2 to 'mimic' UO_2^{2+}

Materials:

- Gallup, NM clay powder (Figure 4) and pellet (Figure 5)
- Double Deionized water
- Silicone molds
- Precision Thelco Model 16 Laboratory Oven
- Thermolyne 10500 Furnace
- Mettler AJ100 electronic balance
- ASAP 2050 Extended Pressure Adsorption Analyzer (Figure 6)
- Liquid Nitrogen
- Gaseous Nitrogen
- Gaseous CO_2
- CO_2 Climate Control Chiller
- Gaseous Argon
- Liquid Argon

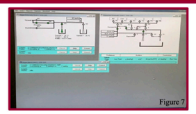






Methods:

1. Clay preparation from raw material
   - A. Grind raw material to a powder
   - B. Sieve powdered material to ~100 mesh
2. Pellet Fabrication
   - A. Clay to Water ratio
   - B. Mold casting for pellet
   - C. Dry pellet
   - D. Fire pellet
3. Surface Area
   - A. Weigh ~3g of powder and pellets
   - B. Load sample for degassing
   - C. Degas for 48-96 hrs. (Figure 7)
   - D. Transfer sample to ASAP 2050 adsorption port (Figure 6)
   - E. 24-48 hrs. to sorb and desorb (Figure 8)
   - F. Weigh final sample

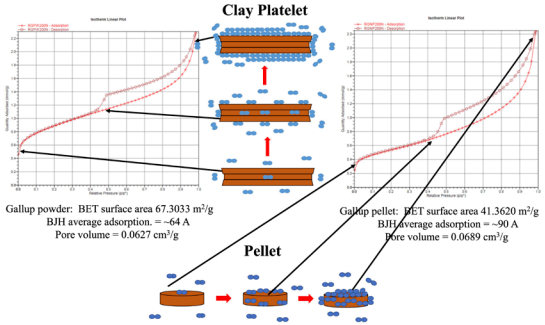




Isotherm Results:

Nitrogen Isotherm

Gallup Powder | Gallup Pellet

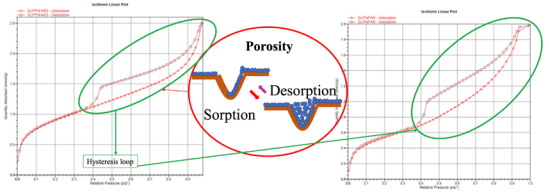


Gallup powder: BET surface area 67.3033 m^2/g
BJH average adsorption. = ~64 A
Pore volume = 0.0627 cm^3/g

Gallup pellet: BET surface area 41.3620 m^2/g
BJH average adsorption = ~90 A
Pore volume = 0.0689 cm^3/g

Argon Isotherm

Gallup Powder | Gallup Pellet

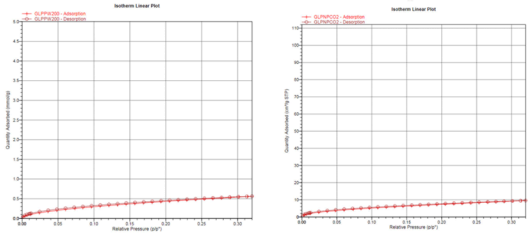


Gallup powder BET surface area 63.0481 m^2/g
BJH average adsorption. = ~69A
Pore volume = 0.0557 cm^3/g

Gallup pellet BET surface area 38.2939 m^2/g
BJH average adsorption. = ~73 A
Pore volume = 0.04948 cm^3/g

Carbon Dioxide Isotherm

Gallup Powder | Gallup Pellet



Gallup powder: BET surface area 42.2562 m^2/g
BJH average adsorption = In Progress
Pore volume = In Progress

Gallup pellet: BET surface area 31.4721 m^2/g
BJH average adsorption. = In Progress
Pore volume = In Progress

Surface Area and Porosity Results:

BET Surface Area — Table 1

Gas	Powder (m^2/g)	Pellet (m^2/g)	% loss from powder to pellet
Ar	63.0481	38.2939	39.2624
N_2	67.3033	41.362	38.5439
CO_2	42.2562	31.4721	25.5208

BJH Pore Size/Volume — Table 2

Gas	State	Size (Å)	% gained from powder to pellet	Volume (cm^3/g)
Ar	Powder	69.530	4.700129441	0.055732
	Pellet	72.798		0.049480
N_2	Powder	64.484	40.09986974	0.062716
	Pellet	90.342		0.068906
CO_2	Powder	In Progress	In Progress	In Progress
	Pellet			

Conclusion:

- Same clay was analyzed with the three different sorbates
  - BET Surface Area measurements for the three sorbates are different (Table 1)
  - Pore size of a pellet can indicate we are creating larger pores when being fabricated (Table 2)
  - Pore volume is the same for powder and pellet (Table 2)
- Hysteresis loop suggests micro-porosity within the powder and pellet
- N_2 and Argon penetrates the micropores of the clay in its various states (Figure 9)
  - it is easier for the smaller gases to channel their way onto the clay and its micropores.
- Pellet fabrication process reduces the surface area (Table 1)
  - not enough to suppress the uranium sorption significantly (data from other research in our laboratory)

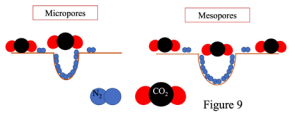


Figure 9

Future Research:

- Surface analysis for other reference and regional clays
  - Test clay from the Navajo Nation and surrounding areas
  - Test parameters for induced macroporous pellets
  - Find an ASTM or procedure for CO_2 pore size and distribution
    - Test CO_2 at a different temperature

Acknowledgements:

New Mexico State Legislature NMWRRI2018-19, administered by the New Mexico Water Resources Research Institute; Water Resources Research Institute FY19 Student Water Research Grant NMWRRI-SG-2019 and Mark Chisdester, Laboratory Research Manager, NMSU Freeport-McMoRan Water Quality Laboratory.

Contact Information: Moticha Franklin, email: moticha@nmsu.edu

Abstract 43) Nitrogen, Carbon Dioxide and Argon Adsorption for Surface Area of an Unknown New Mexico Clay in Order to Elucidate Uranium Abatement (Pg. 136)

Aquaponics Cuts Path to Water-Neutral Agriculture in NM

R. Charlie Shultz Lead Faculty at Controlled Environment Agriculture (CEA) Department, SFCC • **Nate Downey** President at Lettuce, Etc llc, SFCC intern, author *Roof-Reliant Landscaping*

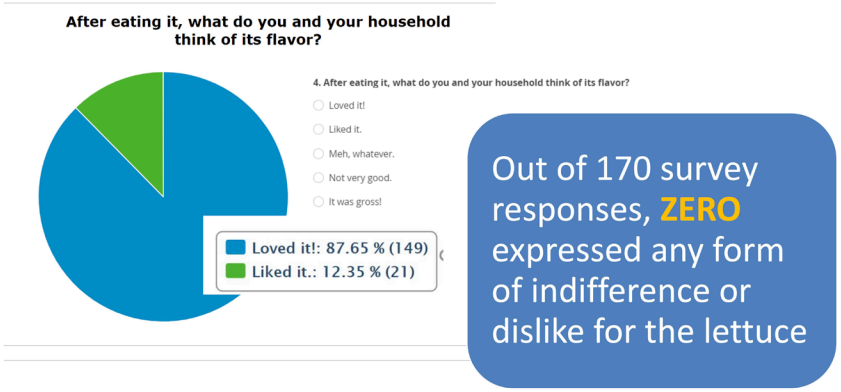
Background

With 12” of annual rainfall, an aquaponics farm could generate enough water for its crops from roof catchment alone. Two barriers to a roof-reliant revolution in agriculture led by aquaponics are the low profit margins generally associated with farming and the costly facilities associated with growing fish and plants in controlled environments. If, however, aquaponics farmers could sell crops at retail prices using a farm-to-door, direct-to-consumer business model, retail prices and delivery fees would be attainable.

Hypothesis

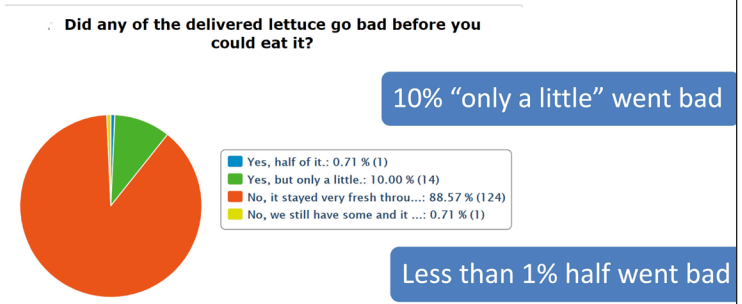
Would a farm-to-home delivery model from an aquaponics facility generate significant profits in Santa Fe, NM?

Much-Loved Lettuce



Out of 170 survey responses, **ZERO** expressed any form of indifference or dislike for the lettuce

Lettuce with a Formidable Shelf Life



10% “only a little” went bad

Less than 1% half went bad

Nine out of ten say NONE went bad.

Abstract 44) Aquaponics Cuts Path Toward Water-Neutral Agriculture in NM (Pg. 137)

Effect of Chloride Salt Solutions on the Unconfined Compressive Strength of Heat-Treated Clay Pellets Made for the Abatement of Uranium in Contaminated Water

Joshua Herrera[1] (joshherr@nmsu.edu), Jeremy Jones[1], Dr. Antonio S. Lara[1]
[1]Department of Chemistry and Biochemistry, New Mexico State University, Las Cruces, NM 88003

Abstract

Uranium contamination in drinking water is an ongoing crisis for citizens of the Navajo Nation. This problem can be mitigated with locally produced clay pellets known to abate uranium, but parameters that effect the robustness of these pellets must be understood before they are utilized. It is known that chloride salt solutions affect the plasticity and liquid limit of clays, but there is little study on how these solutions alter the robustness of a clay, especially after heat-treatment. This is surprising given how cations affect clay platelet coordination, such as with potassium in illite clays. To better understand this effect, chloride salt solutions were mixed into two clays, a sodium-bentonite clay and a local illite-smectite clay, at specific weight ratios during the pellet fabrication process. The chloride salt solutions used were LiCl, NaCl, and KCl with each at a concentration of 0.8M. The robustness of each set of pellets was quantified by the maximum compressive force (MCF) measured during unconfined compression testing. The addition of NaCl had little to no effect on the pellet robustness. The bentonite pellets maintained a MCF of 700±100 ftlb (n=15) while the illite-smectite pellets' MCF slightly decreased from 2300±200 ftlb (n=15) to 2000±300 ftlb (n=15). The addition of the other chloride salts, however, has preliminarily shown to increase pellet robustness. The bentonite pellets' MCF increased to 900±100 ftlb (n=5) when using LiCl and 1300±300 ftlb (n=5) when using KCl. This finding suggests that externally added cations can have a significant effect on heat-treated pellet robustness.

Introduction

- The Navajo Nation is facing health threats due to uranium contamination in drinking water aquifers.
- Solutions are available, but expensive to implement (reverse osmosis)
  - Clays sorb heavy metal ions while being ubiquitous and cost-effective. Easiest to manage when in pelletized form.
- Some clays are more robust than others; a local illite-smectite clay from Gallup, NM, creates robust pellets and a standard bentonite clay creates non-robust pellets [Fig 1].
  - Difference in chemical composition can explain these disparities [Table 1]; note the differences in interlayer cations (K, Ca, Na).

Formula (moles)	Bentonite	Gallup
Al	1.46	1.57
Ti	0.01	0.04
Fe (III)	0.17	0.33
Fe(II)	0.01	N/A
Mg	0.28	0.33
K	0.04	0.25
Ca	0.12	0.32
Na	0.19	0.04

Table 1: Bentonite composition determined by Clay Mineral Society with X-ray fluorescence; Gallup composition found by means of inductively coupled plasma mass spectrometry.



Figure 1: Example of robust Gallup pellet (left) and cracked bentonite pellet (right)

- Interlayer cations can be increased by means of inorganic salt solutions
  - These cations are known to affect clay properties; zeta potential, liquid limits. Little has been done to study cation's affect on robustness, however.
- The lack of research in this area is surprising, given how interlayer cations affect clay coordination, such as with potassium in illite clays [Fig 2]

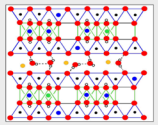


Figure 2: Example of general clay structure; sorption takes place between clay platelets

Hypothesis

•Inorganic salt solutions can alter pellet robustness and may offer an uncomplicated way to increase pellet robustness for areas with non-ideal clays

Materials and Methods

- Samples of bentonite and Gallup clay were ground and sieved to a 100 mesh (149 micron) powder.
  - This included a batch of bentonite clay which had its excess salts removed by repeated suspension in deionized water followed by centrifugation and decanting of the supernatant fluid.
    - ► Referred to as 'washed' bentonite
- Clay was mixed with inorganic salt solution in a Ziplock bag at a specific weight ratio [Fig 3.1]
  - Ratios: (clay wt% / solution wt%) : 30/70 and 50/50 for bentonite, 65/35 for Gallup
  - Inorganic salt solutions: Lithium Chloride, Sodium Chloride, and Potassium Chloride.
- Ratio allowed to equilibrate for a period of 24 hours
- Ratio then cast into silicone pellet mold and allowed to dehydrate [Fig 3.2]
  - Ambiently dehydrated on bench top until ~10% water by mass [Fig 3.3]
    - ► Mass monitored every 24 hours until reaching this point.
- Produced pellets are heat-treated in a Sybron F-A1638 Furnace [Fig 3.4]
- Heat-treated pellets were sanded until their faces were parallel, then measurements of average diameter and height were made using calipers
- Robustness of each set of pellets was quantified by means of the maximum compressive force (MCF) measured using the Instron Model 5882 Compression Tester, with n=15 samples in a complete data set*.

Pellet Fabrication Process

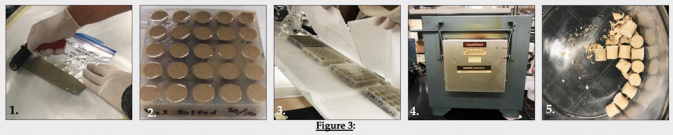
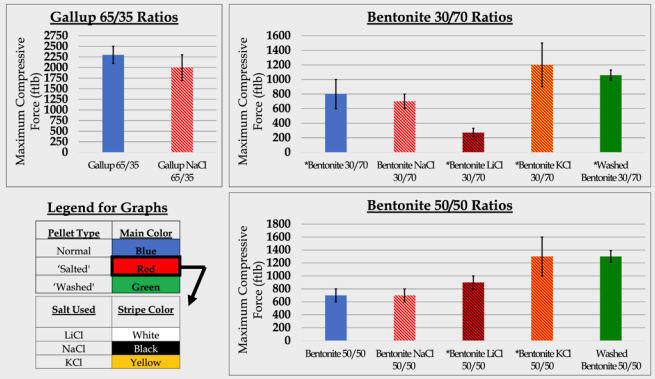


Figure 3:
1.) Clay ratio in Ziploc bag 2.) Ratio in silicon mold 3.) Ambient dehydration 4.) Sybron F-A1638 Furnace 5.) Resulting Pellets

Results



*= number of samples is n=5 instead of n=15

Discussion & Conclusion

- The normal clays without added inorganic salt solutions served as a control.
  - The normal bentonite clay had an average maximum compressive force (MCF) of 800±100 ftlb for the 30/70 ratio and 700±100 ftlb for the 50/50 ratio
    - ►NOTE: 30/70 ratios often fractured during heat-treatment. Thus their sample size remained small.
  - The Gallup clay had an average MCF of 2300±200 ftlb
- NaCl solutions did not greatly alter the MCF in either clay.
  - The bentonite clay remained at ~700±100 ftlb for both ratios
  - The Gallup clay only slightly decreased to 2000±300 ftlb
    - ► May be explained by binding affinity and relative abundance; Gallup clay likely has little binding affinity to sodium considering it already has coordinated potassium and calcium, meanwhile the bentonite clay has a large abundance of natural sodium
- LiCl affected each bentonite ratio's MCF differently
  - 30/70 ratio greatly weakened, at 270±60 ftlb while the 50/50 ratio was strengthened to 900±100ftlb
    - ► Noticeable cracks formed on the 30/70 pellets whereas the 50/50 pellets remained intact; likely cause for MCF difference
    - ► Lithium ions have high charge density and may attract surrounding clay platelets with coulombic forces. These same forces influence ion hydration, however, and could lead to presence of many coordinated water molecules which cause fracturing upon heat-treatment (evaporation), as with the 30/70 ratio.
- KCl doubled the MCF in both bentonite ratios, but increased deviation
  - 30/70 ratio increased to 1200±300 ftlb and the 50/50 ratio increased to 1300±300 ftlb
    - ► Illite structure known for interlayer potassium, which interlinks clay platelets. This is likely the cause of the increased robustness
  - Large deviation may partially be attributed to small sample size (n=5 compared to n=15)
- Removing excess salts in the bentonite clay also increased the MCF of both ratios, and reduced deviation
  - 30/70 ratio increased to 1060±70 ftlb, while the 50/50 ratio increased to 1300±90 ftlb
    - ►The ions which remained in the clay matrix would be only the ones necessary to negate the clay platelet's charge. The void space and coulombic repulsion caused by excess salts upon solvation would not be present, and thus the overall coordination would be maximized.
- Preliminary results; inorganic salt solutions can directly alter pellet robustness, and offer an affordable and effective way to increase pellet strength
  - KCl is the most viable and health conscience choice in this matter, since it is a non-harmful food additive and does not affect brain chemistry like LiCl.
    - ►Also less time intensive than repeated 'washing' of clay

Future Directions

- X-ray diffraction to determine changes in platelet coordination; A pellet with higher coordination in basal spacing would give reason for an increased MCF.
- Study salt's effects on sorption capacity; likely tradeoff between strength and cation exchange

Acknowledgements

A special thanks to Mary Jo Ruthven, Dr. Michael Johnson, Dr. Graciela Unguez, and Dr. Ivette Guzman for their support through the Maximizing Access to Research Careers (MARC) Program, Kenny Stevens and Eduardo Gamillo for the use of their compression tester, the Research Initiative for Scientific Enhancement (RISE) Program.

This research was supported by New Mexico State Legislature NMWRRI2018-19, administered by the New Mexico Water Resources Research Institute; National Institutes of General Medical Health MBRS R25GM061222; National Institutes of Health GM07667.

Abstract 45) Examination of Chloride Salts' (XCl, X=Li, Na, K) Effect on the Robustness of Clay Pellets made for Uranium Abatement (Pg. 137)

Multilevel Assessments of Contribution of Livestock Manure to Nitrogen Budget in Arid-land Ecosystems: The Case of Dairies in New Mexico

Ghimire, Suraj and Wang, Jingjing
University of New Mexico, Department of Economics

Introduction & Objective

- New Mexico leads the country in terms of the average number of cows per large dairy farms.
- Most of the dairy farms are concentrated in the five counties – Chaves, Curry, Roosevelt, Dona Ana, and Lea
- This study aims to quantify the contribution of large dairy farms towards the N budget of the arid land ecosystem with 3 levels of assessments: county, water basin and farm level .
- In the face of an ever-increasing intensification of dairy farms, this study also brings to light the potential benefits of recoupling the crop-livestock system.

Methods

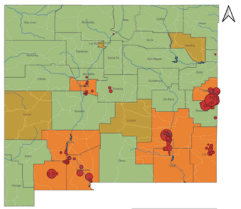
- Nitrogen budget is calculated as the difference between livestock manure N loadings and crop N requirements at various levels.
- Farm-level assessment: Circles corresponding to the application acreage of farms were drawn and land cover data was used to calculate total N utilization by crops.
- County-level assessment: County totals were obtained by aggregating over livestock farms and croplands/grasslands in a county. Based on the location of individual farms, farm-level data was added to get N excretion data for each county.
- Watershed-level assessment: Watersheds totals for potential N-vulnerable watershed were obtained by aggregating over livestock farms and croplands/grasslands in a watershed.
- Sensitivity Analysis: N budgets of watersheds at 4 different levels (20, 40, 60 & 80%) of manure acceptance rates for the grasslands were calculated.

Data

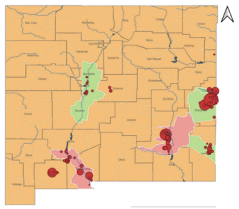
- Farm-level data (location, # of cows etc.) – NMED
- Remote sensing data of the land cover – NLCD
- Watershed data – USGS
- N excretion parameters – Todd et al (2015)
- Crop N requirement – various studies

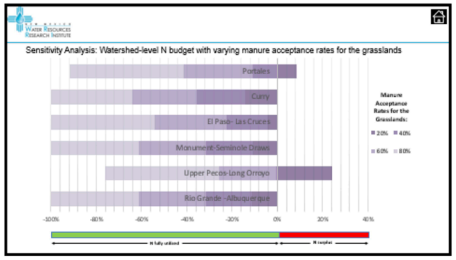
Results

County level Analysis



Watershed-level Analysis





Conclusions

- Farm-level assessment showed that all the farms in our study produced excess N that was beyond the assimilative capacity of onsite croplands.
- Eight counties were identified as having excess N.
- Out of the six watersheds, two watershed were identified as hotspot regions.

Discussions

- Sensitivity analysis showed the possibility of total assimilation of N if the grasslands accept manure at the rate of 40% or more .
- Use of manure as a soil amendment has twofold benefits:
  1. It can provide vital nutrients and organic matter to the plants, reducing the need for commercial fertilizers.
  2. Widespread disbursement of manure reduces the pollutant load in the hotspot regions.

Abstract 46) Multilevel Assessments of Contribution of Livestock Manure to Nitrogen Budget in Arid-land Ecosystems: The Case of Dairies in New Mexico (Pg. 137)

Improving Green Water Use Proportion by Circular Buffer Strips of Perennial Grasses

Paramveer Singh[1], Sangu Angadi[1], Sultan Begna[1], Dave Dubois[2], Rajan Ghimre[1] and John Idowu[2]
[1]Agriculture Science Center, New Mexico State University, Clovis, NM
[2]Department of Plant and Environmental Sciences, New Mexico State University, Las Cruces, NM

Background

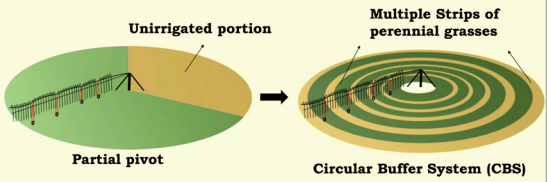
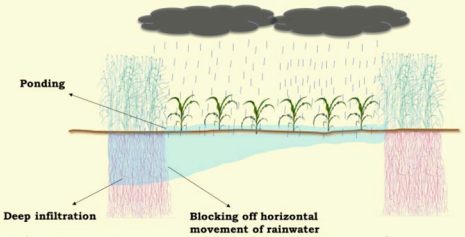


Fig. 1. Due to decline in irrigation capacities, farmers keep a section of the pivot circle dryland since they cannot follow full irrigation management on the entire circle. Rearranging the unirrigated portion of such partial pivot into circular perennial grass strips can improve conservation high intense rainfalls in the SHP of US.

- A simple modification of pivot circles using native perennial grasses in the form of circular strips can improve rainwater conservation and use by agriculture production systems in the region.

Rationale



- With CBS acting as multiple barriers to surface runoff, and horizontal water movement below soil surface will increases infiltration of rainwater and wind moderation effect of grass strips will reduce evaporation loss.

Objective

- Assess and compare rainwater storage and extraction by corn with and without grass strips.

Material & Methods

- **Location:** Agriculture Science Center, Clovis, NM.
- **CBS: :** 5 grass strips of 30 feet width arranged alternately with 5 crop strips of 60 ft width (Fig. 2).
- **Observations:** Neutron probe measurements, leaf water potential and biomass before and after a 44 mm of rain event on 07/04 and 07/05/2020.

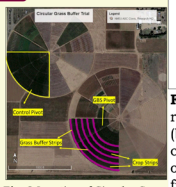


Fig. 2 Location of Circular Grass Buffer System (CBS) and control pivot (CT) at ASC, Clovis NM.

Results

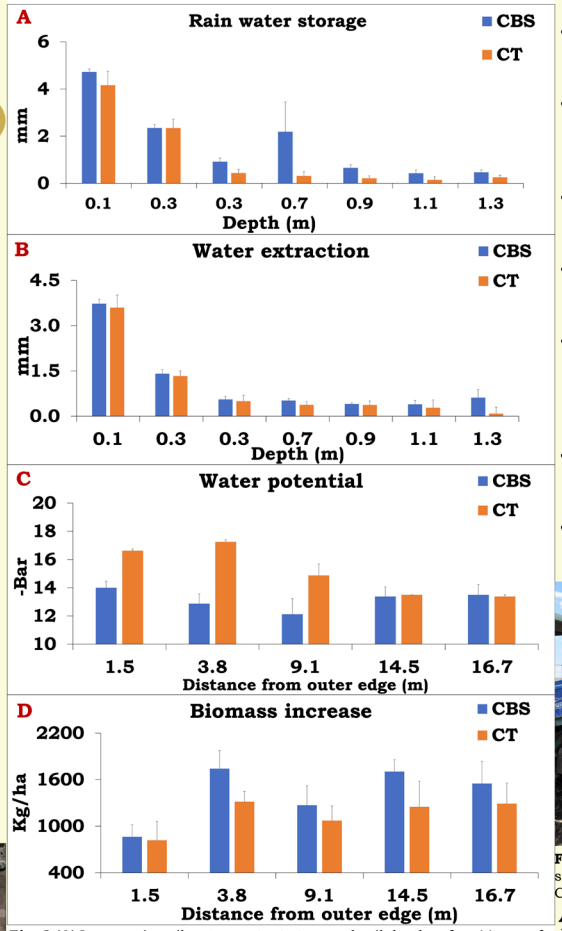


Fig. 3 (A) Increase in soil water content at several soil depths after 44 mm of rainfall was calculated by subtracting moisture measurements of 07/01 (before) from 07/07/2020 (after) in CBS and CT. **(B)** Soil water extraction was calculated by subtracting moisture measurements of 07/10/2020 from the one taken on 07/07/2020. **(C)** Corn leaf water potential at different distances from outer edge in CBS and CT on 07/10/2020. **(D)** Increase in biomass over 10 days (07/01/2020 to 07/10/2020) at various distances from the outer border in CBS (with circular grass buffer strip) and CT (control).

Discussion

- Due to slightly higher rainwater storage and water use in CBS decreased water stress levels and improved crop growth.
- Thus, results indicate that integration of native perennial grasses in the form of alternating circular strips has potential to improve conservation and use of rainwater by irrigated agriculture.
- This will encourage farmers to reduce irrigation inputs as additional water from rain will mitigate the impact of water stress on crop growth and yield.
- Further reduction in irrigation capacities are predicted, as a result most of the irrigated land will either be minimally irrigated or convert to dryland agriculture in near future.
- Improvement in rainwater use by CBS may prove valuable for dryland production system in the region.

Future Plan

- The stable isotope analysis has been successfully used to determine rainwater use by crops under center pivot irrigated system in SHP (Goebel and Lascano, 2019).
- We propose to use isotope signatures to assess improvement in rainwater use by CBS.



Fig. 4. Installing neutron access tubes for measuring water content of the soil profile (left). A scattered thunderstorm bearing down at NMSU ASC, Clovis on 25th June 2020 (right)

Acknowledgement: *We are thankful to New Mexico Water Resource Research Institute for providing funds to carry out this objective of a larger project. USDA-NIFA- Ecosystem Services and Agricultural Science Center, Clovis, NM for financial assistance. We also thank Aaron Scott and his crew member for their technical help. Also, thankful to Jagdeep, David and Jaden for their help.*

References:
Goebel, T.S., and R.J. Lascano. 2019. Rainwater use by cotton under subsurface drip and center pivot irrigation. Agric. Water Manag. 215(September 2018): 1–7. doi: 10.1016/j.agwat.2018.12.027.

Abstract 48) Improving Green Water Use Proportion in a Center Pivot Irrigation System by Using Circular Grass Buffer Strips (Pg. 138)

Sedimentology and Topography of the Confluence Outlet of an Ephemeral Tributary to the Mid Rio Grande – Arroyo de los Pinos

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Introduction

Ephemeral tributary streams are common throughout the American Southwest and deliver high loads of sediment downstream during flooding. River confluences are zones of morphodynamic importance that influence the scale and scope of channel morphology and sedimentology of the mainstem river and tributary. Quantitative relationships have been established (e.g., Best, 1987; Leite Ribeiro et al., 2012) between flow planform, junction angle, bed discordance, sediment type and discharge ratios between the tributary and the mainstem to characterize confluence morphology. These hydrodynamic characterization efforts, however, are mainly concentrated in the trunk stream, with limited information on the effects of the confluence upstream in the tributary proper. The morphology and sedimentologic character of ephemeral tributary outlets are further complicated by the disconnected, episodic nature of flooding.

In this study we apply Structure from Motion (SfM) photogrammetry and Digital Elevation Models (DEMs) of Difference (DoDs) to monitor the confluence topography and roughness of an ephemeral tributary to the Rio Grande in central New Mexico. The morphologic data are combined with sedimentologic information obtained from a trenched tributary-mouth sandbar to categorize seasonal deposition and erosional features.



Location map of basins of interest and the planform geometry of the confluence. The arrows indicate flow.

Questions:

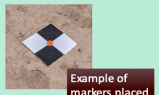
- What morphological changes and surface grain size changes can be observed in the field?
- How does the mainstem river rework arroyo-delivered sediment?
- How does the tributary rework mainstem-delivered sediment?

SfM Workflow

Image processing using Agisoft Metashape Professional :

1. Field work placing ground control point markers and aerial photography.
2. Assess photo quality and data post processing[1]
3. Create a sparse cloud and GCPs placement and control points to establish RMSE.
4. Process dense point cloud
5. Create DEM and Orthomosaics


DJI Phantom 4 Drone


Example of markers placed and surveyed

References: (1) USGS National UAS Project Office. (2017). *Unmanned Aircraft Systems Data Post-Processing Structure-from-Motion Photogrammetry*. Retrieved from https://uas.usgs.gov/nupo/pdf/PhotoScanProcessingDSLRMar2017.pdf
(2) Wheaton, J. M., Brasington, J., Darby, S. E., & Sear, D. A. (2010). Accounting for uncertainty in DEMs from repeat topographic surveys: Improved sediment budgets. *Earth Surface Processes and Landforms*, 35(2), 136–156. https://doi.org/10.1002/esp.1886

Digital Elevation Models

Agisoft Metashape produces DEMs. Applying a free geomorphic change detection software (Wheaton et al., 2010), DEMs of Differences (DoD) can be created to determine the temporal morphological responses at each juncture due to the variability of sediment supply and local runoff events.

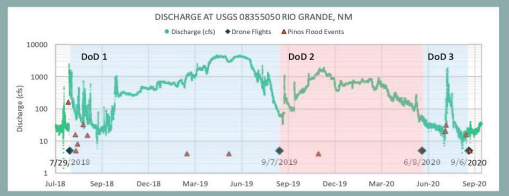


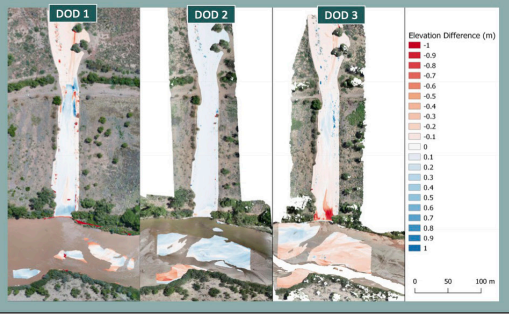
Volumetric Change at the Confluence

$$DEM_{new} - DEM_{old} = DoD$$

Three unthresholded DoDs were based on the four DEMs.

- First DoD: Flow events in August 2018 lowered the tributary bed in the north end of the study reach and deposited sediment just below a man-made ditch crossing. During spring 2019 the Rio Grande experienced abnormally high, sustained discharges, which allowed for the deposition of a large tributary mouth bar.
- Second DoD: Late autumn and winter are usually associated with a few small tributary flow events leading to thin deposition within the tributary in 2019. Poor 2020 snowmelt led to low Rio Grande levels preventing additional deposition at the mouth. Aeolian redistribution reduced the height of the mouth bar and raised elevations just upstream in the tributary.
- Third DoD: Summer is characterized by locally intense rainstorms and sediment delivery to the Rio Grande via flood-driven ephemeral tributaries. In summer 2020, three flood events were observed leading to erosion upstream of the ditch-crossing, deposition just downstream of it, and deep gullying and headward erosion at the mouth bar.



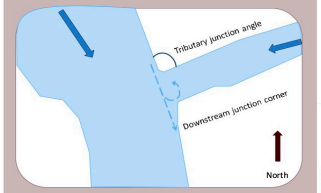


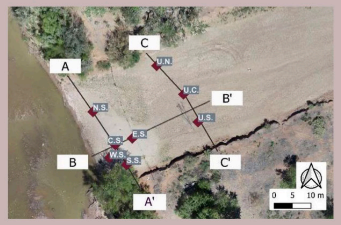
Trenching and Stratification

During the spring of 2019, the Rio Grande experienced abnormal snowmelt runoff which produced peak discharge greater than 113, m^3/s (4000 cfs). During such time, no flow events (> 5cm water depth) occurred in the Pinos, but back flooding from the Rio Grande deposited an asymmetric tributary mouth bar.

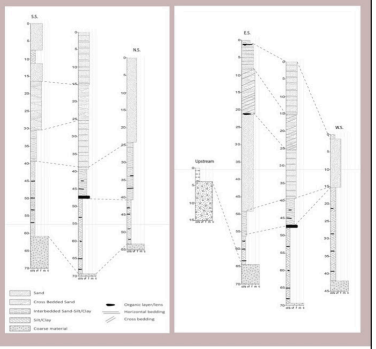


Based on previous work related to the confluence planform symmetry and discharge ratios, it is suggested that the flow structure at the junction angle would create a zone of flow stagnation that would favor the tributary corner outlet. However, because the Rio Grande was at peak discharge, the river did not experience a zone of stagnation at the junction corner. Instead, a zone of flow separation occurred at the downstream junction corner. This created a recirculating eddy that dissipated and deposited the asymmetrical mouth bar.





- Sedimentary structures suggest that a tributary outlet-induced flow separation zone formed, which primarily flowed directly above the downstream junction corner;
- Lateral accretion dipping towards the southern bank and some dipping upstream towards the tributary demonstrated that the bar accreted upstream within the tributary confluence; and
- Mud drapes deposited behind the structure are slack water deposits delimiting the highest water stage of the Rio Grande



Discussion



- When there is no flow from a tributary and peak flow from the mainstem river, the tributary outlet becomes a zone of flow separation and deposits a mouth bar from the recirculating eddies at the outlet.
- Subsequent tributary flow events may dissect this bar, transporting the sand back to the mainstem, along with tributary-derived gravels.

Future Activities

- More work needs to be done to establish appropriate thresholds of propagated errors for DoDs.
- Channel bed roughness will be established from orthophotos thereby comparing changes in surface sediment type that is either eroded or deposited after flood events.
- Event-scale elevation changes in the approach reach of all three tributaries will be analyzed.
- Develop relationships between changes observed at the confluence and peak tributary discharges.

Abstract 49) Sedimentology and Topography of a Confluence Outlet of an Ephemeral Tributary to the Mid Rio Grande – Arroyo de los Pinos (Pg. 138)

The Relationship Between Firing Temperature and the Sorption Effectiveness of Fired Clay Pellets

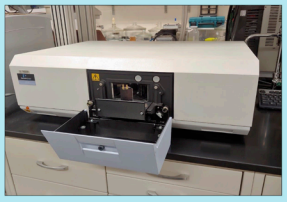
Sarah Bockisch*[1], Jeremy Jones[1], Antonio Lara[1]
[1]New Mexico State University, Department of Chemistry and Biochemistry, Las Cruces, NM, 88003

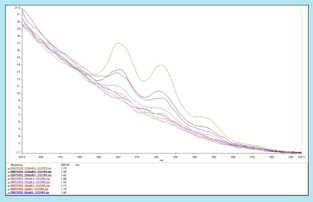
Introduction

- Uranium contaminated drinking water is a prevalent problem in the Four Corners area of the Southwest. Ingesting concentrations greater than 30 ppb causes serious long-term health effects according to the EPA.
- Usual methods for removing uranium are often expensive to maintain and therefore not a viable method for impoverished persons suffering from uranium contamination.
- Fired clay pellets offer a viable alternative to these options, as they can be easily manufactured by lay persons and are inexpensive to obtain.
- Firing clay gives it a sturdy, manageable structure while still retaining sorption properties and the clay's firing temperature affects its ability to sequester uranium.
- A cost-effective method for uranium analysis in drinking water is also necessary. Polyphosphate enhanced fluorimetry is an **inexpensive, nondestructive, and potentially portable** analysis method for both lab and field use and has the potential of being a cost effective analysis method.
  - Fluorimetry is capable of detecting uranyl in ppm concentrations. Polyphosphate compounds enhance the uranyl signal, lowering the detection limit to ppb concentrations.
- Uranyl sorption by low, medium and high temperature fired clay was tested and subsequently analyzed by polyphosphate enhanced fluorimetry and ICP-MS as an orthogonal analysis method for comparison.

Materials and Methods

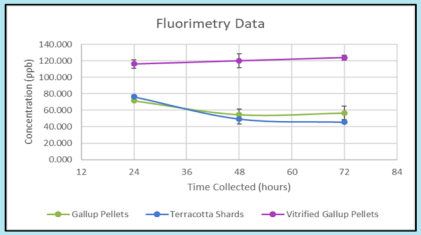
- For low temperature fired clay, fired pellets sourced from Gallup clay were provided by the laboratory.
- For mid temperature fired clay, Terracotta pots were obtained from local store and broken into regularly sized pieces by mass as determined by a Meitler-Tolledo AG 245 analytical balance.
- For high temperature fired clay, vitrified clay was obtained by vitrifying fired clay pellets from clay sourced from Gallup clay, also provided by the laboratory.
- Each sample was run in triplicate, along with uranium and water blanks.
- Samples were exposed to a 125 ppb solution.
  - Uranyl solution was made using a 1000 ppm uranyl nitrate ICP-MS standard solution.
- Samples were placed on an in-house rotator to minimize concentration gradient potential, then removed after 24, 48, and 72-hour periods.
- They were then spiked with polyphosphate solution and analyzed using a Perkin-Elmer LS 55 fluorimeter
- Samples were also acidified with 50% nitric acid and analyzed with ICP-MS

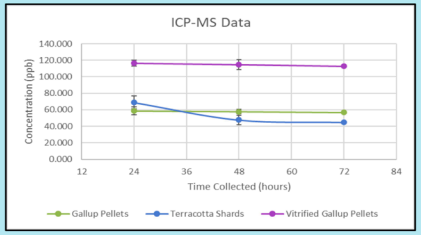




Data

		Uranyl Concentration (ppb)					
		Gallup Pellets		Terracotta Shards		Vitrified Gallup Pellets	
Time (hours)		Fluorimeter	ICP-MS	Fluorimeter	ICP-MS	Fluorimeter	ICP-MS
24	Average	71.614	58.667	76.591	68.838	116.297	116.525
	stdev	4.925	3.837	8.336	5.884	3.126	0.549
48	Average	54.826	57.813	49.421	47.680	120.183	114.824
	stdev	1.815	4.745	6.109	2.973	1.860	0.411
72	Average	56.769	56.730	45.518	44.817	123.990	112.655
	stdev	0.967	7.839	6.704	5.879	8.142	0.322





Results and Discussion

- Low-temperature fired clay and mid-temperature fired clay showed comparable sorption.
- No significant sorption was demonstrated by high-temperature fired clay.
- Similar sorption trends were shown between data obtained by pyrophosphate enhanced fluorimetry and ICP-MS

Future Directions

- Determine water accessible porosity and pore size of clay
- Determine efficacy of fluorimetry for uranium analysis as compared to ICP-MS
  - Find clay sorption relationship between ppm and ppb
- Determine sorption kinetics using polyphosphate enhanced fluorimetry for real-time analysis

Acknowledgements

- New Mexico State Legislature NMWRRI2017-18, administered by the New Mexico Water Resources Research Institute
- College of Engineering New Mexico State University
  Freeport-McMoRan Water Quality Lab
  Mark Chidester

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Biodegradable Porous Hydrogels Designed for Soil Water Retention

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Department of Chemical & Materials Engineering, New Mexico State University, Las Cruces, NM

Introduction

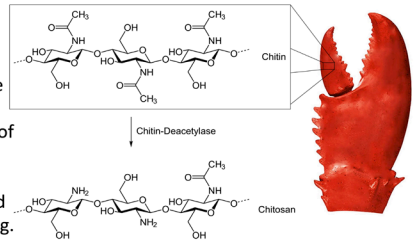
Sandy soils in arid climates have low water holding capacity and high-water loss. This leads to a decrease in plant growth and limiting organic matter content and other water holding factors.

Goals

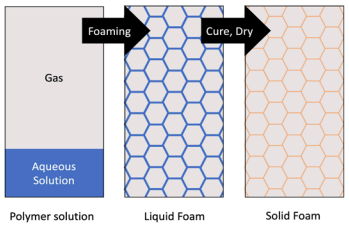
- By making the hydrogel porous save on material cost and ease access of water to plants.
- By using chitosan the hydrogel will be hydrophilic and biodegradable.
- The addition of this hydrogel to the soil will act as a water reservoir stimulating plant growth in times of water stress.

Background

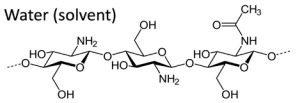
Chitosan: Chitosan is a polysaccharide made through deacetylation of chitin. Chitin derived from crustacean and insect shells e.g. shrimp, crab, cockroach.



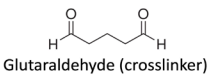
Foam templating: Foams are templated from foamed aqueous polymer solutions. The foam is cured and dried leaving behind a porous interconnected structure.

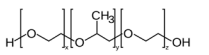


Materials



Chitosan (base material)



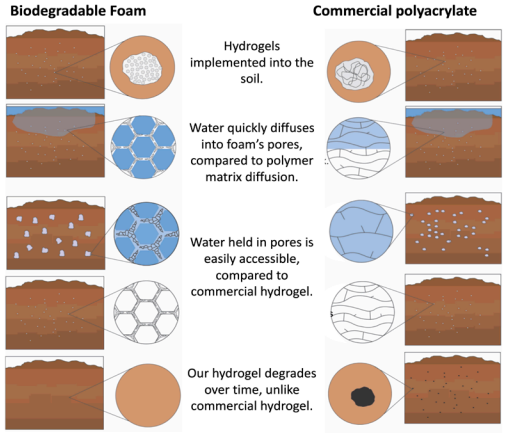


Pluronic F68 (foaming agent)

Implications in Agriculture

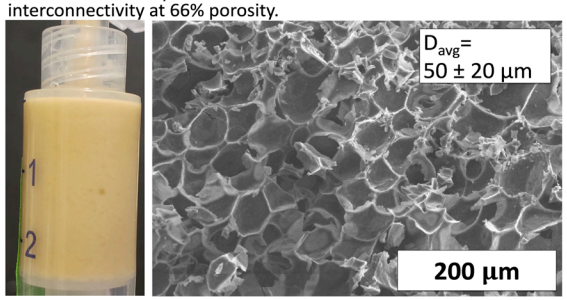
As water becomes more scarce farmers will be looking for more efficient technology to improve efficiency. These hydrogels can reduce the amount of water required for irrigation or reduce water stress between times of irrigation. This material can be implemented as a water retainer within the soil or even as a seed coating to increase likelihood of seed germination.

Comparison of Hydrogels



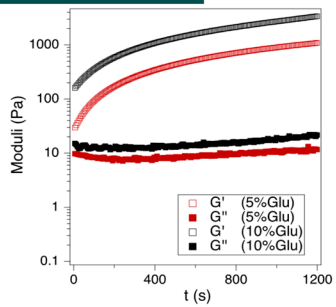
Biodegradable Foam Material

Foams cured within several minutes, and SEM imaging of the foams show a porous structure that contains some interconnectivity at 66% porosity.



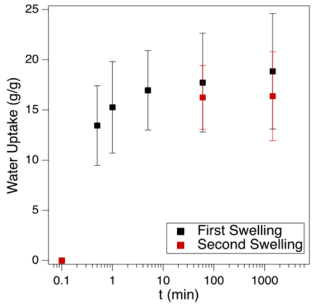
Current Results

Crosslinking study: Rheology tests show that glutaraldehyde crosslinking begins rapidly (<30 sec) as shown by G" (loss modulus) surpassing G' (storage modulus). The crosslinking occurs as quickly even when glutaraldehyde concentration is halved.



Water Uptake study: Samples show water imbibing within the first 30 seconds due to their porous nature. Water uptake is shown to be ~18 g/g for maximum water uptake for sample with 66% porosity.

Sample retained ~87% of its swelling capability after drying and reswelling.



Future Work

- Variation in foam fabrication e.g. porosity, chitosan concentrating, etc.
- Further water uptake and retention studies
- Soil-water retention curves of sandy-type soil with bio-foam amendment.
- Biodegradation studies.

References

Image of crab claw: Retrieved October 04, 2020, from https://www.amazon.com/Lobster-Weapons-Cosplay-Halloween-Costume/dp/B07JLVGGR2

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Abstract 51) Biodegradable Porous Hydrogels Designed for Soil Water Retention (Pg. 139)

Electrical Resistivity Mapping of Rio Grande River-Groundwater Interactions

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65th Annual NM Water Conference
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INTRODUCTION

- Surface-groundwater interactions such as connectivity remain a challenge to characterize, especially for ephemeral rivers like the lower Rio Grande.
- This investigation used a noninvasive and spatially distributed geophysical method (i.e., time-lapse electrical resistivity tomography, or ERT) for mapping the water table below and adjacent to the Rio Grande River before, during, and after irrigation season.
- This has been validated using groundwater table monitoring well data.
- Results have shown resistivity impacts due to a coupling of both variations in water saturation and electrical conductivity (EC) or total dissolved solids (TDS) difference between resident groundwater from the previous irrigation season and the infiltrating surface water.
- This type of spatiotemporal groundwater level assessment advances our connection process characterization capabilities, and will support the sustainable conjunctive use of surface water and groundwater, especially for ephemeral systems.

METHODS

- Water arrived into the lower Rio Grande on March 17, 2020.
- ERT was used from Feb 2020 to present
- Resistivity results are the simple inverse of conductivity, and that can be correlated to water saturation.
- 84 electrodes were installed every 1 m along a cross-section of the Rio Grande, 56 of which are buried within the riverbed for repeated data collection throughout irrigation season
- Separate "snapshots" are taken with a resistivity meter and then the differences are mapped through time. The elevation of the water table is then verified using a sounder within surrounding monitoring wells, and by measuring the EC of river samples, both taken at the time of measurement.

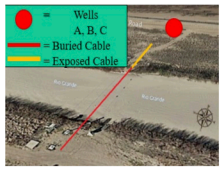


Fig. 1: Lower Rio Grande in Mesquite, NM



Fig. 2: The electrical resistivity meter taking measurements in the field, and in the lab

RESULTS

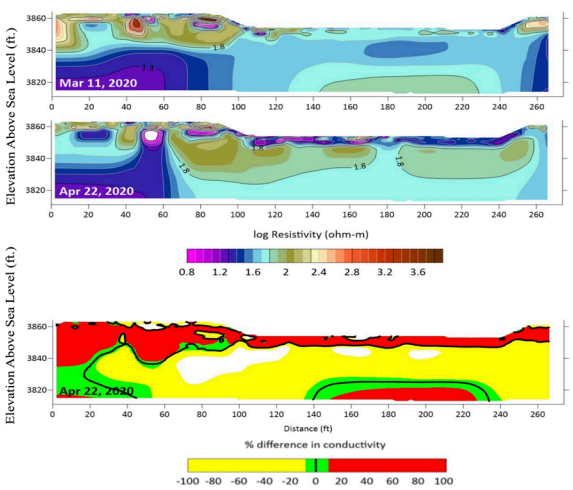


Fig. 3: Top plots: Comparisons of resistivity data from Mar 11 (before arrival of water) to Apr 22 (after arrival of water). This shows a clear decrease in resistivity (i.e. increase in conductivity) in the immediate subsurface of the riverbed associated with the increase in water saturation.

Bottom plot:: % Difference in EC from the aforementioned dates delineating this change.

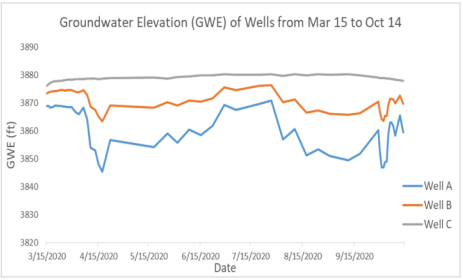


Fig 4: GWE of Neighboring Monitoring Wells from Mar 15 (before the arrival of water) to Oct 14 (after the arrival of water)

DISCUSSION

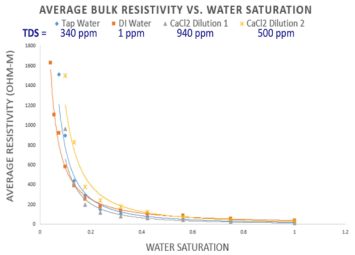


Fig. 5: Lab Testing of Bulk Resistivity vs. Water Saturation

- There is an EC or total dissolved solids (TDS) difference between the pore water from the previous irrigation season and the newly released surface water, and therefore two variables that are impacting site bulk resistivity.
- Laboratory-scale experiments were developed using site riverbed soils to determine the relationships between bulk resistivity vs. aqueous salinity, and bulk resistivity vs. water saturation
- This will be used to subtract the effects of the EC differences between waters from our resistivity results, leaving just the impact of water saturation.

SUMMARY

- We have mapped a change in riverbed hydrology pre- and post-release of water using ERT.
- The relationships between bulk resistivity versus aqueous salinity and bulk resistivity versus water saturation have been developed to evaluate the time-lapse resistivity data and characterization of surface-groundwater connectivity.
- A coupled flow and solute transport model will be used to simulate the infiltration and mixing with a prediction of the resistivity signal for comparison with the ERT measurements.
- Snapshots of resistivity will continue to be taken through March 2021 with the next annual release of water.
- Ideally, the phenomenon of partial riverbed connection will be observed, as it has never been observed at a field site nor in an experiment before, even though it can offer valuable insight for the sustainable use of conjunctive, ephemeral systems.

Acknowledgement:
This work was supported by Elephant Butte Irrigation District and the New Mexico Water Resources Research Institute (NM WRRI) Faculty Water Research Grant Program.

Abstract 52) Electrical Resistivity Mapping of Rio Grande River-Groundwater Interactions (Pg. 139)

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