SESSION THREE

Building a Plan: Best Practices

Moderated by Commissioner Michael L. Connor, Bureau of Reclamation

Michael L. Connor was confirmed Commissioner of the Bureau of Reclamation by the U.S. Senate on May 21, 2009.

Connor has more than 15 years of experience in the public sector, including having served as Counsel to the U.S. Senate and Natural Resources Committee since May 2001. At the committee, Connor has managed legislation for both the Bureau of Reclamation and the U.S. Geological Survey, developed water resources legislation and handled Native American issues that are within the Energy Committee's jurisdiction.

From 1993 to 2001, Connor served in the Department of the Interior, including as deputy director and then director of the Secretary's Indian Water Rights Office from 1998 to 2001. In this capacity, Connor represented the Secretary of the Interior in negotiations with Indian tribes, state representatives, and private water users to secure water rights settlements consistent with the federal trust responsibility to tribes.

Before joining the Secretary's Office, he was employed with the Interior Solicitor's Office in Washington, DC and in Albuquerque, New Mexico. He began his Interior career in the Solicitor's Honors Program in 1993.

Connor received his J.D. from the University Of Colorado School of Law, and is admitted to the bars of Colorado and New Mexico. He previously received a bachelor's degree in chemical engineering from New Mexico State University and worked for General Electric.

The Bureau of Reclamation is a contemporary water management agency and the largest wholesale provider of water in the country. It brings water to more than 31 million people, and provides one out of five western farmers with irrigation water for farmland that produces much of the nation's produce. Reclamation is also the second largest producer of hydroelectric power in the western United States with 58 power plants.

Environmental Water Transactions

David Yardas, National Fish and Wildlife Foundation

David Yardas directs the National Fish and Wildlife Foundation's Southwest and Interior Water Programs. David has a 26-year track record building transactional, collaborative, and legislative initiatives to help restore at-risk rivers, lakes, and wetlands, reduce water conflicts among competing sectors, and settle Native American water claims. His past work covers an expansive western geography that includes the Truckee, Carson and Walker River basins in Nevada and California; the Sierra

Good afternoon everyone. I want to thank Senator Udall, his staff, New Mexico State University, all the organizers, fellow panelists, and all the attendees for your attention today. It's a pleasure to be here representing the National Fish and Wildlife Foundation (NFWF).

First, a few brief words about NFWF: we are a congressionally-chartered nonprofit foundation established in 1984. Like any nonprofit we can accept tax-deductible charitable contributions; but we are also authorized to receive federal appropriations directly, and to manage federal monies in partnership with various federal agencies. We focus on partnerships and collaboration with grantees, agencies, benefactors, corporate partners, and others. In 2011 we granted a total of approximately $130 million for on the ground investments; about a third of that was federal money, with about two-thirds coming from philanthropic dollars and grantee match. The whole idea is to use partnerships to put money on the ground, and to leverage the federal investment.

Nevada/Central Valley/Bay-Delta watershed in California; and the multi-state and bi-national Rio Grande/Rio Bravo and Lower Colorado River systems.

Prior to joining NFWF, David held staff positions at Environmental Defense Fund, Independent Power Corporation, Resources for the Future, and the U.S. Department of Health and Human Services. He was also a founding member of Great Basin Land and Water, a research assistant at the World Bank, and an independent consultant to the U.S. Bureau of Reclamation, University of Nevada, ICF International, and The Nature Conservancy. David holds a B.A. in economics from UC Davis and an M.S. in energy and resources from UC Berkeley.

The Foundation's Western Water Program specializes in environmental water transactions, and the definition here is a pretty broad one: using voluntary agreements to benefit freshwater species and habitats while addressing the needs and interests of willing sellers and other stakeholders. We do this work within the boundaries of the prior appropriation system, and we work almost exclusively within systems that are fully appropriated. Thus, we grapple with many of the challenges that are being faced here in New Mexico today.

The objectives of our program include the restoration of freshwater flows to rivers and streams, riparian and wetland habitats, desert terminal lakes, degraded delta estuary systems, and natural processes like sediment movement and floodplain connectivity. In addition, an important theme of our work is to use transactional initiatives to solve problems and resolve conflicts over water.

Many of our programs interface with some kind of regulatory precedent—for example, the "Reasonable and Prudent Alternative" in the Pacific Northwest which led to establishment of the Columbia Basin Water Transaction Program, and attempting to forestall a critical habitat designation here in the Lower Rio Grande by working with the Elephant Butte Irrigation District to establish a collaborative water transactions program. Our work also involves facilitating water rights litigation settlements; helping to modernize irrigation systems; and bringing flexibility into historically inflexible systems in order to deal with all of the realities of climate change, growth, and hydrologic uncertainty.

Our primary transactional tools include purchase and sale agreements, water lease agreements, and forbearance agreements, all with willing sellers. There is a wide array of tools in the toolkit (Table 1) that we rely on and that form the basis for the kinds of programs in which we get involved. It takes a lot of different pieces of the puzzle to pull these programs together and make things work.

Table 1. Water transaction toolkit

Water Transaction Toolkit

- Annual and Term Lease
- Purchase and Sale
- Partial Season Irrigation
- Source Switch
- Forbearance
- Diversion Reduction
- Land Fallowing
- Stewardship/Revegetation
- Assessment/Deed of Trust
- System Improvements
- Water Banking
- Conveyance/Wheeling
- Standard Offer
- Procurement Auction
- MOUs/Framework Docs
- Monitoring & Assessment

Given the comments in the last panel, I should have prefaced my comments on the Columbia Basin Program by noting that although the Columbia Basin is a very different place, the common theme of this program is that tributary streams, not the main stems, are typically over-appropriated and often run dry in the summer. They do share some common characteristics with admittedly different landscapes. Indeed, all of the western basins are different, and tools have to be tailored to the realities of each situation. But there are also common themes, such as trying to work on a partnership basis by moving transactional activities out to local entities whenever possible.

Another of our existing programs is the Walker Basin Restoration Program, a large-scale restoration initiative in Nevada and California. It uses a variety of authorized tools established by Congress and funded through the Bureau of Reclamation including willing seller acquisitions, water leasing, conservation and stewardship, research, evaluation, and implementation support.

In the Lower Rio Grande, we are working with the Elephant Butte Irrigation District and with Audubon New Mexico, our local on-the-ground partner, with sponsorship from and in partnership with the U.S. International Boundary and Water Commission and the U.S. Fish and Wildlife Service. The goal of the Lower Rio Grande Water Transactions Program is to restore 30 riparian sites along a 105-mile reach of the river to meet the commitments under USIBWC's 2009 Record of Decision, to avoid a critical habitat listing for the Southwest Willow Flycatcher, and to deal with Endangered Species Act assurances related to uncertain water supplies.

Let me conclude by talking briefly about common themes and best practices in all of our transactional work. To invest in local transactions capacity, NFWF generally acts as a fund administrator and tries to push transactions capacity know-how and knowledge out to the ground to local transactors, who know their communities best and who can work directly with local irrigation districts and with tribes. We work closely with landowners, water managers, and other local stakeholders to understand and address their needs. Stewardship programs are a big part of such efforts, whether for revegetation of affected farmlands; restructuring of the water-rights portfolio in order to work with landowners to grow high-value crops that can help to preserve jobs; negotiating water conveyance agreements; or whatever else it takes to get the job done. We utilize independent expertise to establish strategic priorities, business plans, and review annual funding proposals to get the most bang for our buck whenever possible. We help to evaluate program performance; conduct critical due diligence with respect to the full array of property acquisition activities so that you know what you're buying and can put it to beneficial use; and we assist with the water rights change approval process, whether at the local, state, or federal levels. We help define critical outcome metrics, monitor and track performance, and adapt and adjust where needed. And finally, we relentlessly pursue funding in a variety of forums, both public and private, to develop new initiatives such as regulatory flow credits and water restoration certificates, and to partner with other funders to expand the funding available for this important restoration work.

I'm afraid I'm out of time, thank you very much!

Water Leasing Market Experiments

David Brookshire, University of New Mexico

David S. Brookshire is a Distinguished Professor and Director of the Science Impact Laboratory for Policy and Economics (SILPE) within the Department of Economics at the University of New Mexico (UNM). After completing his B.A. in economics at California State University at San Diego in 1970, David earned his Ph.D. in economics at the University of New Mexico in 1976. He was on the faculty at the University of Wyoming from 1976 to 1990. He returned to UNM in 1990 and served as department chair from 1993-2000. David specializes in environmental and resource economics. Among his many appointments, he has served as Policy Sciences Editor of Water Resources Research (published by the American Geophysical Union), served on the Executive Board of the Sustainability of Semi-Arid Hydrologic and Riparian Areas (SAHRA) Science and Technology Center at the University of Arizona, served on three National Research Council panels and worked as an economist for the National Water Commission, the U.S. Department of Commerce, and the U.S. Geological Survey.

David specializes in public policy issues in the natural resource, environmental and natural hazards areas. In particular, he has completed studies pertaining to seismic building codes, earthquake prediction impacts, environmental regulations, endangered species, air pollution, the effects of seismic zoning and the value of geologic information and water allocation. His current research interests include ecosystem valuation, natural hazards issues, endangered species protection, field and laboratory experiments for the estimation of disaggregated

It is a pleasure to be here. I will tell you right up front my comments have morphed a bit as I have listened to the very interesting conversation that we have had throughout the day. The focus of my conversation is going to be on flexibility issues and water reallocation. More specifically, I want to talk about some ideas about water leasing.

Let me suggest that currently in terms of water allocation, we do not have best practices. We have current practices and part of the theme of my talk is that we need to move beyond the status quo and redesign the institutions that we have for water transfers. You've heard quite a bit about this especially from the last panel. In fact, my take-away point from the last panel was that everybody hates markets right up until the moment they love markets.

What I'm going to talk about here is embodied, in some sense, in a book that recently came out, *Water Policy in New Mexico: Addressing the Challenge of an Uncertain Future* edited by myself and Hoshin Gupta and Paul Matthews. I caution you, if you read Chapter 14 of the book you will find that as one colleague has suggested: you didn't try to go from "a" to "b" to "c"—you wanted to go directly to "z." In the book we tried to stir the pot. I'm going to give you a few brief thoughts on that. Now obviously we've heard a lot about the need for more flexible institutions: in the amount of time that it takes to do a water transfer whether it is a lease or a permanent trade. The time is really quite long and is well documented. Those that entered into this process have found it costly.

The need for expedited transfers is fully recognized in the State Water Plan, but this is not fully implemented. In Section C2 and 6-9, words such as "efficient transfers of water that consider economic, cultural, and other custom norms, and water banks" are all talked about. Notice all those words are bundled together. They are not bundled together as: let's do a water market and ignore everything but just the value of the transfer water. It says this market must be, in fact, be constrained in some fashion, and if you think about it for a moment, there are almost no markets in our country that are not constrained in some fashion. So the task at hand in designing an efficient water leasing market that respects cultural norms.

Let me talk about some things that we have tried to do to address this issue. There needs to be, I would suggest, at a minimum, two advances if we are going to move towards what I would call a real-time leasing market. First, we need a "coupled model framework" that integrates the best knowledge from scientists, engineers, lawyers, Native Americans, stakeholders, environmentalists—I probably have forgot someone, forgive me—but everybody basically has to be at the table. We need that model, fully integrated, and fully coupled, so that when one piece kicks the other piece, they all know about it. Second, you need to tie that model to a **voluntary** leasing market. If you don't want to be in the market, you are not in the market. If you go into Smith's and you don't want tomato paste, don't buy tomato paste. It's that simple.

demand of consumer water users, the value of water in non-market settings, and integrated hydrological/biological/economic modeling of alternative institutional and behavioral characteristics of water banking/leasing markets.

You need these two components linked together so that as trades are initiated, it's tracked, and you know what's happening in terms of various kinds of things. By constraining these markets in some fashion, you know that, in fact, for some trades, it will be said, "no, can't do that one—it violates this or that." Essentially, you are giving the policymakers a framework that allows them to stand back and, with low transactions costs, and watch an efficient, adaptive management tool evolve as people interact in these markets. Can this be done? We think so. In fact, we've developed a stylized market based on the Middle Rio Grande where we had these coupled integrated models. After a presentation and at the encouragement of John D'Antonio, former state engineer, he asked us to go do some of this work on the Mimbres River Basin. We have been working down there with stakeholders. Let me say one thing very quickly about that—is this easy? No. We've been at this for a couple of years and it's a very slow process. There's a necessary process for building trust and communication. Will this be a complete success? I can't tell you that, but we will again have learned some lessons in terms of developing this market.

So the idea here is that if you have a real-time market coupled to the physical, engineering, environmental situation at hand, this might imply that all water leasing markets might be specific markets to specific places designed by specific stakeholders. One shoe does not fit all. This will facilitate the transfer process and remember, a market is only going to be as good as a stakeholder's involvement in the design of that market. You can design any kind of market. The poster child of a bad market is the California electricity market. The idea is to avoid that kind of situation.

This conference is about hard choices. My hard choice would be: Are we going to sit with the existing institutions for allocation that soon will be inappropriate in the 21st century, or are we going to move beyond the status quo and begin to try to develop these institutions.

Thank you.

Rio Grande Basin Opportunities

Lee Peters, Peters Law Firm, LLC

Lee E. Peters is the owner of a water and natural resources law firm, Peters Law Firm, LLC. From 1989 to 2010, he handled cases regarding water rights, public lands, grazing rights, wilderness, environmental law and endangered species, as well as general civil law for Hubert & Hernandez, P.A. From 1984 to

Thank you, Commissioner Connor. I'm very honored to be here with Senator Udall. Senator Udall and I have known each other since we were young and struggling attorneys back in the old days in Santa Fe. You haven't heard any jokes today, usually speakers come out and tell jokes, but water law and water issues are just not that funny. We know it's not funny because in New Mexico we are very amenable to our neighbors, but the old saying is modifiable a little bit here where we say "mi casa es su casa, pero mi agua es mi agua." You don't come in and use our water in New Mexico.

1987, Lee was Special Assistant Attorney General, New Mexico State Land Office, primarily responsible for the Land Office's water policies.

He was the lead counsel for the State Land Office in administrative proceedings before the State Engineer filed by the City of El Paso for massive groundwater rights within New Mexico. Since 1987, Lee has been counsel for clients such as the Elephant Butte Irrigation District and the Carlsbad Irrigation District. He received a B.A. in economics and political science from UNM and received a juris doctor from UNM's School of Law in May 1980.

I'm going to talk about New Mexico's Lower Rio Grande area. We have a situation here where we are urbanizing with the City of Las Cruces and other areas like the City of El Paso area, which gets the other part of Rio Grande Project Water, and is highly urbanized as is Albuquerque. All of these cities are surrounded by irrigation or conservancy districts that control the bulk of the surface water in those areas. So there's a need for methods to get that agricultural water into other uses. We've talked about markets and other things, but there are institutional barriers present. You can't just go buy an agricultural water right in these areas and move it to where you want it for whatever purpose you want.

In the Lower Rio Grande, we have the federal Rio Grande Project that runs from Elephant Butte Reservoir to Ft. Quitman in Texas. It's a single-purpose project, authorized in 1906. That single purpose is agriculture. Elephant Butte Irrigation District (EBID) within the New Mexico portion controls virtually all of the surface water. There's a lot of pressure—economic, legal, and otherwise for those ag water rights to be moved into other uses. I'm going to talk about two methods for this. One is in place, and one we are working on.

The first one is special water users associations, which are authorized by state law since the year 2000. Municipal entities, universities, and other kinds of water providers can become a special water user association and apply to an irrigation district and to the state engineer to become such an entity. They can then lease water rights from within an irrigation district and use them within or without the district for municipal and industrial purposes. Thus we have a mechanism to get agricultural water into these other two kinds of uses, which is where much of the demand is coming from.

In this area, nobody is actually diverting surface water for municipal uses. The Doña Ana Mutual Domestic Water Consumers Association will likely be the first. They have plans underway to build a surface water treatment plant near the Leasburg Dam. I understand the City of Las Cruces has some plans to divert surface water. No water has actually been diverted for these purposes, but we will see this happen in the near future. This is a fairly unique statute and authorization because it allows agricultural water to be used within or outside the irrigation district boundaries for these nonagricultural uses.

Another thing EBID is working on in partnership and collaboration with the International Boundary and Water Commission, the Audubon Society, National Fish and Wildlife Foundation, and through the offices of Senator Udall and Senator Bingaman is what we have tentatively called an environmental water transaction program. The program would allow EBID agricultural water to go into habitat restoration and other types of environmental uses. EBID is developing this on the basis that this is another kind of agricultural use: it's a human use of water to grow plants for human benefits, it provides habitat for endangered and threatened species. U.S. Fish and Wildlife and the Bureau of Reclamation are also involved. We have a tentative thumbs-up from Reclamation Commissioner Connor on this approach. This would allow the sale or lease of EBID water for use within the district for wildlife habitat, restoration, and maintenance. It is still within the single purpose of the Rio Grande Project, it's still an agricultural use, although it's a different kind of agricultural use. What we are developing now are protections for this water against sanctions that might be imposed under the Endangered Species Act that would force the use of that water

if it's diverted into an endangered species purpose. We don't have a lot of threatened or endangered species down here—not a lot of habitat is being developed, so we are starting basically from the ground up. As these rights are developed, they will be protected so that the only water that can be used is limited to the regular allotment that any other water right owner within the district has. It's kind of funny to be talking about this at this point because we don't have much surface water. The idea is to keep those depletions for this kind of agricultural use in balance. They would not be allowed any increase in depletions over agricultural use, and the deliveries would be made within the irrigation system.

In conclusion, this is a program to create flexibility and to provide other methods to allow the free market to function within an irrigation district. Farmers have the option to sell or lease or even donate water for these other uses. It opens the market for nonagricultural uses—for urban and municipal uses or for environmental uses. The water remains under the administration of EBID and keeps the EBID viable because the assessments for the water would still be paid and allows EBID to continue to maintain the system. This addresses the same concern that Paula Garcia had for the acequias. Thank you very much.

Bridging the Gap—Transformational Solutions for a More Sustainable Water Future

Howard Passell[1], Jesse Roach[1], Dagmar Llewellyn[2]
[1]Sandia National Labs
[2]U.S. Bureau of Reclamation

Howard Passell works in the Earth Systems Analysis Department at Sandia National Laboratories, in Albuquerque. His work focuses on sustainability and resource management projects associated with water, energy, and food resources, with an emphasis on the links between those and other systems, including ecosystems, demographics, economics, public health, governance, and security.

His work has involved resource monitoring, modeling, management, capacity-building, and policy-related projects at various scales in the U.S., Central Asia, the Middle East, and North Africa. Of special

I'd like to thank my co-authors, Dr. Jesse Roach from Sandia National Labs and Dagmar Llewellyn from the U.S. Bureau of Reclamation, both in Albuquerque, and the WRRI and Senator Udall and his staff for making this important event possible.

I'm going to report on one case study from a set of three we examined as a way of better understanding future water supply and demand dynamics in the western U.S. The other case studies include work from Dr. Vince Tidwell and Katie Zemlick, both from SNL, and Dr. Cliff Dahm from UNM biology.

Data from regions around the world suggest that humans are facing a considerable gap between projected supply and projected demand for water in many regions, with New Mexico in particular, and the U.S. Southwest in general, as prime examples. It is also becoming apparent that the advantage gained by current supply augmentation and conservation technologies being applied around the world are incremental at the margins, and linear, and not adequate for bridging the future gap between projected supply and demand. We set out to examine what we thought might be transformational solutions that would bridge the gap by creating non-linear advantages. We

Sandia National Laboratories is a multiprogram laboratory managed and operated by Sandia Corporation, a wholly-owned subsidiary of Lockheed Martin Corporation, for the US Department of Energy's National Nuclear Security Administration under contract DEAC04-94AL85000.

interest is the relationship between resources, population, ecosystems, and human security. His undergraduate studies were in classical literature and the liberal arts. He earned master's and doctorate degrees in conservation biology and hydrogeoecology at the University of New Mexico.

found solutions that appeared to bridge the gap, but upon closer inspection it became clear that they really shifted the gap from one sector—water—to others, including economics, ecology, and culture. We demonstrate today with one of three case studies.

This case study focuses on work being presented in a poster at the conference entitled "URGSiM Analysis of Climate Risk in the Upper Rio Grande Basin" by Dr. Jesse Roach from SNL, and Dagmar Llewellyn and Warren Sharp from the Bureau of Reclamation. The authors present the final results from a complex sequence of computer modeling approaches used to evaluate how climate change might affect water supply and demand in the upper and middle Rio Grande basin, and how those effects might impact legally binding downstream delivery obligations. This work was part of the Bureau of Reclamation's West Wide Climate Risk Assessment Program. The analyses performed by the West Wide Climate Risk Assessment used 16 different general circulation models and 112 different model runs to simulate and analyze future climate scenarios and their impacts to water deliveries, river flows, and reservoir levels in the upper and middle Rio Grande (Fig. 1). Much more information on the model and the analysis is available on the poster, and from the co-authors.

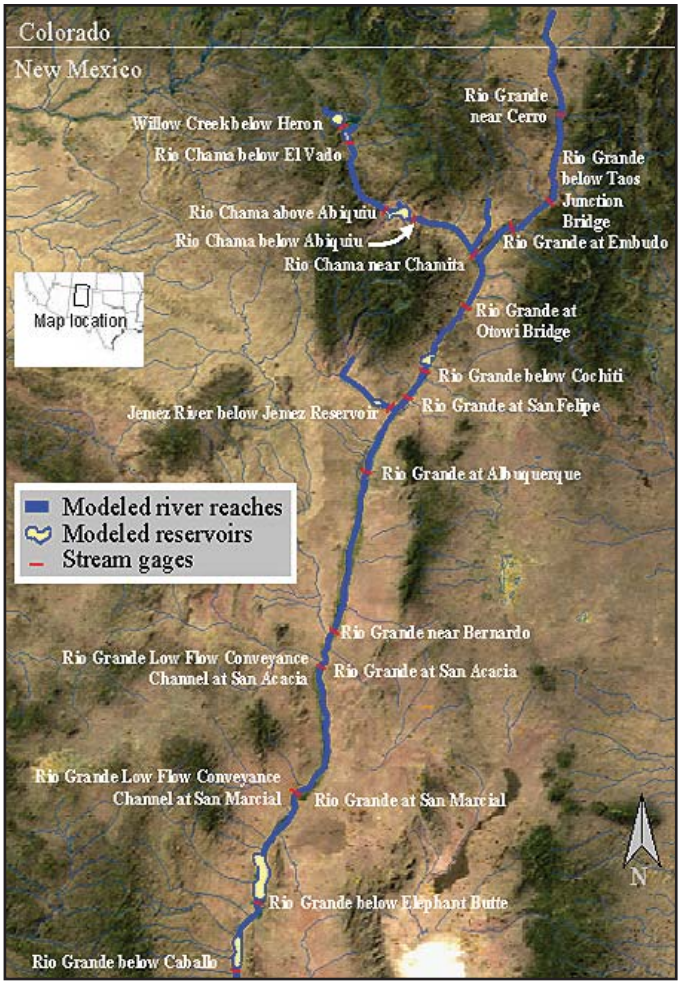

Figure 1. Map of the Upper and Middle Rio Grande

Figure 2 shows surface water supply in the study area out to 2100. These results are not predictions, according to the authors, but rather are a starting point for dialogue and increased awareness of potential impacts. These simulations account for climate change, but not population growth or any kind of water conservation. Declines in surface water supply are evident at Rio Grande at Lobatos, Rio Chama near La Puente, and Azotea Tunnel. These declines are occurring in a region already suffering from surface water shortages relative to current demand.

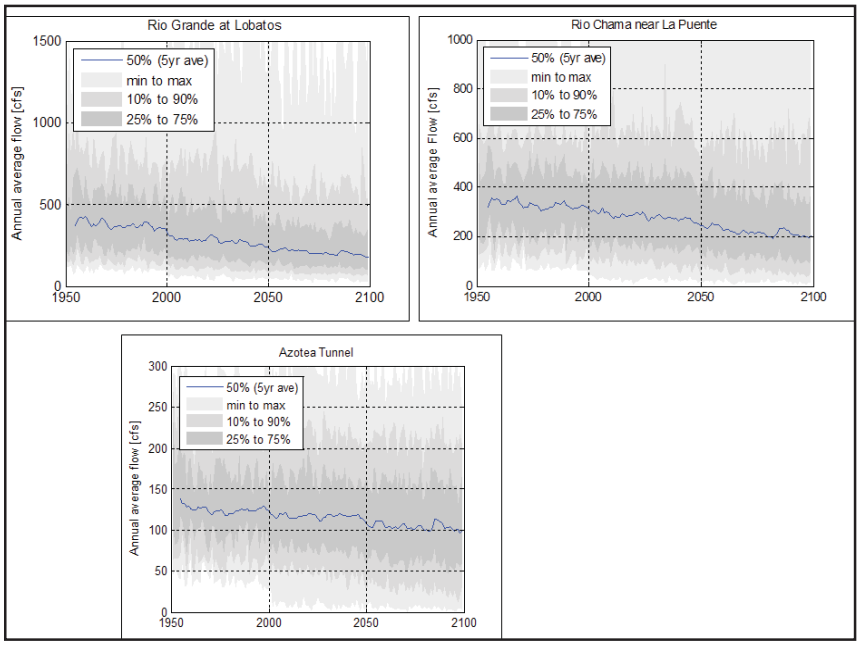

Figure 2. Surface water supply

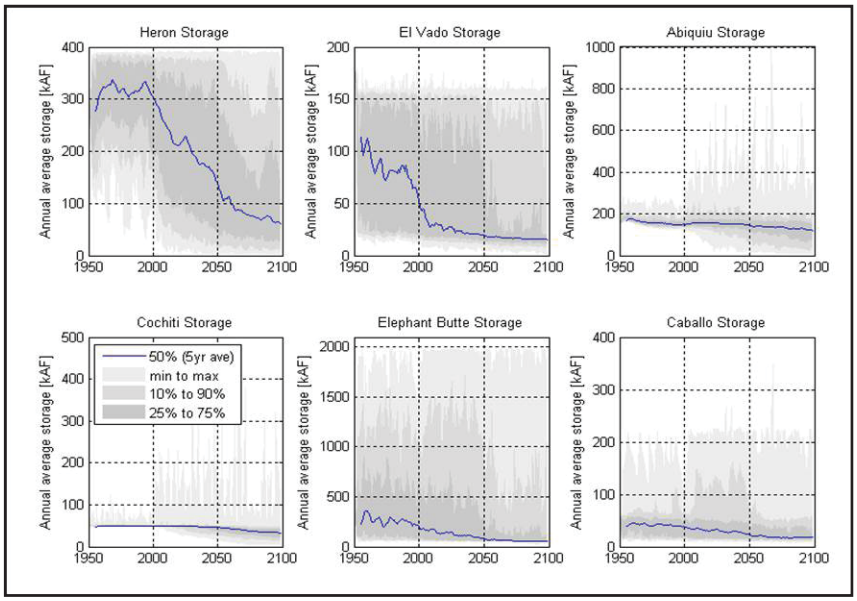

Figure 3. Reservoir storage

Reservoir levels are shown decreasing over time in Fig. 3 for Heron, El Vado, Abiquiu, Cochiti, Elephant Butte, and Caballo. Fig. 4 shows irrigated agriculture, riparian vegetation, and municipal demand all increasing. What's the impact on the Rio Grande Compact? Fig. 5 shows that by 2100, without any sort of proactive or reactive water management policy changes, New Mexico is projected to amass a Compact deficit of over a million acre-feet in more than half of the simulations, which would represent flagrant non-compliance with the Compact and would never be allowed to occur under the current Compact agreement.

The researchers used their operations model to evaluate different scenarios for what might be done to reduce the simulated Compact deficit—or to bridge that gap. Figure 6 shows how the model reduces agriculture to solve the Compact problem. By the year 2100, the model simulates cutting agriculture in the Middle Rio Grande Basin by about 21 percent, from about 58,000 acres down to about 46,000 acres. In other words, the Compact deficit in the Middle Rio Grande Basin is relieved by significantly cutting the agricultural area. Figure 7 shows the result on the Compact when those agriculture reductions take place: we go from an over 1,000,000 acre-foot deficit in Fig. 6 to significantly less than a 200,000 acre-foot deficit in Fig. 7, which is the maximum deficit allowed under the Compact. So cutting agriculture helps bridge the Compact gap, but it creates another gap represented by the loss of agriculture, which would have economic, ecological, and cultural

implications. It could create an important future gap in regional food security if those agricultural lands are lost for good, and fossil fuel prices increase such that it is no longer economical to import food from other states or other countries.

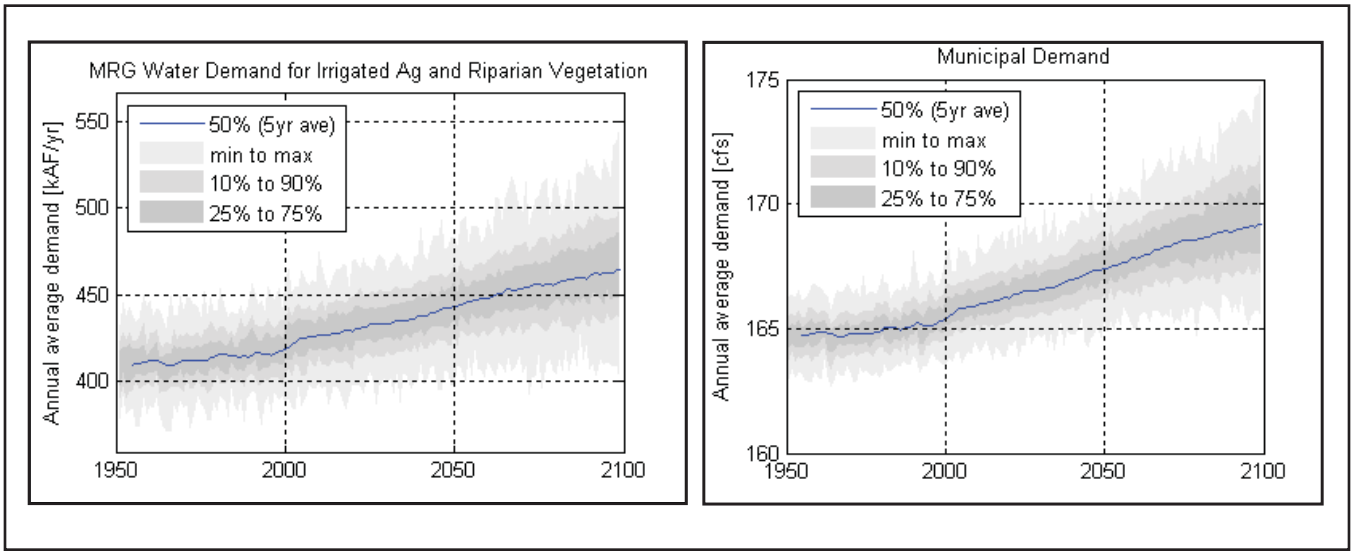

Figure 4. Agricultural, riparian, and municipal demand

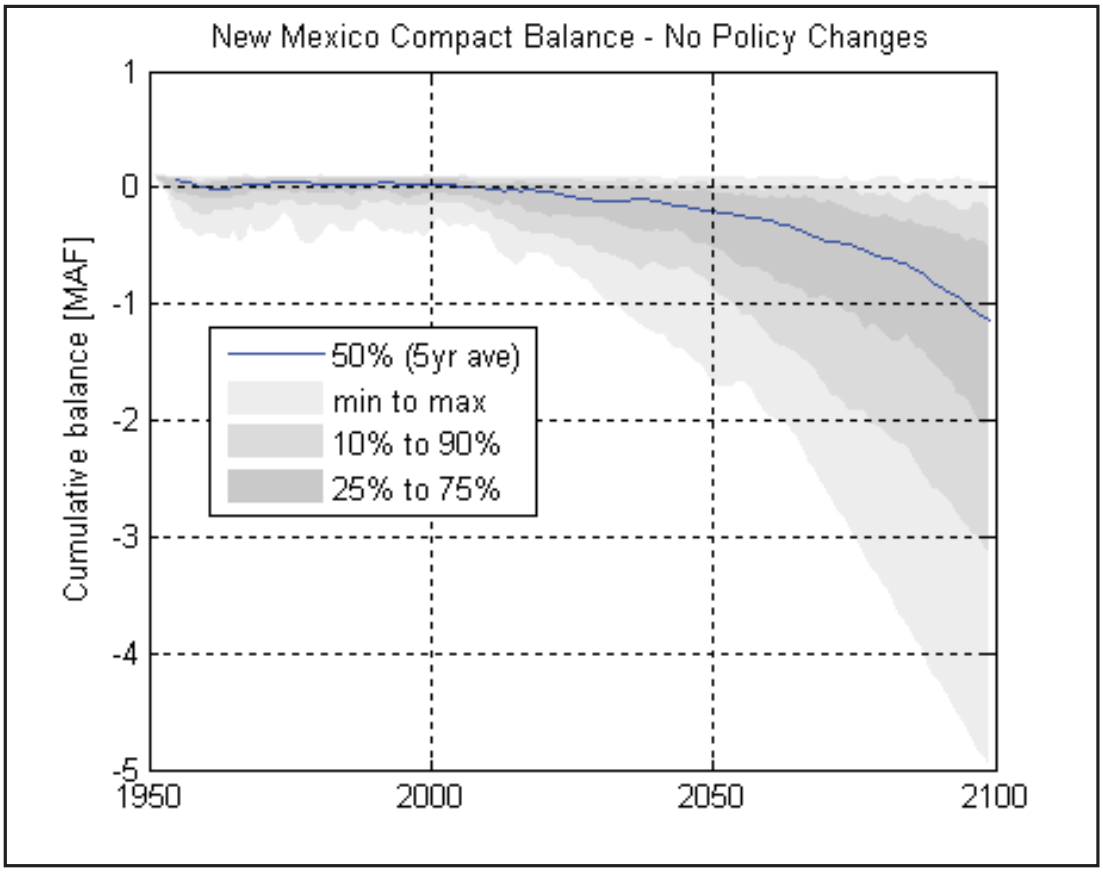

Figure 5. The Gap in the Rio Grande Compact

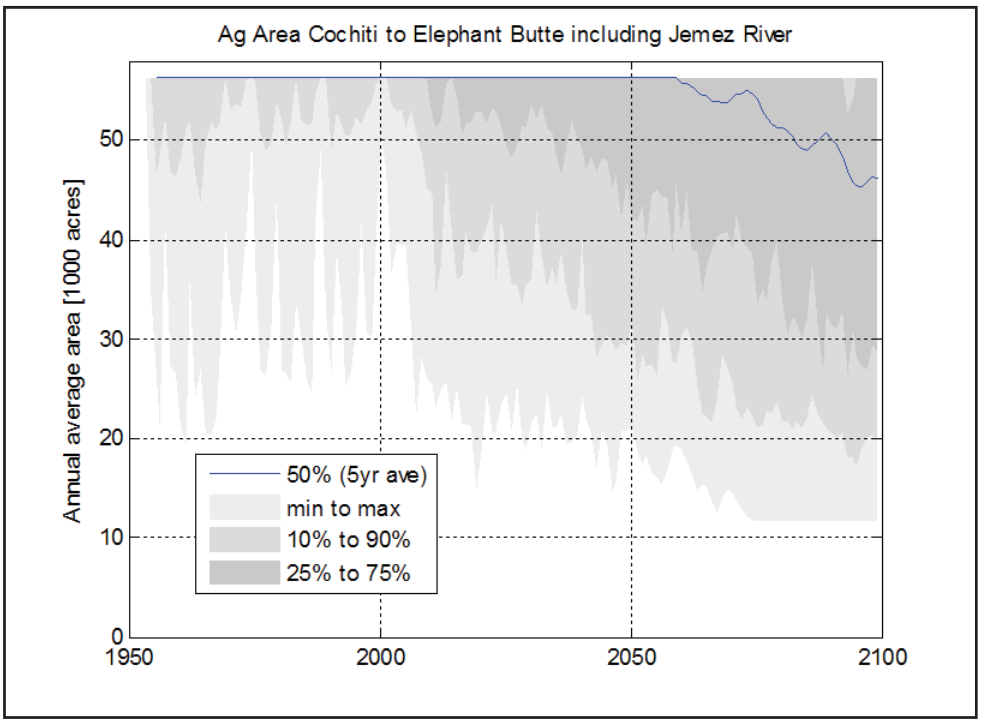

Figure 6. Agriculture reductions as a possible strategy

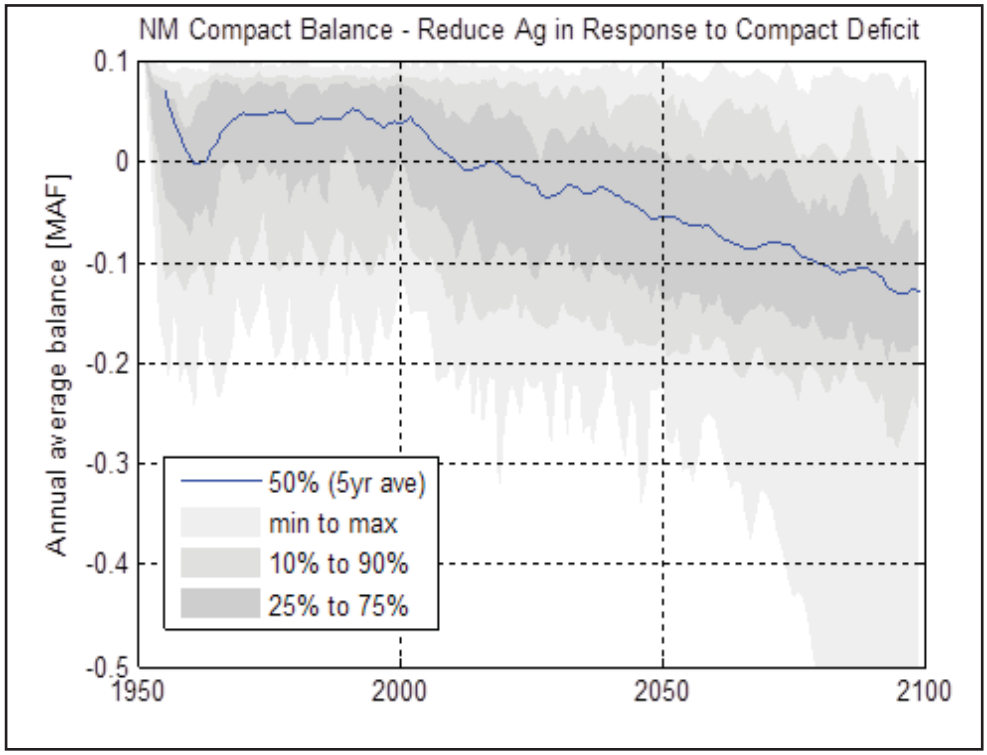

Figure 7. Compact response to Agriculture reductions

Another scenario aimed at reducing the Compact deficit reduces our riparian area, the bosque, in the Middle Rio Grande Valley by about 40 percent, from a little under 55,000 acres down to about 33,000 acres (Fig. 8). That reduction helps bridge the Compact gap, leaving a roughly 100,000 acre-foot deficit instead of an over one million acre-foot deficit in the base-case scenario (Fig. 9). However, it shifts the gap to the bosque, which would have broad ecological and cultural impacts.

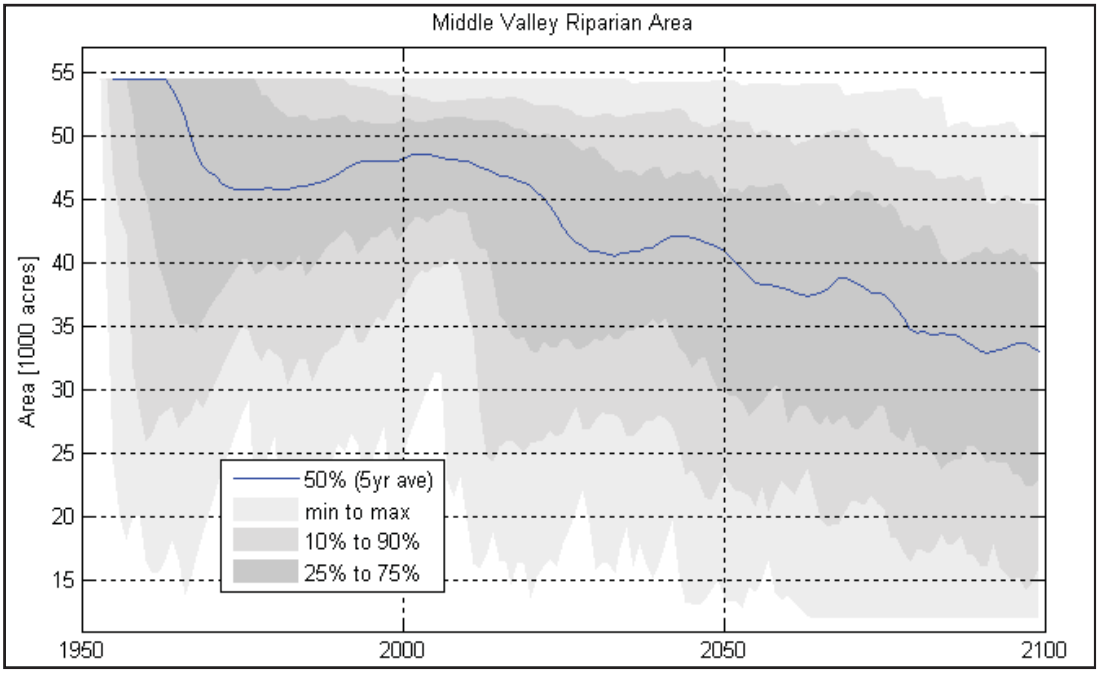

Figure 8. Bosque reduction as a possible strategy

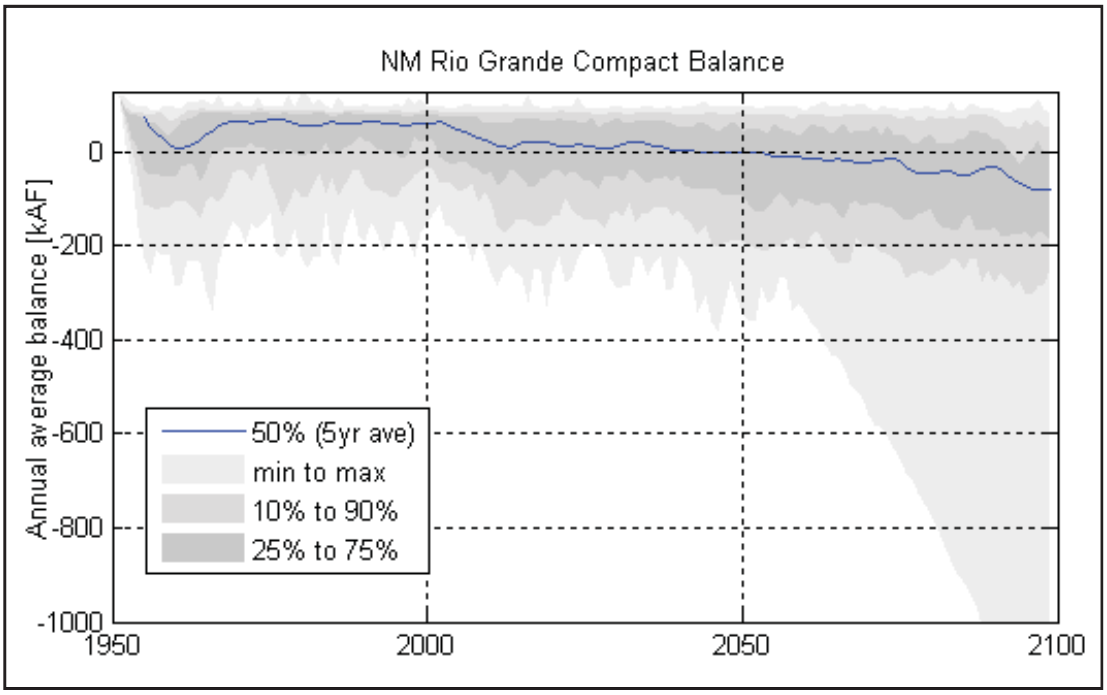

Figure 9. Compact response to bosque reduction

Yet another scenario examined lining the river with cement as a possible strategy for bridging the Compact gap (Fig. 10). Lining about 60 percent of the river between Cochiti and Elephant Butte by 2100 bridges the Compact gap (Fig. 11). However, cementing the river would have the important impact of preventing infiltration to the deep aquifer, which is a primary source of recharge to that aquifer. It would also contribute to drying out the bosque, which receives some of its water from river leakage, it would have impacts on endangered species such as the silvery minnow, and it would have other economic, ecological, and cultural impacts.

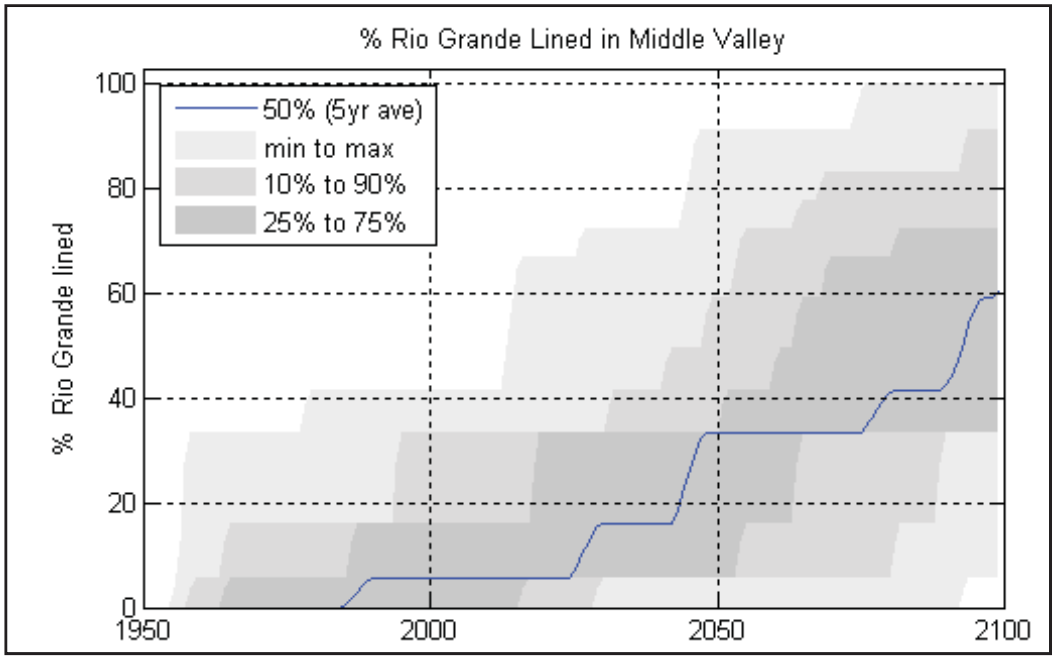

Figure 10. Lining the river as a possible strategy

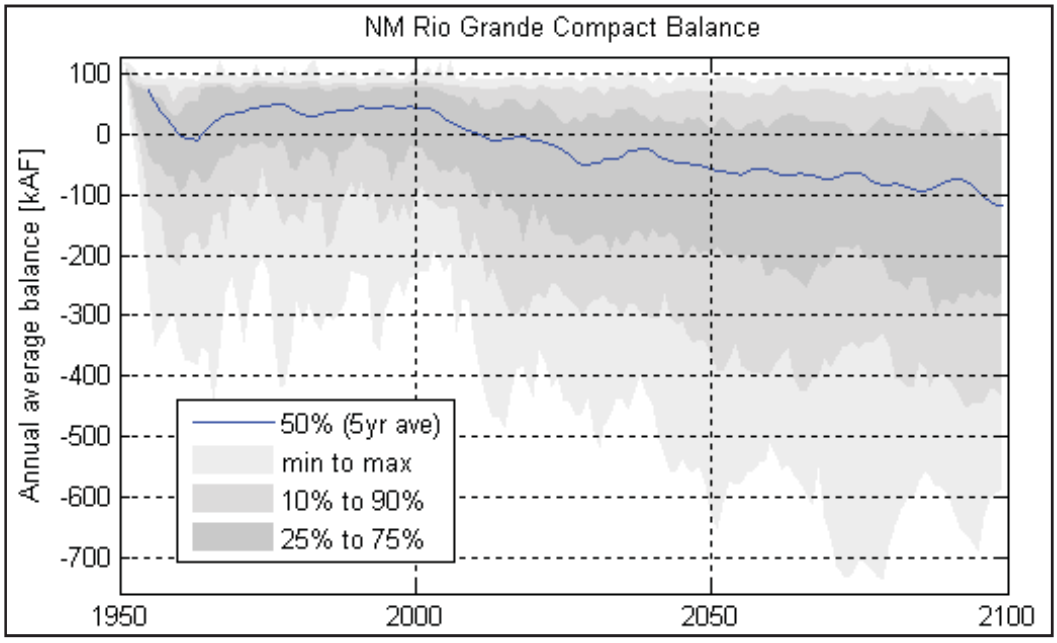

Figure 11. Compact response to lining the river

All of these model results allow us to improve our mental models of what measures might be taken, and at what levels, to relieve Compact gaps that might occur in the future. In fact, some combination of all these measures could be taken, and the operational modeling would allow those kinds of mixed scenarios to be evaluated as well. All these possible solutions, taken individually or mixed, would leave the valley with various kinds of deleterious impacts, and all of these scenarios include the loss of natural capital—agricultural land, the bosque, or the river itself. It's important to remember that these scenarios account only for the effects of climate change on water supply and demand and do not simulate population increase or increasing demand for any other reason, or future conservation. However, the same measures simulated in the work described here could be used to bridge gaps driven by population growth or other factors.

This case study shows that many of the solutions that we currently imagine might help us bridge the gap between supply and demand only shift the gap to other sectors. In other words, we can meet projected demand, but only if we are willing to give up what some may consider to be important values. If this is correct, then what other measures might be taken that do not simply shift the gap? There are many ways we could reduce water demand in New Mexico and the West in general. We can use a mix of the alternatives simulated above. We can reduce agriculture in some places (which is already happening in response to population growth and rising property values), reduce evapotranspiration from the bosque in various ways, or line irrigation canals and ditches (although cutting leakage from the system will also dry out parts of the valley that are now green). The cities can continue with what have been effective water conservation measures.

But the modeling suggests that unless we are willing to see the gap shifted to our regional natural capital, then we must take bolder measures. It is noteworthy that instead of cutting agriculture or the bosque, other modeling done at SNL suggests that the same amount of water savings could be achieved by changing cropping patterns and irrigation technologies, without reducing agricultural acreage itself.

Maybe one of the most important measures we could take in the upper and middle Rio Grande valley would be to start moving away from a 'constant growth' economic paradigm to something closer to a steady state economy. A reduction in population growth rates (with continued reduction in per capita consumption) could help relieve regional water scarcity, although with an impact to the construction industry, and maybe to property values. We do seem to be playing what some call a zero-sum game, in which gains in one sector are mirrored by losses in another. The challenge we face now is to decide where those gains and losses will occur.

I mention some of these bolder alternatives because they have generally not been put on the table as possible solutions. The modeling described today suggests that significant demand reduction is required, probably using means that have not been considered before. None of these solutions, by the way, need to be implemented by some kind of government mandate dictating which crops could be grown or products brought to market, or how people could migrate into NM, but could be achieved gradually and maybe even somewhat painlessly through tax incentives. The great challenge facing us now is to what extent we can manage our own future, and to what extent we will simply be carried into it by currents beyond our control.

Some might say that some of these solutions are so far out of the main stream that they are preposterous. But I would suggest that degrading and eliminating our natural capital and impairing the ecosystem services that allow us to be here in the first place, all in exchange for constantly increasing consumption of resources, is what is actually preposterous. What is the gap that we most want to prevent from opening up? We might argue that it would be a gap in "quality of life." That gap will almost certainly open up if we continue increasing our consumption of resources at the expense of the systems that provide those resources. We need to be looking out of the box for new sets of solutions. If we do not have enough water in the basin to meet projected demand, and that's where the evidence is pointing, then one of the things we need to do is reduce that projected demand in the future—and stop dreaming that all the water we need will just fall from the sky.

NSF Water Infrastructure Engineering Research Center

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Nirmala Khandan (Khandan) holds the Ed & Harold Foreman Endowed Professorship in the Civil Engineering Department at New Mexico State University (NMSU). During his 22 year-tenure at NMSU, he has taught several undergraduate and graduate courses in the environmental engineering area. His research has covered areas of renewable and sustainable technologies in the energy/water nexus, including biohydrogen, microbial fuel cells, biodiesel, and desalination. His research projects have been funded by the Department of Energy, National Science Foundation, Department of Agriculture, and Environmental Protection Agency etc. Currently he is the lead investigator at NMSU of the NSF-funded Engineering Research Center on Reinventing the Nation's Urban Water Infrastructure (ReNUWIt), a collaboration between NMSU, Stanford, Berkeley, and CO School of Mines.

Outcomes of his research projects include 12 PhD degrees, and over 100 ISI journal papers with over 1100 peer citations.

Thank you all and WRRI for this opportunity to talk about the Re-inventing America's Urban Water Infrastructure project that was funded at New Mexico State University recently as a National Science Foundation Engineering Research Center. You may recall this morning that President Couture referred to this project as a collaborative project with Stanford University, UC–Berkeley, Colorado School of Mines, and NMSU. The lead university is Stanford University. The theme of the project is reinventing the nation's urban water infrastructure. As President Couture mentioned, our water infrastructure is almost 50 years old. The designs were done perhaps 50 or 60 years ago when energy was very cheap and CO_2 emissions were not considered at all. The liability and sustainability of the systems were not major considerations at that time. Today, those factors are very important. We want to reinvent the system and we pretty much want a clean slate.

This project went through a two-year review process with pre-proposals, proposals, site visits, reverse site visits, and so on. It was a very tough competitive process, but I'm happy to say that out of the four projects that were granted last year, this was one of the projects selected. We just completed the first year and are into the second year now. Figure 1 gives some details as what we are trying to do. The project is illustrated using a three-plane diagram. We are trying to do fundamental research in the laboratory at the first level, then taking it to the next level of prototype testing, and then to be demonstrated at field scale.

As you can see, it's a multidisciplinary project with biologists, process engineers, chemists, economists, and lawyers involved in this project. Currently, at New Mexico State University we have four projects already in place, two of them in engineered systems and two of them in natural systems. We are supporting four new PhD students, graduate students, and several undergraduates.

He has received several awards for his teaching and research accomplishments. One of his research projects on desalination, funded by NM WRRI, has been selected as one of the 28 "Best & Brightest" projects in the Genius Issue of Esquire Magazine in 2008. This project resulted in a process that has been patented recently.

As part of this research center, education and outreach are very important, as requested by NSF as part of all these large-scale projects. During this past summer we had several activities as part of our education and outreach component. We had a program called the Research Experience for Undergraduates where we recruited two undergraduates from outside the consortium, from UTEP, to work with us at NMSU. We had a program called Research Experience for Teachers where we brought in three teachers from area middle schools and gave them opportunities to work with researchers in water-related areas. We had summer K-12 programs for the Hatch Valley School District. Participants came to NMSU to spend about ten weeks working on various parts of the research. We also had four community college participants working closely with the center's researchers in water-related projects.

Ongoing activities include new courses that are being developed for undergraduate and graduate level programs. Thank you very much.

Figure 1. Re-inventing America's urban water infrastructure