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Water currents in New Mexico: A global reach

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Abstract

This article describes a series of water issues and policy choices for adapting to climate-stressed river and stream systems. It addresses issues that are important both in New Mexico and internationally for which economic analysis can inform and guide ongoing policy debates. Economic analysis is needed both in New Mexico and overseas to guide plans for efficient, equitable, and sustainable water use and for reducing costs of adapting to climate-stressed river and aquifer systems. Special attention is given to three current water issues in New Mexico: climate-stress adaptation through water trading and banking, adaptation through transboundary aquifer sharing, and adaptation through headwater flow capture. All three of these measures face design and implementation challenges both in New Mexico and internationally for adapting to growing evidence of climate-stressed river systems.

Introduction

Growing populations worldwide, rising international needs for food security, climate stress on river systems, and increased economic value of water both in and out of irrigated agriculture continue to challenge water policy-making in New Mexico and other dry regions of the world (Brouwer, Rayner, and Huitema 2013, de Bruin et al. 2009, Jeuland and Whittington 2014, Taylor et al. 2013). These problems challenge attempts to sustain overall economic prosperity, protect key ecological assets, and secure economic welfare of the world's poor who bear a disproportionate share of climate-stressed water supplies and who are often unable to adapt to increased water scarcity when it occurs. Irrigated agriculture is the world's largest water user in dry regions. In addition, by use of conventional methods to measure the economic value of water, irrigated agriculture produces low marginal economic values of water compared to values in competing sectors (Ward and Pulido-Velazquez 2008).

Water resources sustainability for farms, cities, and the environment face numerous drivers of change. These include: 1) agricultural practices and trends, especially increasing production of perennial tree crops such as pecans and greater reliance on groundwater of marginal quality for irrigation, with both quality and quantity

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implications; 2) urban growth and per capita usage, impacting land use, water demand and quality; 3) climate stress that affects both water supply, especially reduced snowpack in the headwaters and increased water demand through increasing temperatures and greater evapotranspiration demand; 4) and growing demand for environmental services such as riparian habitat for endangered species and environmental flows (Hargrove 2015).

New Mexico, a dry region in normal periods, sits on the front lines of challenges faced by the ongoing need to handle climate-stressed river and aquifers. In New Mexico, much recent water planning and policy design is based on a historical trend of 6 to 10 inches of precipitation yearly. New Mexico faces international treaty obligations to Mexico, federal requirements for protecting endangered species, delivery requirements for eight interstate compacts with other states, as well as numerous water development and allocation challenges within New Mexico's borders.

Water Policy Debates Informed by Economic Analysis	Importance (x: some, xx: more, xxx: most)	
	New Mexico	International
Adaptation measures for climate stressed supplies	xxx	xxx
Aquifer storage and recovery	xxx	xx
Basin scale modeling for policy analysis	xxx	xxx
Establishing or renegotiating interstate compacts	xxx	xx
Financing rural water systems	xxx	x
Investments in renewable backstop technologies	xxx	xxx
Managing stream-aquifer exchange	xxx	xx
Meeting growing urban demands and protecting irrigated agriculture	xxx	xx
Production functions analysis: water substitution for other inputs	xxx	xx
Reservoir storage development, restoration, or removal	xxx	xxx
Sustaining affordable water with growing demands	xxx	xx
Settling transboundary water sharing conflicts	xxx	xxx
Water conservation measures	xxx	xx
Water supply portfolio management among diverse sources	xxx	xxx
Design and operation of water trading and banks	xx	x
Irrigation infrastructure for environmental flows	xx	xxx
Mandated water conservation	xx	xx
Measures to protect environmental flows	xx	xxx
Safe minimum standard of reservoir/aquifer storage	xx	xxx
Shortage avoidance: demand reduction v supply expansion v both	xx	xx
Water importation measures	xx	xxx
Water pricing for efficiency, equity, sustainability	xx	xx
Water rights adjudication	xx	x
Economic v financial performance of solar desalination	x	xxx
Economics of water recycling and reuse	x	x
Financing irrigation infrastructure restoration	x	xx
Managing the energy-water-food nexus	x	xxx

Table 1: Waterpolicy Debates

Table 1 ranks by importance many water policy challenges inside New Mexico and internationally for which economic analysis can offer important insights to inform policy debates. The ranking of issues inside New Mexico is qualitative. This can be seen based on our experience working with stakeholders in recent years, and on our assessment of gains in discounted net present values from resolving the conflicts. For the international assessments, the rankings are more limited. They are based entirely on those few places in the international world where the authors have traveled to consult on water issues. That scope is limited to these basins: Murray Darling, Jucar (Kahil et al. 2016), Jordan (Ward and Becker 2015), Tigris-Euphrates, Amu Darya, Nile, as well as several headwater basins in Afghanistan (Acquah and Ward 2017).

While the table is mostly self-explanatory, several policy debates are attention-grabbers that compel the need for economic analysis. The search for sustainable water conservation measures is a good example. For instance, ongoing surveys of irrigators in Southern New Mexico, West Texas, and Northern Mexico since late 2015 continue to reveal a widespread interest by growers in water conservation. Most have expressed a commercially-motivated interest in maintaining farming income while using less water, unless water conservation could threaten the safety of a water right based on historical beneficial use. Conserved water risks interpretation as water use that failed the test of beneficial use.

Water conservation debates face a paradox: when asked directly, most people in New Mexico and worldwide state they favor water conservation. Yet many methods of conserving water are expensive compared to the value of water saved (Ward, Michelsen, and DeMouche 2007). In other words, the cost of substituting other inputs for water to reduce water use are more expensive than the economic value of the water saved by the substitution. For example, conservation can occur by converting from urban grass landscape to xeriscape, converting from flood to drip irrigation, deficit-irrigating crops, shifting into water conserving crops, and taking irrigated land out of production. All these measures reduce water applied, but it takes a careful economic-hydrologic analysis to discover the few that are economically attractive (Ward and Pulido-Velazquez 2008).

Water conservation can be mandated by public declaration or enactment. Still, somebody must pay for its implementation, and the mandated requirement needs to be enforced, which also incurs a cost. Least cost measures to protect environmental flows of rivers and streams are another ongoing debate in New Mexico (Fernald et al. 2015, Ward et al. 2006) as well as internationally. Recently, billions of dollars have been spent in Australia for irrigation infrastructure improvements with the intent of making more flows available for the environment. However, in many of the sub basins of the Murray-Darling, little if any additional environmental flows have been made available (Loch et al. 2012). Subsidies of irrigation infrastructure can reduce water applied. Although, even if applications are reduced, it is not always clear that more water is available for the environment or other uses (Ward and Pulido-Velazquez 2008).

Several measures can promote water conservation. For example, partial root zone drying (PRD) is an irrigation method that could promote conservation by using alternating, directed-water applications to produce a staged, simultaneous, wet/dry cycle between both halves of a root system. In turn, a drought response will be stimulated, even as the plant receives adequate amounts of water to sustain photosynthesis. PRD has increased water-use efficiency and improved yields in some plants. However, to date there has been no research-grade work on its physical or economic potential for PRD pecan production, an important commercial crop in New Mexico (Othman et al. 2014). Urban water studies in New Mexico have also received attention for conservation opportunities. Measures that have been investigated include low-flush toilets, low-flow showerheads, subsidies of water saving appliances, and conversion from turf to xeriscape (Gutzler and Nims 2005).

Adaptation to Climate Stress Through Water Trading and Banking

Considerable interest has been expressed in New Mexico since 2010 in the development of practical water trading arrangements, such as implementation of water banks as a measure to move water to higher-valued uses for handling water shortages when they occur. When practiced, water banking typically involves forgoing water deliveries during some periods, then banking either the right to use the banked water in the future or saving it for someone else to use in exchange for a cash price or an in-kind delivery of water or other assets. Water's productive use increases when there is adequate surface or groundwater storage capacity to permit the water transfers to occur. A water bank can allow a water stakeholder group to meet long-term policy goals, often handed down

by state legislation or court order, while still protecting their local water, water rights, agricultural economies, endangered species, and more. This is often accomplished by creating a financial instrument that allows one water user to give up their short-term claim to the water in exchange for compensation with no loss of their long-term water right.

Two studies of farmers in the region downstream of Elephant Butte Reservoir conducted at New Mexico State University have found that the farmers of the region are interested in designing a water bank to prepare for future shortage. A survey from 2008 (Hadjigeorgalis 2008) asked 168 farmers a set of short, directed questions. The results indicated that more than 80% expressed interest in short-term water transfers with long-term rights protections, such as a water bank, could provide. An ongoing, intensive study, for which we are currently conducting hour-long, one-on-one farmer interviews, has reached similar conclusions. To better design a water bank that will meet the specific needs and goals of the region, we conducted an analysis of the water banking literature. From this work, the need for a theoretical framework by which to better analyze the success or failure of real world water banks has become clear.

The best framework would allow us to analyze water as a common pool resource, ground our findings in the localized economic uses and management of resources, and provide a comprehensive structure for analysis. Ostrom’s Eight Principles for Managing Common Pool Resources (Ostrom 1993) provided that framework, and also furnished us with a rigorously-researched, organizational scheme by which to elaborate upon the reasons for success of existing water banks. Having seen little application to describe common property management in a western country, we believe analysis through this framework would offer insights on water bank design.

Long-running banks with economic or goal-based success have several characteristics in common. They have strong ties to localized needs and economies, and they closely follow the model established by Ostrom with few exceptions. To illustrate, the Idaho State Water Bank has been through several well-documented changes in its nearly 50 years of operation, reflecting the kind of flexibility and localized control that Ostrom’s principles dictate. The Kansas State Bank naturally evolved to include specific rules for localized use in different hydrologic regions covered by the bank. The rules included local monitoring, penalties for non-compliance administered locally, and a strong conflict resolution mechanism. These water bank examples are mapped against Ostrom’s Eight Principles in Table 2.

Ostrom’s Eight Principles for Managing Common Property Resources Applied to Water Banking			
Principle (Ostrom 1993)	Idaho State Water Bank	Central Kansas Water Bank	Texas State Water Bank
1. Clearly defined boundaries.	✓	✓	X
2. Congruence between rules and locality.	✓	✓	X
3. Collective choice arrangements.	✓	✓	✓
4. Monitoring.	X	✓	X
5. Graduated sanctions.	X	✓	NC
6. Conflict resolution mechanisms.	✓	✓	X
7. Recognition of organization’s rights.	✓	✓	✓
8. Nested enterprises	✓	NC	NC
Key: has characteristic (✓), lacks characteristic (X), unclear (NC)			

Table 2: Ostrom’s Eight Principles for Managing Common Property Resources Applied to Water Banking

In contrast, the Texas State Water Bank has met numerous barriers in its short life. Although water is available for transfer, a brief investigation of the water listed on their web site as available in the marketplace shows the bank's important limitation: water is available in unconnected basins with little transferability. The state of Texas covers multiple topographies, climates, and types of water storage/delivery, separated by vast distances. This disconnection combined with the size of the state and Texas' different standards for surface and groundwater rights makes oversight difficult.

While research is ongoing, it appears at this early stage that Ostrom's Eight Principles are likely to provide guidance on the design of workable and practical water banking or trading arrangements for moving water to higher values when shortages occur. As a result, the effective cost of adapting to climate-stressed river systems will be reduced. In New Mexico, new long-term goals for water could be imposed by court decisions, legislation, or climate change. We conclude that designing a water bank to meet such goals, both in this region and elsewhere, using these principles has a greater chance to succeed.

Adaptation to Climate Stress Through Transboundary Aquifer Sharing

Sources of freshwater in Southern New Mexico suitable for municipal, industrial and agricultural uses are scarce. Additional population and economic growth and development will require either the transfer of water from existing, primarily agricultural uses, and/or procurement and development of costlier alternative sources. Beneath one thousand square miles of the desert sands of Southern New Mexico, far West Texas, and the northern state of Chihuahua, Mexico lies an estimated 65 million acre-feet of fresh to mildly brackish groundwater (Hawley 2017).

The Mesilla Basin (figure 1) is a valuable reserve of available water that is poised to be more heavily- used to serve domestic, agricultural, and industrial users across the region. Putting a conservative value of \$50/acre-foot reveals an in-situ value for the aquifer more than \$3.25 billion. Water values have been described for this region in existing studies (Ward et al. 2001, Hurd and Coonrod 2012), indicating this valuable regional asset can assist in providing important and sustaining services broadly across the community of users.

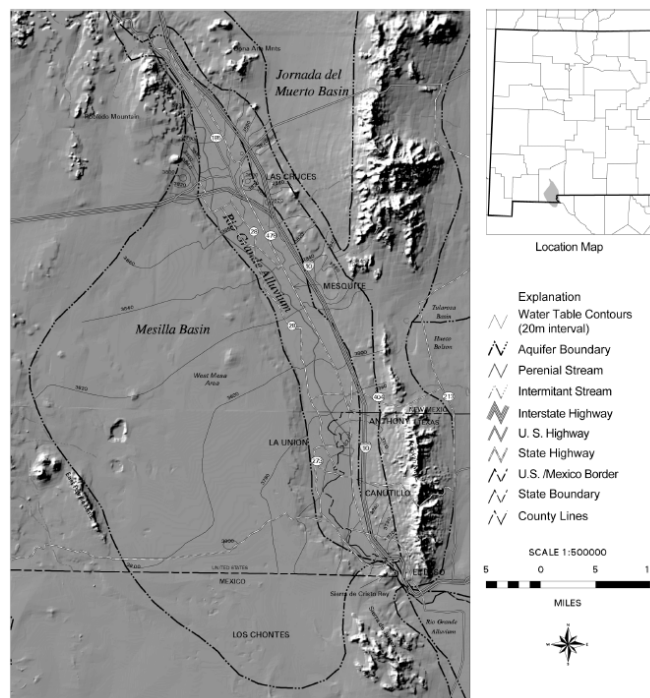


Figure 1: Shaded-relief index map of the Mesilla Basin area of Southern New Mexico and adjacent parts of Texas and Chihuahua showing extent of modeled basin-fill (Santa Fe Gp) and Mesilla Valley aquifer systems. Source: Hawley, Kennedy, and Creel. 2001, Figure 7-2.

Historically, a lack of management, cooperation, and oversight regarding access and use of this shared virtual ‘trust-fund’ can be seen. There is no treaty or governing agreement concerning sharing or joint management of the aquifer. Control and access is left to each of the three governing jurisdictions, states of Texas and New Mexico, and the federal government in Mexico. Indeed, shared-governance is further complicated by legal conflict and an on-going assertion by Texas that New Mexico pumpers are diminishing surface flows, in alleged violation of the Rio Grande Compact (New Mexico Office of the State Engineer 2018).

Recent changes on both sides of the US- Mexico border have accelerated pumping rates and contributed to rapidly falling water tables. North of the border, persistent drought coupled with significant institutional changes in 2008, has seen Mesilla Valley irrigators rely more heavily on pumping as their primary water source. In 2008, an accord was struck between the two US irrigation districts who share the surface waters of the Rio Grande Project. The settlement offered Texas irrigators directly downstream of New Mexico in the El Paso Water Conservancy District No. 1 a greater share of released project waters in exchange for affirming the groundwater pumping of New Mexico irrigators in the Elephant Butte Irrigation District. In effect, New Mexico irrigators exchanged their surface access for groundwater access as their primary water source in meeting their irrigation demands. This change improved surface reliability to Texas farmers and relieved New Mexico farmers from on-going legal threats from the Texas district. Moreover, it afforded New Mexico irrigators with a reliable and highly controllable water source.

Figure 2 illustrates effects of the settlement on groundwater levels from 2004 - 2015. The dramatic fall in the water table shows the extent to which Mesilla Valley farmers realized the opportunities of greater reliance on groundwater. These effects were especially pronounced because of the enduring drought that continued to affect the region. As a result, yields and production of most crops in the Mesilla Valley remained high or exceeded average levels in spite of the drought (New Mexico Department of Agriculture 2016).

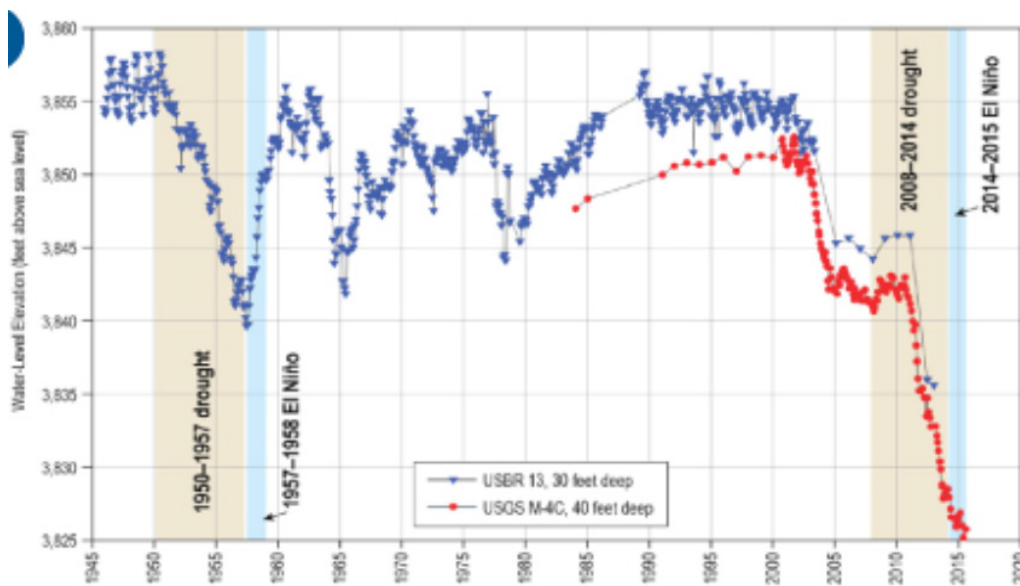


Figure 2: Water Table Trends in the Mesilla Basin (1946-2015)

Source: New Mexico Institute of Mining and Technology

South of the border, the changes have been even more dramatic and potentially consequential for users across the region. Beginning in 2010, Ciudad Juárez (a city of over 1.3 million) began drilling from 23 wells and pumping about 20 thousand acre-feet of water annually from the Mesilla Basin (on the Mexican side the aquifer is the Conejos-Médanos). This is about as much as the nearby city of Las Cruces, New Mexico pumps annually. The result has been an estimated drawdown of three feet per year in the aquifer below the well field just south of the border (Villagran 2017).

Economic development in the region is needed, on both sides of the border. Many residents live in at-risk and disadvantaged communities that lack access to safe and reliable water-services. Furthermore, these communities are vulnerable and ill-prepared to cope with growing risks of severe drought and climate change. The potential is high for mismanagement and misuse of this vital aquifer. This 'trust-fund' resource, for which insights for improved management could come from Ostrom's eight principles described earlier. Without rules, the stage is set for the unfortunate cooperative over-use and misguided exhaustion of this valuable resource, just as with any trust-fund account in rivalrous competition in the absence of rules and constraints.

Adaptation to Climate Stress Through Headwater Storage Capacity Development

Increased use of water for agriculture in support of protecting food security for growing populations is a growing issue worldwide. At the headwaters of the Lower Colorado Basin in New Mexico, the Gila River runs through very dry country. One of many remarkable historical events illustrates the point: Three German prisoners of war during WWII planned to escape to Mexico by taking their hastily assembled boat down the Gila River, then to the Colorado, and then into Mexico. It was a fine plan except for their ignorance of the Gila, which appeared as a wide blue river on their map. It turned out to be a dry streambed (Moore 2006). All were caught.

Continued evidence of climate stress at the headwaters of the Gila River New Mexico, in the Lower Colorado River Basin, raised interest in reservoir development as an old method with new possibilities under the Arizona Water Settlements Act of 2004. If developed, that new storage would increase water supply reliability. Like most other proposals for handling climate-stressed river systems, economic review takes on a vital role. These challenges are elevated in the face of climate stressed water supplies and growing demands for environmental flows in the Gila Basin, one of the last basins in the United States without storage developments at the headwaters. Climate-stress adaptation measures by farmers in this region include fallowing land, altering cropping patterns, elevated groundwater pumping, reservoir capacity expansion, reduced scale of acreage, and continued production of crops like cattle forage that can handle unreliable water supplies. Farm and urban water users in this basin have lived with a long history of high fluctuations in water supply producing a history of flooding as well as the need to adapt by producing low-valued crops that can handle unreliable water supplies, thus pointing to the need for an assessment of an investment in expanded storage capacity.

Recent work conducted by researchers at New Mexico State University reviewed the economic performance of storage reservoir development near the headwaters (Ward and Crawford 2016). A mathematical programming model was developed to predict irrigation patterns and potential farm income under two reservoir development scenarios. The first scenario was a status quo development plan with no new storage capacity. The second investigated additional storage capacity under which several existing institutional and technical barriers to producing higher-valued crops were removed.

That analysis found that storage capacity expansion in the basin's headwaters could lead to a higher-valued mix of irrigated agriculture combined with a more sustainable economic value of farm livelihoods. Results of that work show that compared to the first scenario, the second increased regional farm income by 30%. Some of the counties in that study would achieve farm income gains exceeding 900% relative to base levels.

The analysis found that added storage would be most economically attractive when technical and institutional barriers facing the region's irrigated agriculture are overcome. Important constraints that need to be dissolved include poor transportation capacity, small production scale, weak access by farmers to up-to-date information, limited capacity to bear risk, low levels of management skills, low and unreliable labor supply, and limited scale of food processing capacity. Removing most or all these barriers can elevate the economic value of additional irrigation capacity development in the Gila. Results of this work provide guidance to policy makers, farm managers, and water suppliers. All carry the burden of securing additional farm income and urban use benefits, protecting water and food security, and enhancing rural economic development in New Mexico as well as in dry places internationally faced with the need to adjust to climate-stressed water supplies. Similar analysis supporting policy debates of handling the food-water-energy nexus is ongoing worldwide (Bazilian et al. 2011, Conway et al. 2015, Ringler, Bhaduri, and Lawford 2013, Siddiqi and Anadon 2011).

Conclusions

Ongoing evidence of climate-stressed water supplies in many of the world's dry regions, including New Mexico, elevates the importance of finding low cost adaptation measures. The desire on the part of many of New Mexico's stakeholders to protect an acceptable amount of water in irrigated agriculture while ensuring enough affordable water is available for growing cities, is an important institutional requirement.

A core question posed by this article is how can water be managed so that the three competing sectors — agricultural, urban, and environmental — can simultaneously thrive in this stressed water system in both New Mexico and in the world's arid regions. New Mexico exemplifies an important category of agricultural water sustainability challenges. It is an arid to semi-arid river basin relying on conjunctive use of surface water and regional groundwater to sustain irrigated agriculture. Significant areas of the Western United States face similar challenges as do other intensively-used desert-river basins around the world.

This article has presented water lessons learned from New Mexico with international application. It has presented a series of water issues important both in New Mexico and internationally for which economic analysis can inform important debates over policy design and implementation. Economic information is essential information needed to guide efficient, equitable, and sustainable water futures for reducing the cost of adapting to climate water stress. The article gave special attention to three ongoing water issues in New Mexico: water trading, US-Mexico aquifer management, and capture of headwater flows to protect future water use when needed. All of these continue to face implementation challenges in the face of growing evidence of climate-stressed river systems.



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