Water Needs in the Next Decade

How Will Institutions Evolve to Meet Our Water Needs in the Next Decade?

55th Annual New Mexico Water Conference

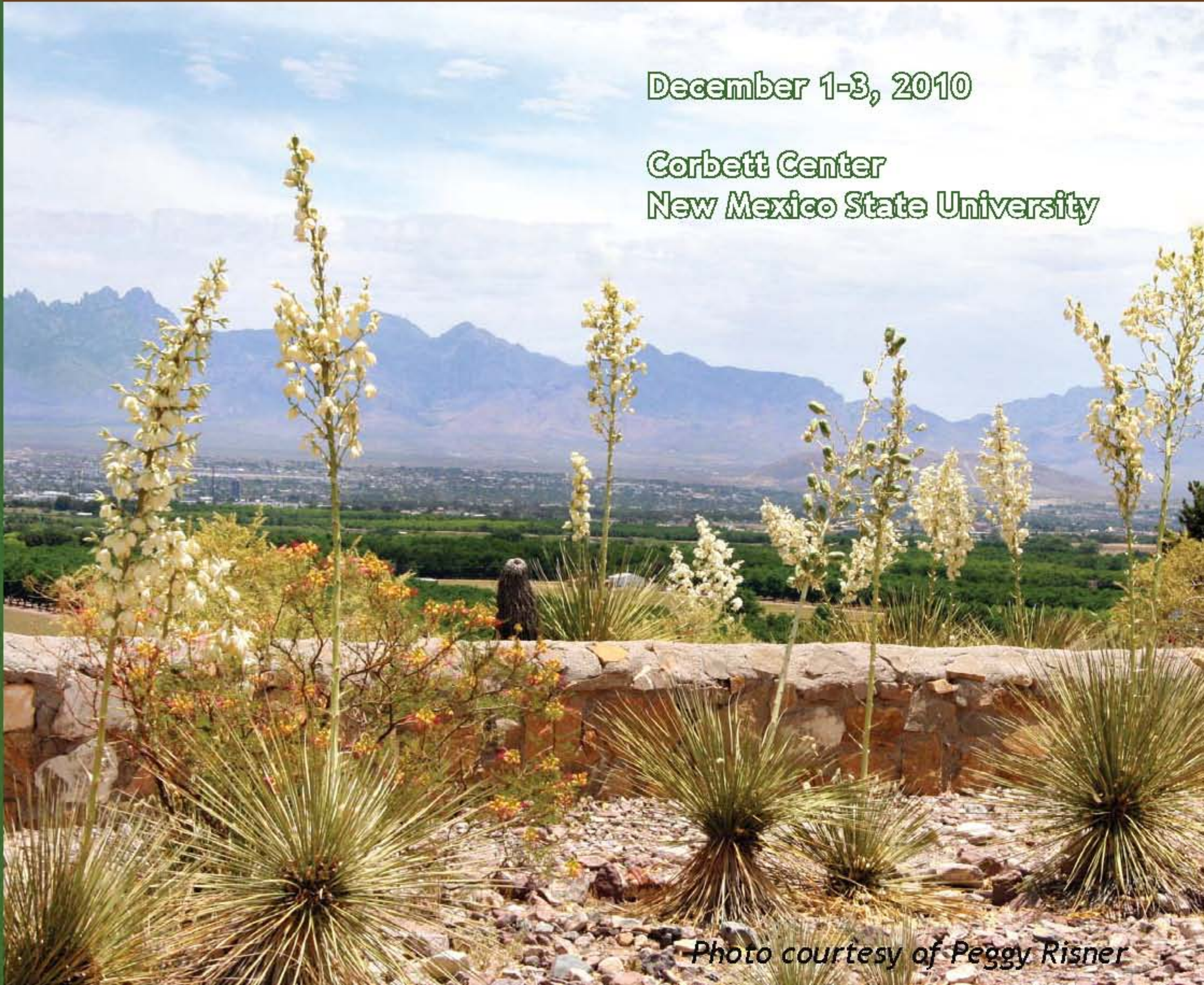


Photo courtesy of Peggy Risner

55th Annual
New Mexico Water Conference

NM WRRI Report No. 359

Water Needs in the Next Decade:

How Will Institutions Evolve to Meet Our Water Needs in the Next Decade?

Corbett Center
New Mexico State University

New Mexico
Water Resources Research Institute

In Honor of Bobby J. Creel

1943 - 2010

On February 15, 2010, the New Mexico Water Resources Research Institute lost a dear colleague, Bobby J. Creel. Dr. Creel began working for the NM WRRI in 1986 and served as Associate Director and Interim Director. Prior to working fulltime at the institute, he had worked on many institute projects starting in 1972. Throughout his career at NM WRRI, Bobby received nearly 60 grants and oversaw many projects, including the development of one of his favorite projects, the Geographical Information Systems Lab, which employed many students over the past decade. Having authored dozens of reports and complex maps, Bobby was involved in many water-related projects in the state and region. In the days following his unexpected death, the staff received many calls and emails with condolences of the great loss of a gentle person and friend who had great knowledge and insight into water resources management and planning in New Mexico. It was repeated many times that he was someone who could be counted on professionally. He will be greatly missed. To honor Bobby, the NM WRRI dedicates the 55th Annual New Mexico Water Conference to his memory.

I WISH I'D KNOWN BETTER

Now, this is a man; I wish I'd known better!
Some would say a friend, a teacher, and a mentor.
He left behind his nuggets of silver and gold.
Sharing his insights and the many stories he told.

Dedicated to his profession; a legend at WRRI.
The cornerstone of the institution and that's no lie!
Everything related to water he knew or was on GIS.
Not much he didn't know and rarely would he guess.

Quite the quintessential and renaissance true expert;
From his interdisciplinary, the knowledge would spurt!
Particularly, for those who relied on him on a daily fashion;
His knowledge of New Mexico water was his passion.

He was an eminent water resource research administrator
And could "think outside the box", a real catalytic motivator.
Turning challenges into opportunities; he'd fine the way
And still slip out with colleagues to eat at Dick's Café.

His love for the Southwest and its Mexican connection,
Instinctively drew consensus, common good and perfection.
Diplomacy, camaraderie and often a good cold beer,
Drew him closer to the transboundary aquifer he held so dear.

His manner was gentle, but underneath, his true grit,
Country humor and his good hearted nature truly did fit.
Riding tall in the saddle on his mountain-side ranch,
Anything found in his sights; had no fighting chance.

A few knew of his arsenal, guns and ammunition.
Priming shells and loading buckshot, a favorite ambition.
A prairie dog standing at 200 yards away,
An easy target for him, many friends would say.

Transforming from cowboy and hunter to mechanic at best;
Converting horse to engine power he could meet the test.
Working on his dune buggy, jalopy, or his favorite Corvette,
What came out from his man cave, no one could bet.

There was a man, Bobby Creel, I wish I'd known better!
From all that I've heard, a real die hard go getter.
Condolences and memories they all deserve their place.
In God's given time, perhaps to see him again, face to face.

Descansa en paz

Anonymous

TABLE OF CONTENTS

Dedication to Bobby J. Creel ii

Water Conference Advisory Committee vii

Conference Program viii

The Future of Water Adjudications
Judge Jerald Valentine, Third Judicial District Court 1

The Future of Water Adjudications in New Mexico
Greg Ridgley, Office of the State Engineer 9

Sandoval County Plans for Future Growth: Rio Puerco Desalination Plant
Guy Bralley, Sandoval County 17

Challenges When Combining Mutual Domestic Organizations to Meet Community and Colonias Water Needs
Martin Lopez, Lower Rio Grande Public Water Works Authority 25

Interbasin Transfer Projects: Impacts on Communities and Ecosystems
Bruce Thomson, University of New Mexico 31

How Santa Fe Plans to Meet its Growing Water Demands
Claudia Borchert, Sangre de Cristo Water Division. 39

Luncheon Guest Speaker
The Future of Our Water Agencies: Do We Have the Right Agencies Doing the Right Things?
Bill Hume, journalist and formerly with Governor Richardson's staff. 45

Permanent Storage at Elephant Butte: Meeting the Needs of Recreationists
Neal Brown, Marina Del Sur, Rock Canyon Marina and Damsite Resort at Elephant Butte Lake 49

The Benefits of Restoring Our River Ecosystems
Beth Bardwell, Audubon New Mexico 53

Sustaining Rivers through Instream Flows
Steve Harris, Far Flung Adventures and Rio Grande Restoration 59

Environmental Flow Issues and Science
Tom Annear, Wyoming Game and Fish Department 63

Innovations in Rural Wastewater Management - Decentralized Approach
Graham Knowles, New Mexico Environment Department 71

Increasing Institutional Resilience for Water Conservation
Frank Ward, New Mexico State University. 75

Agriculture in New Mexico
Aron Balok, Pecos Valley Artesian Conservancy District 79

Rainwater Harvesting and Recharge Techniques for Flood Control and Improved Stormwater Quality
Vaikko Allen, CONTECH Construction Products, Inc. 85

The Role of Decentralized Artificial Recharge Systems in Water Resources Management
Daniel B. Stephens, DB Stephens and Associates, Inc. 97

How Do We Deal with Our Aging Structures?
Bruce Jordan, U.S. Army Corps of Engineers 107

Dealing with Aging Tribal Water Infrastructure
Derrick Lente, Middle Rio Grande Conservancy District, Pueblo of Sandia 113

Water Rights Settlement Agreements in New Mexico: Institutional Change Underway
Elizabeth Richards, Sandia National Laboratories 117

Participant List 129

2010 Water Conference Advisory Committee and Representatives

Cecilia Abeyta, Farm Bureau

Hilary Brinegar, New Mexico Department of Agriculture

Peter Castiglia, INTERA

John D'Antonio, Office of the State Engineer

Gary L. Esslinger, Elephant Butte Irrigation District

Lt. Col. Kimberly M. Colloton, Army Corps of Engineers

April Fitzner, U.S. Army Corps of Engineers

Susan Fry Martin, Los Alamos National Laboratory

John Hawley, Hawley Geomatters

Matt Holmes, New Mexico Rural Water Association

Marcy Leavitt, New Mexico Environment Department

Fidel Lorenzo, Acoma Pueblo

Julie Maitland, New Mexico Department of Agriculture

Stephanie Moore, DB Stephens and Associates, Inc.

Nathan Myers, US Geological Survey

Bill Netherlin, Pecos Valley Artesian Conservancy District

Craig Runyan, New Mexico State University

Blane Sanchez, Interstate Stream Commission

John Shomaker, Shomaker and Associates

Karin Stangl, Office of the State Engineer

John Stomp, Albuq. Bernalillo County Water Utility Authority

Bruce Thomson, University of New Mexico

John C. Tysseling, e3c, Inc.

Linda Weiss, US Geological Survey

55th Annual New Mexico Water Conference Program

Water Needs in the Next Decade:
How Will Institutions Evolve to Meet Our Water Needs in the Next Decade?

Thursday Morning, December 2, 2010

8:30 am	Welcome by *Karl Wood*, WRRI Director, *Barbara Couture*, NMSU President, and video message by *Senator Tom Udall*
8:45	Tribute to *Bobby J. Creel*, Associate and Interim Director WRRI 1986-2010
9:00	The Future of Water Adjudications *Judge Jerald Valentine,* Third Judicial District Court *Greg Ridgley*, Office of the State Engineer
9:50	Sandoval County Plans for Future Growth: Rio Puerco Desalination Plant *Guy Bralley*, Sandoval County
10:15	Break
10:45	Challenges When Combining Mutual Domestic Organizations to Meet Community and Colonias Water Needs *Martin Lopez*, Lower Rio Grande Public Water Works Authority
11:15	Interbasin Transfer Projects: Impacts on Communities *Bruce Thomson*, University of New Mexico
11:45 pm	How Santa Fe Plans to Meet its Growing Water Demands *Claudia Borchert*, Sangre de Cristo Water Division
12:15	Luncheon
	The Future of Our Water Agencies: Do We Have the Right Agencies Doing the Right Things? *Bill Hume*, journalist and formerly with Governor Richardson's staff
1:30	Permanent Storage at Elephant Butte: Meeting the Needs of Recreationists *Neal Brown*, Marina Del Sur, Rock Canyon Marina and Damsite Resort at Elephant Butte Lake
2:00	The Benefits of Restoring Our River Ecosystems *Beth Bardwell,* Audubon New Mexico
2:30	Sustaining Rivers through Instream Flows *Steve Harris*, Far Flung Adventures and Rio Grande Restoration
3:00	Break
3:30	Environmental Flow Issues and Science *Tom Annear*, Wyoming Game and Fish Department
4:00	Innovations in Rural Wastewater Management - Decentralized Approach *Graham Knowles*, New Mexico Environment Department

Friday, December 3, 2010

8:30 am	Increasing Institutional Resilience for Water Conservation *Frank Ward*, New Mexico State University
9:00	Agriculture in New Mexico *Aron Balok*, Pecos Valley Artesian Conservancy District
9:30	Rainwater Harvesting and Recharge Techniques for Flood Control and Improved Stormwater Quality *Vaikko Allen*, CONTECH Construction Products, Inc.
10:00	Break
10:20	Role of Artificial Recharge in Conjunctive Water Management *Daniel B. Stephens*, DB Stephens and Associates
10:50	How Do We Deal with Our Aging Structures? *Bruce Jordan*, U.S. Army Corps of Engineers
11:10	Dealing with Aging Tribal Water Infrastructure Derrick Lente, Middle Rio Grande Conservancy District, Pueblo of Sandia
11:30	Water Rights Settlement Agreements in New Mexico: Institutional Change Underway *Elizabeth Richards*, Sandia National Laboratories

The Future of Water Adjudications

Judge Jerald A. Valentine, Third Judicial District Court

Judge Valentine has been the presiding judge in the Lower Rio Grande Adjudication since 1995. He is a native New Mexican and earned a BS in mechanical engineering from NMSU and a law degree from the University of Texas, Austin. Judge Valentine has been District Judge, Division IV, 3rd Judicial District Court since 1993 and Chief Judge, 3rd Judicial District Court from 1999-2002, and again from October 2008 to the present. He is a contributor to the soon to be published book, One Hundred Years of Water Wars in New Mexico 1912-2012. This book is part of the New Mexico Centennial History Series and Judge Valentine has contributed a chapter on "Managing Water Wars in New Mexico."

The following is an outline of Judge Valentine's presentation.

Schema of the Water Code

Statutory Procedure: (Surface Water Code [Code] effective 1907. Before the Code, diversion and application to beneficial use established the priority and other elements of the right)

Administrative duties of Office of the State Engineer (OSE).

The state engineer is an expert not a litigant

1. Permit process through license

A. Application

§72-5-4. Notice; publication, opportunity for others to object.

B. Objections

C. Evaluation

The state engineer "shall determine,"from the evidence presented by the parties interested, from available surveys of the water supply and from the records, whether there is unappropriated water available

§72-5-7. If there is no unappropriated water available, state engineer rejects application.

D. Deadlines

E. Licenses

§72-5-13. (1907)

If the state engineer determines there is unappropriated water and accepts the application, on or before the date set for the application of the water to a beneficial use, the state engineer inspects the diversion works.

The state engineer shall issue a license to appropriate water to the extent and under the condition of the actual application to beneficial use, but in no manner extending the rights described in the permit.

Before the 1907 Water Code

The 1912 New Mexico Constitution declared unappropriated water of every natural stream to belong to the public and to be subject to appropriation for beneficial use. Priority of appropriation will give the better right. For New Mexico, this did not establish new water law but merely incorporated the existing "prior appropriation doctrine" which pre-dated the Constitution.

To establish a water right, claimant would divert unappropriated water and apply for beneficial use. No governmental approval required. There was no express law authorizing adjudications. Water disputes generally arose between conflicting claims of specific water users and did not require joinder of all claimants on a stream system. The prior appropriation doctrine did require, in a manner similar to the subsequent code, "diligent prosecution to completion of the necessary surveys and construction for the application of the water to a beneficial use." NMSA §72-1-2.

State Engineer's Permitting Process After the Surface Water Code of 1907

The Code established the Office of the Territorial (now State) Engineer and authorized the state engineer to supervise the apportionment of water belonging to the public "according to the licenses issued by him and his predecessors and the adjudications of the courts." NMSA §72-2-9 (1907).

After the Surface Water Code became law, anyone who wanted to acquire a water right in unappropriated water had to file an application for a permit with the state engineer NMSA §72-5-1.

When he receives the application, the state engineer must first make an administrative determination that there is unappropriated water. §72-5-7. He must also determine if the proposed appropriation is not contrary to the conservation of water within the state and is not detrimental to the public welfare of the state. NMSA §72-5-6.

The permitting process includes publication of notice of the application and an opportunity for other water right claimants to object to the state engineer's issuance of a permit. NMSA §72-5-4 and §72-5-5.

If the state engineer finds that there is unappropriated water that can be applied to beneficial use by the applicant, he will issue a permit and the permit will authorize the applicant to prepare diversion works to divert water up to a maximum amount stated in the permit. NMSA §72-5-6.

On or before the date set for the application of the water to a beneficial use, the state engineer must inspect the diversion works and, if appropriate, he will issue a license for the applicant to appropriate water for application to beneficial use up to a maximum of the rights described in the permit. The licensed right could be less than that described in the permit. The amount stated in the permit establishes a ceiling. NMSA §72-5-13. Although the Water Code indicates that the licensing process is mandatory, relatively few licenses have been issued by the state engineer.

A similar permitting process for underground water exists. §72-12-1 et seq. In a hydrologically connected stream system, the state engineer manages surface stream water and underground stream water conjunctively as one stream. §72-5A-2. See *Montgomery v. Lomos Altos, Inc.*, 2007-NMSC-002, 141 N.M. 21, 150 P. 3d 971 (2006).

Statutory Duties of the State Engineer

All natural waters flowing in streams and watercourses, whether such be perennial, or torrential, within the limits of the state of New Mexico, belong to the public and are subject to appropriation for beneficial use. §72-1-1.

For water right claims before the date of the Surface Water Code, the water right relates back to the initiation of the claim. All water right claims initiated thereafter will be the date of the receipt of an application filed with the Office of the State Engineer in compliance with the Water Code and the rules and regulations that are established. §72-1-2.

When an owner conveys the water right to another, the new owner of the water right must file a change of ownership form with the state engineer. 72-1-2.1.

Any owner of a water right that was vested prior to the Surface Water Code, may file a declaration in the Office of the State Engineer describing the water right. §72-1-3.

The state engineer has general supervision of waters of the state and of the measurement, appropriation, and distribution plus other duties as required. §72-2-1.

The state engineer has the supervision of the apportionment of water in this state according to the licenses issued by him and his predecessors and the adjudications of the courts. §72-2-9.

The Office of the State Engineer must purchase, install, and study prototypes of alternative devices that accurately measure the flow of river water. §72-2-9.2.

The state engineer has authority and power to formulate rules and regulations. The state engineer promulgates rules and regulations with regard to hearings to be conducted before examiners. §72-2-12.

The state engineer may and in some circumstances must appoint a water master for water districts. The water master has charge of the apportionment of waters in the district under the general supervision of the state engineer, and the water master shall so appropriate, regulate, and control the waters of the district to prevent waste. §72-3-2.

The state engineer hears appeals from the acts or decisions of the water master, his decision is final unless an appeal is taken to the district court. §72-3-3.

To get a water right after the Surface Water Code, a person has to apply for a permit. The filing of an application for a permit initiates specific administrative duties of the state engineer. §72-5-1 et seq. and §72-12-1 et seq.

Any applicant or other party dissatisfied with any decision, act, or refusal to act by the state engineer may appeal to the district court of the county in which the work or point of desired appropriation is situated. The proceeding upon appeal is *de novo* as cases originally docketed in the district court. Evidence taken in a hearing before the state engineer may be considered as original evidence subject to legal objection, the same as if the evidence was originally offered in the district court. §72-7-1, Art. XVI, Section 5, New Mexico Constitution. The courts therefore are the final arbiters that determine the water right.

Adjudications

The state engineer is directed to make hydrographic surveys and investigations of each stream system for the determination, development, and adjudication of water supply for the state. NMSA §72-4-13. Under the Water Code as drafted, the state engineer has limited involvement in an adjudication. He must prepare and file a hydrographic survey and request that the attorney general file an adjudication. Implicitly the state engineer is the state's expert. When a hydrographic survey is completed, the state engineer will deliver a copy of the survey to the attorney general who brings an adjudication suit on behalf of the state for the determination of all rights to the use of such water and to determine the amount of unappropriated water. NMSA §72-4-15.

This has been modified in practice. The attorney general does not prosecute an adjudication. He appoints the legal staff of the Office of the State Engineer as deputy attorneys general. Regardless of the legal effect of the attorney general deputizing state engineer legal staff, the Office of the State Engineer typically files adjudications, not the Attorney General ex rel. for the State of New Mexico. The Water Code directs that the attorney general file adjudications on behalf of the State of New Mexico when the state engineer requests the adjudication and files a copy of a hydrographic survey. In actual practice, it is the state engineer who is the plaintiff. The only action taken by the attorney general is to deputize the state engineer's legal staff.

General Stream Adjudications require joinder of "all those whose claim to the use of such waters are of record and all other claimants, so far as they can be ascertained, with reasonable diligence. . . ." NMSA §72-4-17.

When the Court has adjudicated the water rights, the clerk of the Court must prepare and file a certified copy of the decree in the Office of the State Engineer. The decree declares the priority, amount, purpose, periods, and place of use, and as to water used for irrigation, the specific tracts of appurtenant land. §72-4-19.

Purpose of Adjudications

1. To determine if there is unappropriated water on a stream system (The Lower Rio Grande [LRG] stream system is considered to be "over appropriated" but this has not been legally determined. Over-appropriation may be the case for most stream systems in New Mexico.)
2. To give the state engineer the information necessary to supervise and manage the public waters. (The state engineer can also supervise the public waters by licenses.)
3. To adjudicate and clear the title of individual water rights.

Completed adjudications will give the state engineer the fundamental information necessary for him to supervise and manage our public waters. They will materially reduce the possibility of New Mexico being sued by another state or other sovereigns for their equitable share or treaty share. They will reduce uncertainty of ownership, priority, and quantity and other elements of a water right. Water right owners who want to sell their rights and purchasers of those rights will have substantially better information that should simplify the water rights market.

Territorial and state engineers have not always followed the procedures set out in the Water Code.

Lessons Learned from the Lower Rio Grande Adjudication

1. Train the judge

   Water law

   Complex cases

   Great concern with constitutionally required due process when there are thousands of litigants

2. Train the OSE lawyers

   Need consistency as judges change and OSE legal staff change

3. Better integration of data

   A. Internally the OSE needs better integration of data between administrative activities and adjudicatory activities

   B. Between the Court and the OSE

4. Pre-adjudication suit education of water users

5. Judge has the duty to control the pace of litigation and must have case management orders in place for that control

6. The Code requires the hydrographic survey before suit is filed (controversial; there should be some formal way to bring the Court in before and during the hydrographic survey so that the Court can begin development of case management orders)

Issues

1. Pace of the adjudication

2. Evaluation of resources needed both by the OSE and the Court

What Can be Done to Expedite and Control the Pace of Litigation

1. Should all parties be joined immediately?

2. Should stream system be segmented by geography, water shed or common issues?

3. Should sub-file adjudication be done in small batches?

4. How and when should legal issues be addressed by the Court?

Recommendations for the Middle Rio Grande Conservancy District (MRGCD)

Before an adjudication is filed:

1. OSE and MRGCD work to coordinate information in their respective databases

2. Require that wells, including domestic wells, be metered

3. Begin an intensive educational program for anticipated *pro se* parties

4. Fund and expand the Stell Ombudsman Program

5. To the extent practicable, within available budget, and without delaying an adjudication, the OSE should investigate permitted usage and issue licenses

6. With input from hydrologists, divide the stream in coherent sections based on watershed or common or similar issues; these divisions should be large to include 5,000 to 15,000 users; schedule adjudications for each of these divisions so that the entire MRGCD Adjudication could be completed within 15 or fewer years.

If the legislature can provide adequate resources.

1. Work with legislature for adequate funding for hydrographic surveys and adjudications

2. Bifurcate the hydrographic surveys

   A. Identify addresses of water users; join all users in each section promptly even before the hydrographic survey is completed and filed

   B. Encourage water right users to file claims with adequate description of the parameters of the claim

   C. Identify stream system issues as soon as they can be reasonably done; the Court should take the lead and encourage identification and focus the description of the stream system issue

   D. The state engineer should make prompt field surveys of current usage, encourage water right users to come forward with a description and information regarding their claims and the state engineer should issue licenses when appropriate

The state engineer should evaluate needed resources and plan to do hydrographic surveys on sections or sub-sections into which the stream system has been divided as swiftly as possible. The OSE should serve offers of judgment in sub-sections to claimants as soon as a section or sub-section of the hydrographic field survey is completed to minimize the possibility of the hydro-survey becoming stale.

Tri-State Generation and Transmission Association, Inc. et al. v. John D'Antonio, Jr. NM St Engr

Constitutional Separation Challenge to Sec. §72-2-9.1.

§72-2-9.1 Priority administration; expedited water marketing and leasing; state engineer. (2003)

A. The legislature recognizes that the adjudication process is slow, the need for water administration is urgent, compliance with interstate compacts is imperative, and the state engineer has authority to administer water allocations in accordance with the water right priorities recorded with or declared or otherwise available to the state engineer.

B. The state engineer shall adopt rules for priority administration to ensure that authority is exercised:

(1) so as not to interfere with a future or pending adjudication;

(2) so as to create no impairment of water rights, other than what is required to enforce priorities; and

(3) so as to create no increased depletions.

C. The state engineer shall adopt rules based on the appropriate hydrologic models to promote expedited marketing and leasing of water in those areas affected by priority administration. The rules shall be consistent with the rights, remedies, and criteria established by law for proceedings for water use leasing and for changes in point of diversion, place of use and purpose of use of water rights. The rules shall not apply to acequias or community ditches or to water rights served by an acequia or community ditch.

D. Nothing in this section shall affect the partial final decree and settlement agreement as may be entered in the Carlsbad Irrigation District Project offer phase of *(State of New Mexico ex rel. State Engineer v. Lewis, et al.,)* Nos. 20294 and 22600 (N.M. 5th Jud. Dist.).

Court of Appeals Held

"The New Mexico Constitution contains nothing to indicate that determination of the elements of water rights is consigned exclusively to the judicial branch; it merely provides for *de novo* review."

Referring to Water Code, the Court of Appeals said,

". . . Statutory authority enables the State Engineer to determine certain elements of water rights as part of this supervision."

§72-2-9.1 does not grant additional authority for the state engineer to administer water allocations. "We infer that the legislature believed that the State Engineer already had the necessary authority to adopt rules." And the legislature did not need to expand upon the state engineer's authority.

None of the statutory provisions nor any published decision addressing them suggests that the state engineer has authority to engage in an *inter se* process or to determine priorities for the purpose of curtailing rights from evidence other that adjudication decrees or licenses.

Licenses are issued in the final stage of the water right permitting process, which involves an initial application to the state engineer publication of the application, a protest period, evaluation by the state engineer, an administrative hearing, and an appeals process to the courts.

There can be no administration of junior rights as against senior rights until the parties have had an opportunity to contest priorities *inter se*.

Case Management Orders

Sixth Amended Order (Order) Regarding Stream Adjudication Procedures filed September 14, 2009

The first case management, entered by the Court in the Lower Rio Grande Adjudication, set out sub-file procedures. A seventh iteration of the original case management order is now in effect. The procedure is designed to ease the uncertainty and concern of claimants who do not have attorneys to assert their individual claims. It gives individual claimants the option to combine with other claimants to minimize costs. It requires the state to notify the Stell Ombudsman Program and for the Program to contact claimants to provide them with information important to the assertion of the claimants' rights. It provides for simplified forms to respond to the service of the complaint, and explains the consequences of failing to respond.

This Order covers both sub-file and *inter se* proceedings, and controls when specific water rights are to be determined. The Order begins with definitions of terms. It defines stream system issues, *inter se* proceedings and expedited *inter se* proceedings. The Rules of Civil Procedure apply except as expressly modified.

The Order provides for simplified forms for water right claimants to use when served with a summons and complaint; coordination with the Stell Ombudsman Program; the state to make offers of judgment that are the state's proposal to stipulate to claimant's water rights; explanation of stipulated sub-file orders, sub-file orders-implied consent and sub-file orders-default; directions to claimants regarding objections to the offer of judgment; explanation that claimants can negotiate with the State to determine whether their water rights can be resolved by stipulation; direction to mediate through the Court-annexed mediation program if initial negotiations are unsatisfactory; trial before either a special master or a judge, if the claimant cannot resolve issues by mediation with the state; and explanation that stipulated sub-file orders, implied consent sub-files and default sub-files are not appealable or modifiable except as permitted under Rule 1-060 (b) NMRA, or as may be necessary after *inter se* issues are decided.

The Order further provides that several parties may be represented by one attorney if there is no conflict of interest; corporate entities may answer and file updates of their address and ownership records without an attorney and, when a corporate entity wants the Court to take action or grant relief, it must retain an attorney. Individual claimants may form an independent, non-governmental, voluntary, corporation or other appropriate corporate entities to act on behalf of its members to resolve issues between its members and the State. There must be written confirmation that its members have authorized the corporate entity to act on their behalf.

First Amended Case Management Order for Stream System Issues and Expedited Inter Se Proceedings Authorizing Notice by a Monthly Report and Setting Procedures, filed September 14, 2009.

The Court has entered a case management order addressing service of process. This case management order is on its second iteration. The ordinary rules of civil procedure require service by first class mailing after parties have been joined. When motions on stream system issues are filed, the cost of mailing notice to all claimants would be high. The state engineer has identified the names and addresses of almost all of the water right claimants in the hydrographic survey. First class mail should be sufficient for due process.

This Order provides for notice to claimants through a quarterly report for matters of general concern to the adjudication, stream system issue proceedings and expedited *inter se* proceedings. The Order explains how a stream system issue or expedited *inter se* proceeding may be initiated. The quarterly reports are posted on the New Mexico judiciary's website, www.nmcourts.gov (click on Lower Rio Grande Adjudication). The posting of the quarterly report and the posting of documents on the website is effective service on all claimants.

Parties must file timely notices of intent to participate in stream system issue proceedings. Lists of parties with their addresses, who have filed notices of intent to participate, are published on the website. The ordinary rules of civil service of documents apply to parties participating in a stream system issue proceeding. A final decision by the Court on a stream system issue, or in an expedited *inter se* proceeding, will bind all parties whether or not they have participated in the proceeding.

To date, four stream system issue proceedings have commenced. There are approximately 30 parties participating in each of the following stream system issue proceedings.

SS 97- 101: Consumptive Irrigation and Farm Delivery Requirements for All Crops in the Lower Rio Grande Basin.

SS 97-102: Elephant Butte Irrigation District's Claim to Underground Waters on 90,640 Acres of Its Members' Lands.

SS 97-103: Priority, Transferability, and Beneficial Use Elements of a Domestic Well Water Right.

SS 97-104: The United States Interests in the Stream System.

SS 97-101 has been set for trial June 6, 2011. The Court has recently received notice that SS 97-102 has been resolved by stipulation. Scheduling deadlines are currently being considered in SS 97-103. SS 97-104 has been partially stayed pending mediation.

The Order provides an opportunity for all claimants to participate in stream system issue proceedings, but has the practical effect of reducing the number who will actually participate to those represented by knowledgeable attorneys, or parties who are familiar with rules of litigation. Participating parties must follow the rules of civil procedure with respect to other participating parties. The Order provides an inexpensive method of giving notice to claimants who are not participating parties by posting activity on the judiciary's website. This protects the due process rights of those who choose not to participate and will greatly reduce the cost of service, and will allow the Court to ensure that stream system issues are resolved promptly.

Order for a Hydrology Committee

In 1999, the State of New Mexico, Elephant Butte Irrigation District (EBID), the United States, the City of Las Cruces, the City of El Paso, New Mexico State University, joined by Stahmann Farms, Inc. and Amicus Curiae El Paso County Water Improvement District No. 1 established a hydrology committee. The purpose of the committee was to promote cooperation among the parties and their experts and to provide technical assistance to the parties. The protocol expressly provided that the hydrology committee would not act as a technical advisor to the Court.

The Court has recently entered an Order for the hydrology committee that materially changed the function of the committee. The committee will now operate in a manner similar to a court expert as described in Evidence Rule 11-706, NMRA. The changes to the hydrology committee were based on procedure and rules adopted by the Colorado Supreme Court. Any party may name, but is not required to name, a hydrologist to the committee.

The members of the hydrology committee must disclose their expert reports to each other and discuss the matters of fact and expert opinions. Thereafter, they jointly submit to the presiding judge a written statement setting forth the disputed matters of fact and expert opinion that remain for trial. No claimant is required to name an expert to the committee. Any claimant may retain an expert, who need not be a member of the hydrology committee, to testify at trial.

The hydrology committee should narrow the issues that need to be addressed by the Court. This Order encourages parties' experts to have open discussion on matters that require the expertise of hydrologists and to advise and explain hydrology issues to the Court that are actually disputed. This should reduce the overall expense litigating complex hydrological questions.

Most duties of the state engineer are administrative functions, and he can supervise the apportionment of water in this state according to the licenses issued by him administratively. The state engineer may also supervise the apportionment of water according to adjudications.

Why does the Code allow the state engineer to alternatively select either licenses or adjudications?

Other water right claims may assert an earlier priority date or larger quantity that may be adverse to licensed water right holders. Therefore, they have a right to challenge administratively determined licenses. Adjudications provide the mechanism to assert that right.

The state engineer has the administrative duty to make hydrographic surveys and investigations of each stream system and source of water supply in the state, beginning with those most used for irrigation, and obtaining and recording all available data for the determination, development, and adjudication of water supply of the state. NMSA §72-4-13. Although there is no reference to when the surveys should be done, hydrographic surveys on all stream systems in New Mexico are mandatory. Nevertheless, state engineers have delayed initiating hydrographic surveys and in some cases have actively resisted attempts require the state engineer to make the surveys.

The hydrographic surveys are the evidentiary basis for court adjudications to determine water rights on the stream system. NMSA §72 4 15.

As the Code is drafted, when the state engineer completes a hydrographic survey of a stream system, the state engineer delivers a copy of the survey to the attorney general, who, when requested, will begin an adjudication suit on behalf of the State. The adjudication is to determine ownership of water rights in the stream. When these rights are determined, the state engineer will know the amount of unappropriated water subject to appropriation and can supervise the public waters the apportionment of water.

Modifying this procedure, the attorney general deputizes the legal staff of the Office of the State Engineer and they prosecute the adjudication. Most water disputes filed in District Court are brought as State, ex rel. state engineer, or a variation. This is the correct form if the state engineer is the party. Regardless of the legal affect of the attorney general deputizing the state engineer's legal staff, the overwhelming majority of water right claimants know that the state engineer's legal employees are prosecuting the adjudication and perceive that the state engineer is an adversarial plaintiff and not just an expert.

An interpretation of the Code as originally written is that the state engineer is an expert for the state, not the real party in interest.

The Future of Water Adjudications in New Mexico

Gregory C. Ridgley, Office of the State Engineer

Greg is the Deputy Chief Counsel for the New Mexico Office of the State Engineer, where he coordinates the work of the hydrographic survey staff and Special Assistant Attorneys General of the OSE Litigation and Adjudication Program who represent the State of New Mexico in the 12 water rights adjudication suits currently pending in New Mexico's state and federal courts. During his 12 years at the OSE, he has worked with Indian Pueblos and Nations, federal agencies, local governments, acequias, and private individuals to resolve water right claims through negotiation or litigation. He received his BA from Harvard University in 1984, and his JD from the University of California, Hastings College of the Law in 1992. He lives with his wife and two spirited teenagers in Santa Fe. In addition to cheering for his kids on field and stage, he roots for the Boston Red Sox and San Francisco Giants.

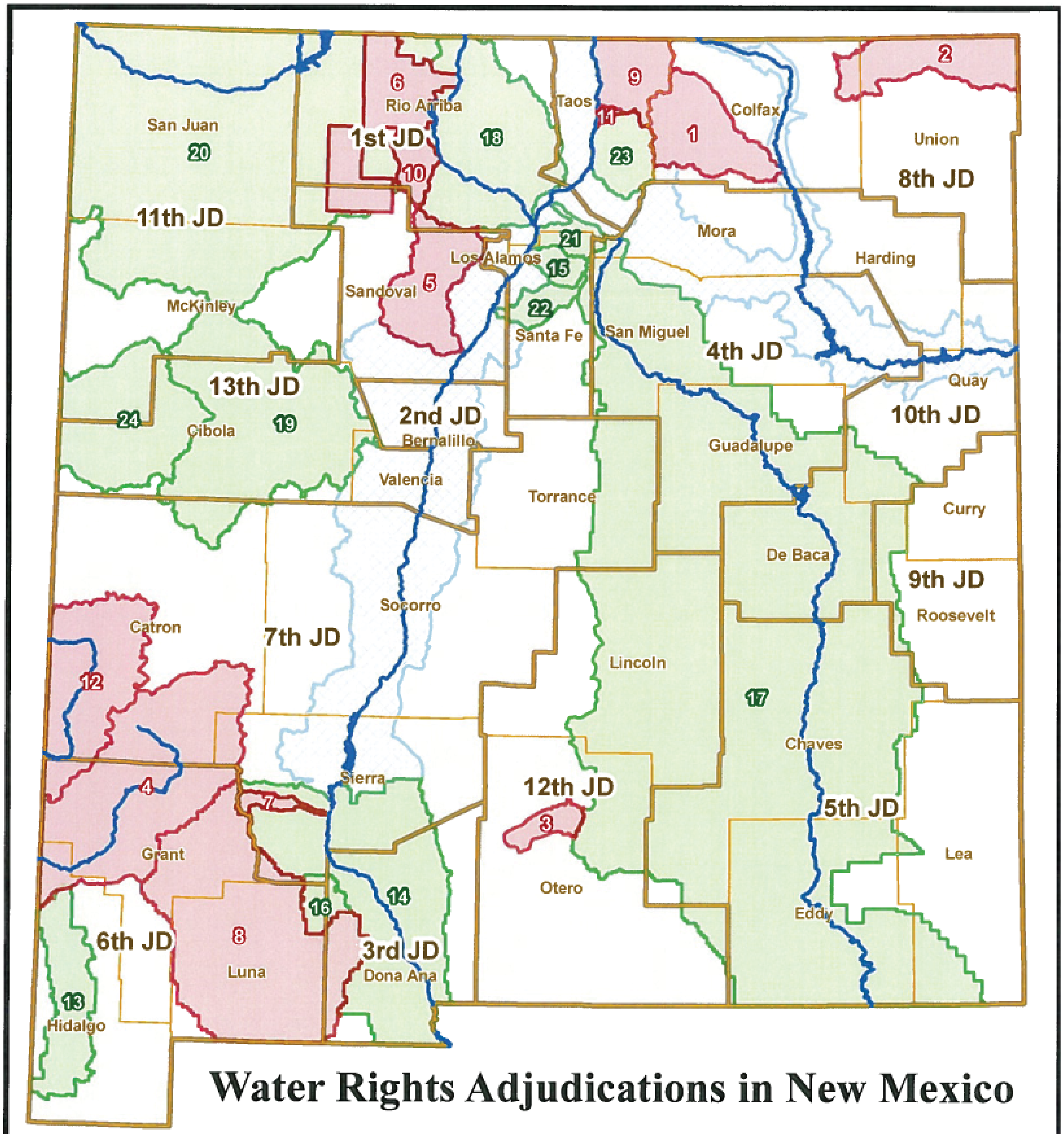
Good morning. Before I start, I first would like to say a word of thanks to Judge Valentine. We just heard that the Judge is retiring at the end of the year, after presiding over the Lower Rio Grande water rights adjudication for over a decade. I have appeared before Judge Valentine myself many times. I have also worked with Judge Valentine on many matters relating to adjudications over the years, and I've always appreciated the strength of his commitment to improving adjudications in New Mexico, and his tireless efforts to do so. So I would like to thank him on behalf of all New Mexico water right owners – and all the citizens of the state – for his distinguished service in this challenging but very important field. Thank you, Judge.

As we all know, New Mexico state government is in an era of tight budgets. Today I will discuss what that means for water rights adjudications. The resources available to work on adjudications will be the most important factor in the next few years on how much progress we make in these cases. I will address four specific topics today: first, provide a brief overview of adjudications; second, review the budget of the Litigation and Adjudication Program (LAP) of the Office of the State Engineer (OSE) and what that means in terms of people and other resources available to work on adjudications; third, introduce the annual Rule 71.3 Report, which describes the State's priorities and resource allocations for pending water rights adjudications in the coming fiscal year; and finally, wrap up with a brief discussion of lessons we have learned from our experience prosecuting adjudications and how we can work smarter to achieve lasting incremental progress in adjudications.

Adjudications Overview

In the handouts we passed out you should have received a copy of this map (Fig. 1); on the back of the map you'll see there is a chart presenting some summary statistics (Fig. 2). These provide a very high-level overview of water rights adjudications in New Mexico. The map shows in red adjudications that over the years have been completed to a final decree, and in green the adjudications that are currently pending. There are 12 water rights adjudication suits pending today in the state and federal courts, half in the state courts and half in the federal courts.

Let me take a moment here to explain what a water rights adjudication suit is, because I don't think this is always clearly understood. Although adjudications get a fair amount of attention from the press and the legislature, the public is often unclear on the difference between adjudications and other litigation involving water rights. The State Engineer supervises the appropriation of the waters of the state largely through permits that he issues. If someone is unhappy with the permit they receive then they can request an administrative appeal before the State Engineer, and if they don't like that decision then they can appeal that to the district court. We have attorneys and hydrologists and other technical staff who work on those



Completed Adjudications

Number	Name
1	Cimmaron / Rayado
2	Dry Cimmaron
3	Fresnal / La Luz
4	Gila River
5	Jemez non-Indian
6	Jiccarilla Apache
7	Las Animas Creek
8	Mimbres Basin
9	Red River - Cabresto Creek - West Latir
10	Rio Gallina
11	San Cristobal
12	San Francisco

Active Adjudications

Number	Name
13	Animas Valley
14	Lower Rio Grande
15	Nambe / Pojoaque / Tesuque
16	Nutt - Hockett
17	Pecos
18	Rio Chama
19	Rio San Jose
20	San Juan
21	Santa Cruz / Truchas
22	Santa Fe
23	Taos / Hondo / Grande
24	Zuni

Legend

- Streams
- County
- NM Judicial Districts
- Completed Adjudications
- Active Adjudications
- Stream Systems for Future Adjudication

Figure 1. Map of New Mexico water rights adjudications

appeals from State Engineer permits, and those appeals can involve litigation in district court, but those suits are not adjudications. Adjudications are distinct, specialized legal proceedings in district court to comprehensively determine all water rights in a given stream system. Whereas the parties to an appeal of a State Engineer permit are typically the permittee, the State Engineer, and perhaps a handful of protestants, the parties to a water rights adjudication are the hundreds or thousands of owners of water rights in the stream system being adjudicated.

Figure 2 shows just how large these suits are: the 12 pending adjudications have a combined total of around 72,000 defendants. These are big and cumbersome cases, and they take a lot of time as a result. The Pecos is by far the largest in terms of geographic area, while the Lower Rio Grande has the largest number of defendants and water rights involved. Figure 2 shows the differences in the number of defendants in each of the 12 suits. These suits also vary greatly in terms of age – the Pecos adjudication has been pending for over 50 years, while the Animas, the newest, is only a few years old. The handout also provides statistics on the number of acres and subfiles adjudicated in each case that show the varying stages of completion of the different suits.

Figure 1 shows the locations and different geographic areas covered by the 12 pending adjudications. Probably the most notable thing shown on this map is something that Judge Valentine mentioned: there is no adjudication currently pending for the Middle Rio Grande. The area cross-hatched in blue on the map along the Rio Grande from Cochiti down to Elephant Butte shows the likely geographic scope of a future Middle Rio Grande adjudication. Periodically over the years we have heard calls to initiate this adjudication. There is no debate that it is the most significant area of the state where an adjudication suit has yet to be filed. When it is eventually started it will be the most challenging and resource demanding adjudication New Mexico has ever attempted. It is precisely because it will demand so many resources that the State Engineer and his Chief Counsel DL Sanders and I have consistently made clear in our public statements over the years that we need to finish several of the currently pending adjudications before we will have the resources available to be able to take on a new adjudication of the magnitude of the Middle Rio Grande.

When discussing the progress that New Mexico has made in adjudications, an estimate frequently cited is that about 20 percent of water rights in the state have been adjudicated. I think that estimate is too low. On the map in Figure 1, the completed adjudications shown in red cover about 20 percent of the geographic area of the state that needs to be adjudicated. Beyond these completed adjudications, the only geographic areas of the state left to be adjudicated are the 12 pending adjudications shown in green and the areas for future adjudication shown in blue cross-hatching. The 12 currently pending adjudications cover over 60% of the geographic area of the state that needs to be adjudicated. (Areas on the map that are not outlined in either red, green, or blue do not have significant numbers of water rights developed from surface water, and therefore will not need to be subject to a stream system adjudication suit.) The statistics in Figure 2 show that of the total irrigated acreage at issue in the 12 pending adjudications, about 67% has been adjudicated with a subfile order. So by that measure, at least, the 12 pending adjudications are about 2/3 complete. If we put that together with the adjudication suits that have already been completed to a final decree (shown in red on the map), I think a better estimate is that we have adjudicated between 40 and 50% of the state's water rights that need to be adjudicated.

Another gauge of progress in water rights adjudications in recent years is provided by the performance measures set by the legislature for LAP. The next two figures present these performance measures. Figure 3 shows over the last seven years how many people in the 12 pending adjudications have been served with what is known as an offer of judgment to determine their water right. Service of this document initiates the process before the court that culminates in an individual subfile order adjudicating a water right. Beginning in fiscal year 2004, a total of a little over 2,000 people had been served with an offer of judgment. Over the last seven years we have raised that total to 13,000. So in seven years, the adjudication process was initiated for 11,000 people who own water rights. Figure 4 presents our results for the performance measure that measures the number of subfiles in the 12 pending adjudications that have received individual subfile orders that adjudicate a water right. This figure shows the steady progress we have made over the last seven years; by this measure, by fiscal year 2010 close to 50% of all water rights in these pending suits have been adjudicated by final subfile order.

STATE OF NEW MEXICO

OFFICE OF THE STATE ENGINEER

Acres Adjudicated, Subfiles, and Defendants in Pending New Mexico Adjudications

Totals and Estimates as of June 30, 2010

NORTHERN NEW MEXICO ADJUDICATIONS

Stream System	Total Acres	Adjudicated Acres	% Acres Adjudicated	Subfiles	Defendants
San Juan	37,829	3,991	11%	9,000	11,400
Jemez	2,033	2,033	100%	1,011	1,095
Red River	12,185	12,185	100%	1,202	1,605
Zuni	980	-	0%	950	1,000
Rio San Jose	undetermined	-	0%	1,800	2,000
Rio Chama	34,889	34,329	98%	3,655	4,626
Taos/Hondo	13,756	13,692	100%	4,026	5,224
Santa Cruz/Truchas	7,218	7,218	100%	3,446	5,139
Nambe/Pojoaque/Tesuque	2,755	2,747	100%	3,430	5,598
Santa Fe	827	612	74%	1,284	1,550
Subtotals	**112,472**	**76,807**	**68%**	**29,804**	**39,237**

SOUTHERN NEW MEXICO ADJUDICATIONS

Stream System or LRG Section	Total Acres	Adjudicated Acres	% Acres Adjudicated	Subfiles	Defendants
Animas Underground	15,912	-	0%	300	500
Nutt Hockett	11,554	11,554	100%	43	73
Rincon Valley	21,964	17,180	78%	1,227	1,429
Northern Mesilla	20,032	3,493	17%	5,884	7,422
Southern Mesilla	53,923	10,140	19%	5,320	7,203
Outlying Areas	3,801	283	7%	1,233	1,738
Subtotals	**127,186**	**42,650**	**34%**	**14,007**	**18,365**

PECOS ADJUDICATION

Section	Total Acres	Adjudicated Acres	% Acres Adjudicated	Subfiles	Defendants
Gallinas	8,162	6,841	84%	1,680	1,994
Upper Pecos(Ground Water)	685	660	96%	99	92
Upper Pecos(Surface Water)	undetermined	-	0%	undetermined	2,000
Pecos Supplemental/Misc.	4,651	365	8%	49	100
Hondo Basin	6,748	6,739	100%	588	657
FSID	6,500	-	0%	undetermined	480
Fort Sumner(Ground Water)	7,444	7,444	100%	80	44
PVACD	128,274	123,032	96%	1,900	2,522
River Pumpers	6,063	6,063	100%	19	22
Carlsbad Underground	11,350	320	3%	320	240
Carlsbad Irrigation District	27,053	26,912	99%	1,109	1,328
Penasco	undetermined	-	0%	undetermined	5,000
Subtotals	**206,930**	**178,376**	**86%**	**5,844**	**14,479**

ACTIVE GRAND TOTALS	**446,588**	**297,833**	**67%**	**49,655**	**72,081**

Figure 2. New Mexico adjudication summary statistics

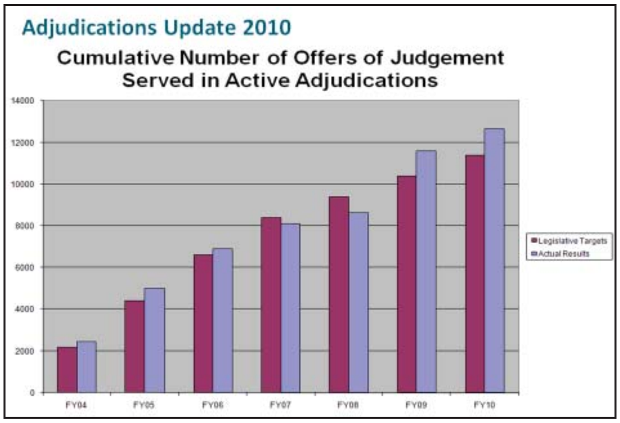


Figure 3. Offers of judgment served in 12 pending adjudications

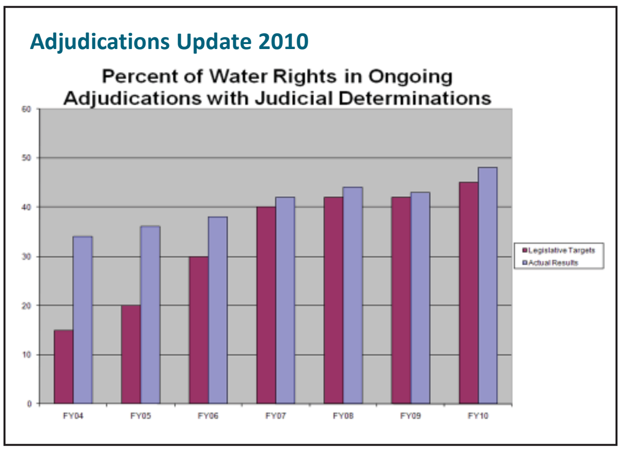


Figure 4. Percent of water rights adjudicated in ongoing adjudications

Figure 5 shows the progress we can make when we are able to focus resources on a single adjudication without interruption. The data are for sections 3, 5, and 7 of the Chama adjudication, where for the last ten years we have been able to dedicate a single attorney, supported by hydrographic survey staff, to move the suit forward. The darker blue bars show the total number of subfiles in these three sections of the adjudication, while the light blue bars show the subfiles that have been adjudicated by subfile order entered by the court. As you can see on the right side of the chart, subfile work is now almost complete, and this year and next we will be focusing on *inter se* proceedings and the entry of partial final decrees for these three sections of the Chama.

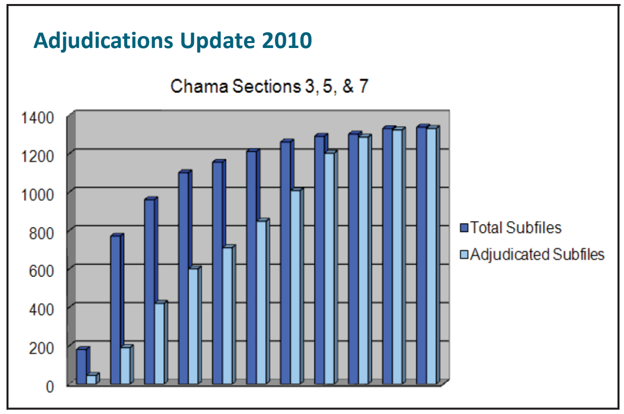


Figure 5. Subfiles adjudicated in Chama sections 3, 5, & 7

OSE LAP Budget and Resources Available for Adjudications

The difficult budget climate and its impact on LAP staffing levels is limiting our ability to make progress in adjudications, and likely will continue to do so in the next few years. But the resource problems we have encountered are more complicated than a simple matter of the dollar amounts budgeted by the legislature.

The budget amounts set by the legislature for the current fiscal year have not significantly affected the resources available to LAP for adjudication work. Figure 6 compares LAP's budget for the current fiscal year 2011, which began July 1, 2010, to our budget for the previous fiscal year 2010. The legislature appropriates LAP's budget in three basic areas: salary and benefits, contracts, and all other expenses. You can see that the budget amount for salary and benefits – the amount budgeted for LAP to pay employees – is basically flat. It was not reduced in FY 2011 from the amounts budgeted in FY 2010. You can also see that the amount budgeted to LAP for contracts was reduced in FY 2011 by 15% from the FY 2010 level. That has had an impact, because we employ contract attorneys to work on adjudications. The majority of our attorneys working on adjudications are salaried agency employees, but we do employ some contract attorneys with specialized expertise in areas like Indian water rights. The reduction in our contractor budget has directly reduced our ability to use contract attorneys to work on adjudications. But because LAP's salary and benefits budget has not been reduced, the overall impact of the budget reductions has been only moderate.

LAP Budget and Staffing

Budget Appropriation Amounts - FY11 compared to FY10

Salary & Benefits	Flat
Contractors	<15%>
All Other Costs	< 4%>

Figure 6. LAP budget - FY11 vs. FY10

Our real resource problem has been that even though we have enjoyed close to flat budgets on paper over the last two fiscal years, we have suffered significant shortfalls in actual funds received to pay those budgeted amounts, and these shortfalls have left us unable to fill vacancies when staff leave the agency. This problem started with House Bill 1110 passed by the legislature a few years ago. The idea of that bill was to provide additional funding from the water project fund to the OSE to work on adjudications, over and above our base general fund budget. Unfortunately, the moment that additional funding was added to our budget, the legislature took away an equivalent amount of general fund money. This left our overall budget flat, which doesn't sound so bad, but Figure 7 shows the real problem it caused. Our budget for salary and benefits in the current fiscal year was $4.86 million. Of that total, $3.4 million was appropriated from severance tax bond proceeds in the water project fund. But because those severance tax bonds only generated $2.7 million, we were left with a shortfall of $700,000.

LAP Budget and Staffing

- HB 1110
- FY11 LAP Salary & Benefits budget shortfall

Total Budget:	$4.86 M
STB Proceeds (Budgeted):	$3.40 M
STB Proceeds (Actual):	$2.69 M
Shortfall:	<$ 700 K>
(14.5% of $4.86M)	

Figure 7. LAP FY11 salary and benefits shortfall

Because of that $700,000 funding shortfall, we have not been able to fill vacancies as agency employees leave for other opportunities. Since November, 2008 the Governor has imposed a hiring freeze on state agencies. While there has been a lot of reporting in the press that this hiring freeze has been very porous, that has not been the case for LAP. Because of the $700,000 funding shortfall, we have not been able to request an exemption to the hiring freeze, and so we have not been able to fill any vacancies. Figure 8 shows the resulting impact over the last 18 months. On the left is fiscal year 2010 and the right is fiscal year 2011. These little icons represent the attorney and hydrographic survey positions in LAP. These are not all the positions in LAP, just the core technical and legal positions that are assigned to our four main adjudication bureaus. We have a total of 43 of these adjudication positions in LAP. At the beginning of fiscal year 2010, only four of these 43 positions were vacant – a nine percent vacancy rate. Those four vacancies are shown as the little "ghost" icons in gray on the end of the rows. Today, in the middle of fiscal year 2011, we have a lot more ghosts: 14 of the 43 positions are now vacant – a 33% vacancy rate. With 33% of our core adjudication technical and legal positions now vacant, our capacity to work on adjudications has been reduced by almost 25% over the last 18 months. That has had an unavoidable, direct impact on our ability to make progress in adjudications.

LAP Budget and Staffing

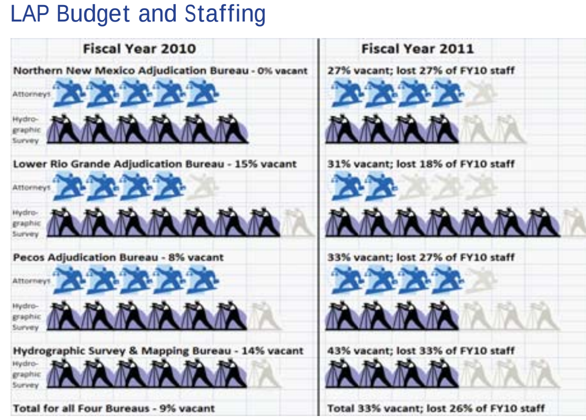


Figure 8. Vacancies in LAP technical and legal positions

Rule 71.3 Report

Rule 71.3 is a rule of civil procedure recently adopted by our Supreme Court. It requires all the state court judges presiding over adjudications and the attorneys representing the state in those suits to get together once a year for a working session. The purpose of the working session is to discuss the state's resources available to prosecute adjudications and the state's priorities for adjudication work in the coming fiscal year. For this meeting the state's attorneys prepare a report that outlines all the resources we have to work on adjudications and how those resources are going to be allocated in the coming fiscal year. Figure 9 shows a sample of a page from that report. This report is the most detailed description we provide every year on resources and the prioritization of adjudication work. It is an essential tool for communicating these matters to the public and the courts.

Figure 9. Rule 71.3 report

Of course, things change, and at the time the report is compiled at the beginning of the fiscal year we cannot anticipate every development during the year. For example, we received some wonderful good news this week. On Tuesday, November 30, 2010, the House of Representatives passed the legislation authorizing and funding the federal portion of the Aamodt and Taos Pueblo Indian water rights settlements. (On December 8, 2010 President Obama signed the bill, the Claims Resolution Act of 2010, into law as Public Law 111-291). This is wonderful news for New Mexico and an extraordinary achievement by our congressional delegation. But it is also one of those "be careful what you ask for" situations, because those settlements are now going to impose new deadlines upon the Aamodt and Taos adjudications to get things done to be able to get those decrees entered. That may require some reallocation of resources to achieve those new deadlines.

Lessons Learned

Finally, let me present some lessons we have learned from our experience prosecuting adjudications. This is adapted from a talk I gave to the adjudication judges at our Rule 71.3 working session earlier this year. It is an attempt to boil down our experience to a set of principles that describe the best way to make lasting, incremental progress in adjudications, regardless of the amount of resources we have available. Given the nature of adjudications in New Mexico and the resource limitations we face, I think these principles are going to be important for years to come. This presentation is structured as a light-hearted parody of "All I Really Need to Know I Learned in Kindergarten," but the principles it tries to present are serious.

1. The first and most important principle is that we need to finish what we started before moving on to something new. By that we mean that we must focus on achieving incremental progress by resolving discrete matters with finality before we move the resources involved on to other matters. For example, when we start subfile work in a section or subsection of an adjudication, we need to complete the adjudication of all rights in that section or subsection before we move those resources elsewhere. It has been a recurring problem over the decades that after starting work on one adjudication or section of an adjudication, another pressing matter forces us to pull those resources away. When we finally are able to allocate those resources back to the first adjudication, we have to do even more work to bring matters back to where they were when we left it. This principle also applies at the highest level. As I mentioned earlier, we can't afford to start a new adjudication now for the Middle Rio Grande until we have finished several of our pending adjudications.

2. Second, cookies are best warm out of the oven, by which we mean that we need to schedule both hydrographic survey and adjudication subfile work to minimize the chance that the data and information in the hydrographic survey will grow old and become stale. Judge Valentine made this point very well and I agree with him that this is something we need to do better. We need to work smarter and schedule our survey work so that

as soon as it is completed we are ready to begin working on the adjudication of subfiles.

The Judge's comments also touched on another point related to this one. We've learned that when we join individual defendants to the adjudication, we should not join defendants en masse, thousands at a time. Instead, we should be joining them only when we are ready to work on their individual subfile. Joining water right owners as defendants and then taking no other action in the adjudication on their subfiles for months or years only creates confusion, misunderstandings, and more problems down the road.

3. Third, don't bite off more than you can chew, by which we mean that we must focus our limited technical and legal resources and avoid over-committing those resources. This principle applies both across adjudications and within each adjudication. Across adjudications, we strive to focus our resources on a few adjudications rather than spreading our resources thinly across all pending adjudications. The annual Rule 71.3 working session with the judges is an important opportunity to communicate to the judges and adjudication defendants where we plan to focus our adjudication work in the coming year. Within adjudications, we divide the adjudication into sections and focus our resources on one or two sections at a time.

4. The last principle is to play fair, share, and not hit people. We have advocated this approach before the legislature several times in recent years; this is sometimes referred to as the "Chama adjudication model." The idea here is to promote the informal, out-of-court resolution of subfile disputes over the formal litigation of those disputes. We do that by minimizing the adversarial aspects of water rights adjudications. These are civil lawsuits, and so they are necessarily adversarial at some level. It's intimidating to the average person, for example, to receive a summons and be forced to answer the State's adjudication complaint. But we have learned we can make more progress in adjudications when we minimize the formal litigation of disputes and instead work to resolve disputes informally and promote an atmosphere where there is an open exchange of information between the state and individual defendants. We can do that by a variety of techniques, including public outreach and education, mandatory field offices where the State's legal and technical representatives meet with individual defendants, and follow up field checks by hydrographic survey staff when requested by defendants.

To conclude, I've outlined the fundamental principles we have identified that promote the achievement of incremental and lasting progress in adjudications. Today, at a time where resources are at a premium, it is more important than ever to work smart. These principles are scalable – they can be applied at different levels of resources and they will produce results in any budget climate – but they are even more important in our current difficult budget climate.

Sandoval County Plans for Future Growth: Rio Puerco Desalination Plant

Guy Bralley, Sandoval County

Guy is the Water Resources Administrator for Sandoval County. He is engaged in project management for the County's water related projects, including the deep brackish water wells in the Rio Puerco area, located west of Rio Rancho Estates. Guy was previously with contractor services providers in support of the City of Rio Rancho and the Eldorado Area Water and Sanitation District (near Santa Fe). Prior to his water career, he served in the Air Force (1966-70) and Navy (1973-95). Following retirement from the Pentagon in 1995, Guy worked for Dynamics Research Corp as a consultant/project manager to the Department of Defense and the Department of the Treasury for 3½ years, and 1½ years with Sikorsky Helicopter as VP of a joint venture with Lockheed Martin to support the H-60 maritime helicopter fleets worldwide. Guy has lived in Rio Rancho since 2000. He received a bachelor's degree in university studies from the University of New Mexico and master's degree in systems management from the University of Southern California.

Thank you very much, Karl, for the opportunity to be here today. For those who may not know, Sandoval County is located north of Albuquerque; it's about 3,200 square miles, and we are expecting the 2010 population number to be somewhere around 125,000 people (Note: 2010 census number came in at 131,561; representing a 10-year growth rate of 46.3 percent). Most of those people are concentrated in the City of Rio Rancho (2000 census value: 51,765; 2010 population: 87,521; a growth rate of 69.1 percent), which has been one of the fastest growing cities in the state and pulled the county into the position of being the fastest growing county in the state. The growth rate figures indicate a growth rate of 42 percent between 2000 and 2009, but in 2008 to 2009 that dropped off quite a bit. To get 42 percent, you'd be at almost 4 percent a year compounded; the 2008-2009 rate was down to about 1.5 percent and didn't even make the census list of the 100 fastest growing counties in the country. This means it went from #43 when based over a nine-year period to "not even on the list" in one year. That's not uncommon, the county that was the #1 fastest growing county in the country earlier in the decade was Flagler County in Florida but in the past couple of years, they weren't even on the list of 100, which obviously is a function of how the economics changed over the last two or three years.

So how does the county address this rate of growth? Although a bit unusual, this county doesn't really have a water system per se; we don't run a water utility at this time and probably will not in the near future. The county does have a subdivision regulation as does every other county. Appendix A of the subdivision regulations indicates that instead of the 40- or 50-year requirement for water supply to issue building permits for subdivisions, this area of the county requires a 100-year assured water supply. Some participants here today have done studies for developers to support the water supply numbers. I think it's a good policy to have a 100-year extended window to look at these things, especially in a faster growing county where you could potentially overextend your commitment. In 50 or 80 years, you could find yourself in an uncomfortable position.

Sandoval County's 100-year requirement applies to the southern part of the county, the lower 12 miles up from the Bernalillo County line, and extends from Highway 14 on the east side of the Sandias, westward to the lands of the Laguna Pueblo. This includes the parts of the county that grow the fastest. County policy does not apply to municipalities, so this does not apply in the City of Rio Rancho; they have their own requirements. It doesn't apply to federal or Native American lands, so its impact is limited, but it is in effect in those areas where there is the most potential growth.

Figure 1 data are from a Rio Rancho website showing single family residential growth from

1985 to 2009. The high growth period was that unbounded exuberance period of the mid part of this decade. And if you look at it on a year-to-year basis, you can see it a lot more clearly in Figure 2. I didn't have as many years of data from the City of Albuquerque; they have about three or four years on their website, but it looks similar.

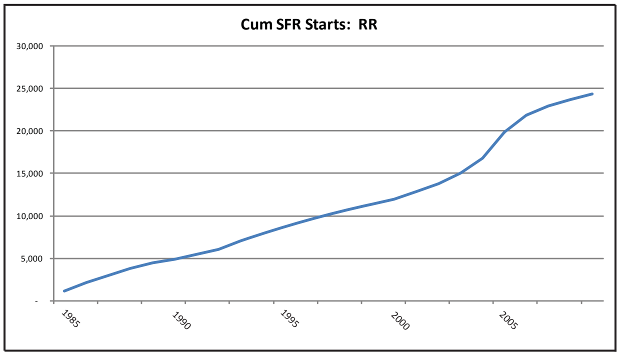


Figure 1. Cumulative residential starts for City of Rio Rancho

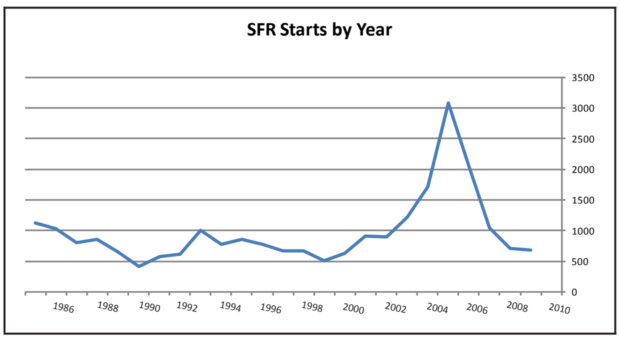


Figure 2. Residential starts for City of Rio Rancho

To be clear, a permit being issued to build a house doesn't mean the house gets built right away and there were other permits issued for multi-family developments. Consider also that permits for dwelling units are issued, but sometimes don't get built. The demand doesn't really show up right away but it is on-line to do that. Most of the growth in Sandoval County is in the south.

As we look forward, the third bullet in Figure 3 mentions the opportunity for growth; there is a lot of land that was previously owned by AMREP. Before Rio Rancho was incorporated in 1981, it was pretty much all owned by AMREP. They were in the business of developing and selling land. When Rio Rancho was incorporated, it was a small amount of land that ran from what is Southern Boulevard to Northern Boulevard, and it has expanded quite a bit since then. Currently it is 102 square miles. The area that AMREP had owned that is now not inside the city limits, is called Rio Rancho Estates. It is sparsely populated, has very little in the line of utilities or services, and is poised for growth. Given the current economy, we have time to take a sober look at what's going on. There are other areas considered for potential service by desalination that are not in the Estates. Some areas are adjoining ranch land and some are developments that were proposed in Bernalillo County (what was once Quail Ranch that became land annexed by the City of Rio Rancho). So there may be a demand for water being passed through the City of Rio Rancho to those areas. It remains to be seen how that will be addressed. As mentioned before, the slow-down in the growth has caused many of these permitted units to not have been started.

- Most growth in County is in South
- Concentrated in City of Rio Rancho
- Opportunity for growth in surround area
- Projections need period adjustment
- Rio West Master Plan approved by County Commission in 2006; is in Rio Puerco valley
  - Not started to date
  - Desal initiative was for this area/ development

Figure 3. Looking forward

Sandoval County worked with a developer for a planned community; the County approved the master plan for Rio West in 2006 and a desalination plant was proposed for that area. It is more than 11,600 acres of land in the Rio Puerco valley west of the Rio Rancho Estates. There is other mixed land; including some state land and some private land closer to the Bernalillo County line. That Rio West master plan indicated that work would start in 2008, but that has not happened yet. The number of housing units proposed in the master plan will also probably be scaled back quite a bit; the number of housing units was between 25,000 and 29,000 over a period until about 2031. (Note: The County and the developer have ended their joint efforts on this project. Continuing effort will be by the developer.)

Discussions with other community areas and developers were undertaken (Fig. 4). In some cases these communities do not currently exist, and the purpose was to determine how big a desalination facility should be planned. Obviously, you don't build a 25 or 30 million gallon a day plant on day one; (El Paso is different and they could do that) we couldn't because we didn't yet have customers with the demand for 25 million gallons per day. To decide how big to make this first unit, we performed an engineering evaluation, which came up with a five million gallon/day increment. The plan called for additional increments as demand developed. The trade-off was to either build a small less expensive plant or to build something larger that would allow expansion over time.

- In addition to Rio West, talks with others in the area to ascertain "need" for water
  - City of Rio Rancho
  - AMREP
  - Quail Ranch (before it became part of Rio Rancho)
  - King Brothers Ranch
  - Breezy Point
- Goal: How big plant should be? When?

Figure 4. Other developments in the area

What would happen if AMREP decided to develop the land they own? County tax records indicate there are about 40,000 lots in the Estates: some owned by AMREP, about half of which have been sold. These have been sold to people all over the country. When you try to provide utility service to these randomly distributed lots, it is very difficult because there is so much undeveloped and open space with often unknown ownership. We know what the property/tax records databases show, but we don't always know where those people are all the time. Folks regularly come to the County while visiting New Mexico to see the land that they found the deed for in Grandma's safety deposit box after she died. In many cases they didn't even know that they owned the property they ask: What is the land worth? Where will I get my water? When is the county going to drill my well? I am sure other Counties deal with similar issues and that Sandoval County is not unique in this regard.

If you build a five million gallon capacity today, there is only one potential buyer who could take five million gallons a day. In our case, that would be the City of Rio Rancho. We talk to the City quite a bit. We must sell water in large volumes to be able to pay off the debt incurred to build the plant in the first place. So it can become less about water and more about economics and finance.

What was it that the developer had done? The developer contracted Balleau Groundwater to do a study, which was a good idea. Having looked at that study before and after the wells were drilled, it appeared to me to be a good study. Balleau made estimates as to how deep you might have to go to get water. It recognized the fact that through the 11,000 acres of land, you have a lot of faulting: One of these is the Moquino Fault, which begins further up the County around La Jara and is associated with the Nacimiento Front (mountains to the west of the Valles Caldera, north of Cuba).

Based on these estimates to water depth, the developer filed for well permits with the state engineer; three of those locations were in Sandoval County and three were in Bernalillo County. We drilled two of those exploratory wells. The first one drilled was 3,840 ft deep. We found water at 3,700 feet and more water about 3,772 ft. The screened interval was from 3,598 to 3,809 ft. The water was contained in the San Andreas and Glorieta formations. The formation where we completed the well was the Yeso. The second well was drilled about 3,500 ft away. We hit water at about the same level, but we continued to drill to the granite. Total depth was 6,450 ft deep.

Our purpose was to find out if there was more water below and unfortunately we didn't find more water. In drilling through the Madera, we learned that it is very hard and therefore expensive when you are paying a day rate on a drilling rig. We were hoping to find fractures in the Madera. That did not happen. We were interested in fractures because it might help us answer the question that will come up about what to do with the concentrate stream from the desalination process. We do not know exactly what that answer is, but it is likely that injection will be evaluated as an option. Having drilled to the granite, we know more about the formations. Considerable additional study will be required to make a final case, should that injection option be pursued (approval of that option will have to be in accordance with the injection wells permitting processes/policies).

At 3,700 ft this water was quite saline. The reason to even go after this water is because of state statute 72-12-25. Basically that statute indicates that the state engineer doesn't control water that has more than 1,000 ppm total dissolved solids if the aquifer is more than 2,500 feet from the surface.

As it turned out, this water qualified. (Note: The statute was partially repealed in 2009. The statute now allows some uses of deep waters, but excludes water utilities. Issues of grandfathering might be entertained by the Office of the State Engineer (OSE), but are not clear to me at this time.)

Until the well encountered the water (3,700+ ft), we couldn't determine the water "quality"; we could have done with less than the 12,000 TDS (instead of just getting over the 1,000 TDS drinking water standard). The 12,000 TDS is about one third of the amount of solids/salinity contained in normal ocean water. The biggest difference between this water and ocean water is that this water is hard and ocean water is soft. We have high TDS, a fair amount of salt, and more arsenic than you want to think about. It has carbon dioxide and silica. All pose challenges to overcome to achieve an economical process. So it will require a fairly sophisticated treatment process to remove selectively the constituents from the water and ensure a good life span for our membranes: Also desirable is a good return in terms of percent recovery in the treatment process. (Note: The water quality test values were from four tests done at the first well only; second well quality testing has not been done at the time of this presentation, and should be of considerable importance going forward. Efforts of the land developer in April 2011 will include additional testing for water quality data.)

In October of 2008, we performed a 30-day flow test on the first well. We learned as much as we could from having only two wells instrumented. We flowed one and observed the response in the other well; after 30 days of flow we observed the recovery. These wells both flow artesian so we didn't have to put a pump in either one of them. You just open the valves. The first well flows 600-900 gallons/minute depending on what size orifice you want to use and how much risk you are willing to accept. If you close the valve, you have about 160 lbs of pressure at the head of the first well. The second one flows at about 125-150 gallons/minute, and when you close it in, you get about 200 lbs of pressure. You'll have to find someone with more experience than I to explain that but you don't get as much flow out of the second well (with higher pressures). The last step, the pilot testing, we did about a year ago (Fall of 2009), and I spoke about that effort at the 2009 water conference.

To support the test, we had a trailer-mounted pilot plant on site to determine a sequence of processes for treatment. Our prime contractor for this work is Universal Asset Management and one of their principle sub-contractors is CDM, which brought the trailer out to the site. This effort was funded with legislative money in the amount of about $700,000. Water flowed into the process trailer at 15 gallons/minute once we got the process balanced. We then ran it daily for about a month. The process begins with multi-stage solids removal so that we do two things: extend the life of the membranes and try to recover marketable products. If we can find markets to sell these constituents it (1) reduces the amount of injection that we have to do, and (2) there is the economic aspect of selling the removed materials. I never wondered how much you pay for a carton of salt in the store, but sell it in large enough quantities and you get numbers like $40 to $80 per ton for food grade salt. We have the potential to produce 250 tons a day of salt.

The water is going into the process at about 12,000 ppm (TDS) and the water coming out is about 300 ppm; observed recovery rate is about 82 percent. Whether that can be scaled up and maintained from a physical or economic point of view at production levels remains to be seen (you are making serious investments in both chemistry and energy to achieve 82 percent at production levels of 5+ mgd).

Figure 5 show the process trailer. In this photo, the well is hard to see. It is at the end of the black hoses, near the black barrels. The processed water comes out of the well, goes up on top of the trailer to the white container (that doesn't show very well in the photo) to allow the gases to be stripped from the water. It then flows down through this claricone (the large green funnel shaped device); lime (caustic) is added to get carbonate to precipitate out. Behind the claricone is a granular activated charcoal system (outside). The polishing system, kind of like a household water softener on steroids, is located inside the trailer.

Figure 5. Pilot plant

All of this occurs before you get to the membranes (Fig. 6), which are inside these large white tubes. There is a fifth tube on top you can't see but that is where the final stage membranes are. These are small membranes (pipe size); there is a "magnum" membrane coming on the market today. I haven't seen them installed but they are about a sixteen-inch diameter, so there is some really large membranes out there. I think the El Paso plant runs eight inches.

Figure 6. Membrane containers

In addition to the water arriving under artesian pressure, it is 150° F. This presents an opportunity for energy recovery. We can use the pressure of the free-flowing water, we realize that nobody guarantees us that we will have pressure forever. We don't know its source. The geologists here could probably tell you three or four different ways you could have that kind of pressure. We don't know which one or which combinations, we have. This means we must plan for a day when the pressure somehow diminishes or the temperature goes down and we can still have a process that works with those parameters.

Among issues in the process stream we have the dissolved CO_2 stripping (container on top of the trailer) and arsenic and radium are elements we'd like to take out early to reduce disposal volumes. In the beginning, we believed they could be a hazardous material for disposal, but since then we've learned that it probably won't be as big a deal. However, we still need to be careful with it and certainly it has to come out of the water before it meets potability standards.

I mentioned that we had a fair amount of arsenic, nearly 700 ppb. The standard is 10 ppb for drinking water, so we know we have to deal with that. The warm lime softening in that big green claricone (visible in the Pilot Plant image, Fig. 5) removes large masses of carbonate, the primary sources of the hardness in the water, and is a potential fouling agent for the membranes. Media filtration (GAC) is located behind the claricone. Further polishing of the water is done in a zeolite canister in the van.

To make the economics feasible, given the carbonate volumes we will be removing, we have contemplated a recalcination process onsite. Rather than importing railroad car sized quantities of lime to deal with the softening, we could make the lime onsite. At the end of these processes, water gets to the membranes. This is the 10,000 foot view of the sequence we are planning (Pilot Process, Fig. 7). How well it scales up from pilot size (at 15 gpm, to 3,500 gpm) will be a major factor in achieving cost objectives.

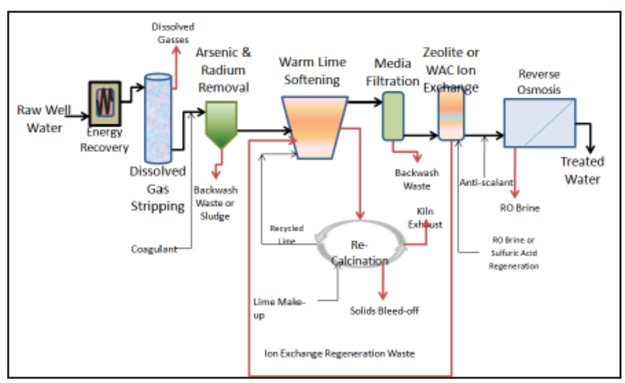


Figure 7. Pilot process

The next step was developing of the preliminary engineering report. We submitted it to the New Mexico Environment Department (NMED) and to the OSE. Their comments are being reviewed now.

Things we need to do before we commit a whole lot of money (in the $100+ million range), include gathering more information about aquifer characteristics. We harbor no illusions that this would be a fully sustainable source where we could get water recharged on a one-to-one basis matching everything we take out.

We obtained a sample from well EXP-6 during the early stages of well development and submitted this sample to University of Arizona in order to obtain the approximate age of the water in the sample. The laboratory reported a result for this sample of 29,000 years based on a Carbon-14 analysis. Given the Permian age of the aquifer (about 200 million years old), this result was surprising. Additional testing of samples from this well and EXP-5 are necessary to provide some degree of certainty regarding the age of the ground-water in these brackish water aquifers. Of further note is the limitation of Carbon-14 dating. Some sources state that 30,000 years is nearing the edge for Carbon-14 accuracy. (Note: This age data was from the first well only, and the tested sample was taken shortly after the initial flow testing. It is highly probable that subsequent testing may provide different results. In addition, the faulted nature of the area and the fact that the two wells showed markedly differing flow rates, leads to a lack of precision concerning some characteristics of the resource.)

The recovery, when the well was turned off, after the flow test (Fall 2008), was about 80 percent of what we observed as drawdown within 48 hours of shut down. The flow test rates 150 gallons/minute followed by a period of 250 gallons/minute from the 30-day test that we ran for making estimates of aquifer volumes and capacity. We need to know more about that, and we will need additional wells. The wells we drilled cost about $2 million each and that is a fairly expensive price for risk reduction and confirmation of data that we need to know. (Note: The recovery observations were based on pressure data from down-hole sensors, and not static levels of the water. Down-hole water pressures at the beginning of the testing were 1,504 psi. After 60-90 days of recovery, the pressure had recovered to 1,499 psi.)

Areas we need to know more about looking forward: impacts and interferences due to well locations and placement/spacing are to be determined. There is a lot of faulting in the area, which adds complexity. Any case to support assumptions on recharge and sustainability are tied to data that may be collected from more wells and additional flow testing. We understand that knowledge gained in this collection process may lead to conclusions other that “more water.”

This year’s conclusions are similar to the final thoughts from last year. We acknowledge that water is a limiting factor for growth in the county. There are many other costs that haven’t been fully quantified in the estimates so far. More information on treatment costs is needed. More importantly, infrastructure for transporting and distributing this water is not included in the cost numbers so far. The County proposed to be a wholesaler of water: the customer builds his pipeline to take water from the desalination facility to his point of use/sale.

Other topics to be addressed will be by the developer concerning wastewater collection, sewers, and the potential reuse of wastewater effluents. This includes the possible reuse and treatment of effluent to potable standards. On a dollars per gallon basis, it is cheaper to treat wastewater to drinking water standards than it is to treat this 12,000 TDS water. We haven’t figured what to do with the concentrate disposal. We know it will be expensive and would like to reduce its volume by marketing other by products.

Future considerations beyond this specific project include:

- Water statute- NM legislature partially repealed NMSA 72-12-25 (as noted above). Impacts of this action are not fully understood at this time.
- Eventually the customer will be asked to cover the costs to run this, and we recognize that. The bottom line is how much can you charge per 1,000 gallons of water? We think we can do this in the neighborhood of $6/1,000 gallons. Grant funding can reduce these costs by about $1/1,000 gallons for each 25 percent of the construction costs offset by grants. Interest on debt incurred to build the plant will be the largest expense over the life of the repayments.
- A group approached the County about co-locating a power plant at the desalination facility, which would have dropped the price by about $1/1,000 gallons, but we haven’t heard much from them lately.

John Trever gave me permission to use this cartoon (Fig. 8); I thought it fits here. I'd be glad to answer any questions.

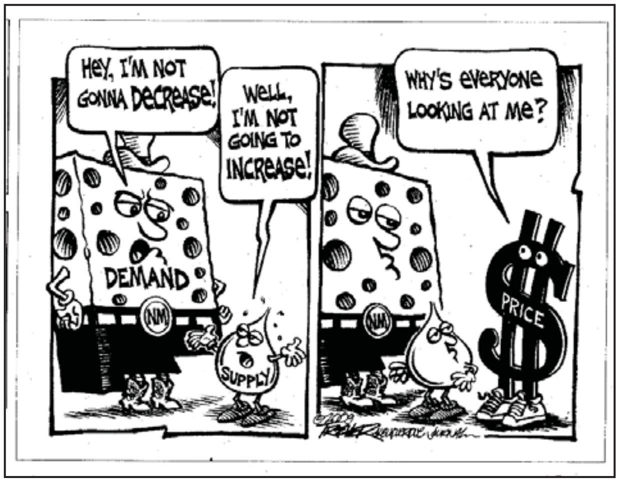


Figure 8 . Cartoon by John Trever

Challenges When Combining Mutual Domestic Organizations to Meet Community and Colonias Water Needs

Martin Lopez, Lower Rio Grande Public Water Works Authority

Martin is the General Manager for the Lower Rio Grande Public Water Works Authority, the Registered Agent for the Lower Rio Grande Mutual Domestic Water Association, and the General Manager of the Mesquite MDWC & MSWA. Martin has worked in the water and wastewater industry since 1987 and was a technical assistance provider for the Rural Community Assistance Corporation promoting water and wastewater technical, managerial, and financial capacity to rural and small communities throughout New Mexico and the Western U.S. Martin attended the Utility Management Institute in San Antonio and is a part-time instructor at the Doña Ana Community College Water Technology Program. He has a BA in agriculture business and agriculture economics from NMSU, two associate's degrees in water technology and business technology, and certification in NM as both a Water Level IV and a Wastewater Level IV operator.

Thank you and good morning. I am Martin Lopez, the general manager with the Lower Rio Grande Public Water Works Authority. I am new in that capacity as of November 3. The mutual domestics that created the Lower Rio Grande Public Water Works Authority consist of five different water systems serving 8,000 people: Berino, Desert Sands, La Mesa, Mesquite, and Vado. Mesquite is located closest to Las Cruces, about 15 miles south of Las Cruces, and the furthest is Desert Sands, located at the Anthony, NM boundary. These five water systems serve nine colonias and have been in existence since the mid to early 60s and 70s.

Some of the common problems facing the authority include: increased regulations such as arsenic restrictions; high operating costs; aged and undersized infrastructure; limited water rights; lack of volunteer board members; and many others. Our biggest hurdle has been with the two systems located close to Anthony that have arsenic issues. We have looked at the cost of dealing with arsenic and have tried to figure out other avenues to address the drinking water standard.

We have high operating costs, mostly associated with meeting requirements to employ certified drinking water operators, of which there is a shortage. Anybody knowledgeable about water operations understands the economies of scale, and any time that you have a larger entity in the vicinity, that entity will recruit and hire the area's available operators. The Authority doesn't have the funds to provide a lot of the benefits available from larger entities so we kept losing operators, not only to El Paso and Las Cruces, but to other systems as well.

Another issue has to do with our aged infrastructure and lining, some of which was installed in the 1960s. USDA funding for the colonias provided drinking water to the communities; it did not provide funds to address fire flow or anything along those lines. Out of the five systems, we have many areas with very aged or undersized lines. The corridor from Las Cruces to El Paso has grown substantially and new development has taken place, along with new fire-flow requirements by Doña Ana County. Much needs to be upgraded and individual systems cannot afford to make upgrades on their own.

Another issue has been limited water rights. One of our systems, due to nitrate contamination in the 1980s and a failure to transfer their point of diversion to another system or another well, had their water rights not necessarily lost, but the rights are no longer recognized. The two southern systems with arsenic problems have abundant water rights declared, while the Mesquite and La Mesa systems are nearing their capacity with declared water rights. So we face limitations with our water rights.

The biggest hurdle was appointing a board of directors, who serve for life. It is very difficult to find folks to volunteer to serve on the board with no pay while they'll often receive criticism. I've been a general manager and operator for several of these systems for many years and quite frankly, I tell board members that I would not put myself in their position.

There were many other hurdles as well. For example, we have some operators who have never taken a day off because the system cannot afford to pay a backup operator. And there are issues with outages and emergency situations.

The five individual mutuals started looking into coming together and today in the audience is one of the responsible parties, County Commissioner Oscar Butler, who helped the mutuals look into options. There is a territorial element to the mutuals, but when you have commissioners and other elected officials including state legislators saying that they cannot afford to fund all of you individually, you look toward a regional solution. What evolved was an alliance of water and wastewater providers in Doña Ana County. The group spun off into systems both north and south of Las Cruces.

One of the biggest issues with mutual domestics was that they could not declare a service area. Our only protection from encroachment was federal indebtedness, so we actually took on loans from the federal government to make sure we could protect our service areas. Legislation pertaining to the Lower Rio Grande Public Water Works Authority now includes a declared service area.

At first, we did not have the funding ability to float bonds; we had our hand out requesting grants and loans with repayment coming from user fees. We were even limited to charging impact fees under some of the regulations given to us by the Department of Finance and Administration. Another hurdle that we had was how to retain autonomy for each of these communities. The mutual domestics have been in place for 30 to 50 years and community recognition was important.

During the 2009 legislative session, House Bill 185 was passed unanimously through both houses and signed by then Governor Bill Richardson. We nearly camped out at the round house during the session and it is an eye-opening experience for small rural communities that don't really understand the legislative game. We spent many days during the session thinking everything was fine, but also a few days in which we encountered some opposition and were called back to testify. The Governor signed the legislation on April 6, 2009 that merged the five mutual domestics into the Authority and gave it legal standing.

The legislation allowed the Authority to file a service area and we partnered with the Office of the State Engineer to rectify the "Point of Use" for individual mutuals. Many of the mutuals had grown beyond their recognized service areas (some areas were declared in locations without a service area), there were gaps between the five systems, and so on. We made sure in the legislation that we did not have to be contiguous so we wouldn't need a physical interconnect between systems. This allowed us to jump around the area when a new entity chooses to join us. The other big issue concerns the water rights themselves; would we lose any by combining and commingling? Unfortunately, that has not been answered so challenges remain.

We wanted to make sure we merged properly. Typically, the state provides $50,000 Community Development Block Grants and we knew that amount would not cover attorneys, engineers, and other required professionals. We requested $100,000 and were provided that funding. I think state agencies realized that predetermined amounts for these planning grants will not always work. Larger grants are sometimes needed as there are many hurdles that aren't anticipated.

The planning grant created a governance structure. The legislation authorized the Authority but we needed planning and governance guidelines. The documents spelled out why we were organized, our authority, instructions for the board of directors, guidelines for growth, and strategies for administration and management.

We were dealing with five very different systems; one of the smaller systems had 180 connections, the largest had 1,500, some had several levels of management, for example Mesquite had a general manager, while Vado contracted out operations. We had to develop the administrative and management guidelines that would meet a wide spectrum of needs. Then we had to look at operational and implementation strategies. Operations were do-able, operating five systems is pretty standard. But when the Environment Department recognizes you as one large system, things change. At what point do we eliminate our public water system ID numbers? When do we switch from being recognized by the Environment Department as smaller entities to one authority? A whole process emerged that we had never envisioned.

The process was completed in September 2010. Some challenges remain and we have to redo some of the documents. The Rural Community Assistance Corporation (RCAC) had a technical systems provider that was contracted, and as we started to implement their proposed strategies, many did not apply. So we have to redo things even as basic and minute as job descriptions for some employees.

In an effort to try and harness some of the money that was being thrown at regional groups, we created an interim association, the Lower Rio Grande Mutual Domestic Association. Our previous contract was with the RCAC board and now we had a new authority board that didn't always accept our recommendations. We had to acquire a Duns Number, which is a tracking number required to access federal funding. But there was a catch. To get a Duns Number, you need to have a federal tax ID number, and to get a federal tax ID number, you need a State CRS Number from Taxation and Revenue, and to get that number, we had to establish a permanent address and bank account, which was difficult as all the funds still sat with the individual mutuals.

Our first legal task was to develop a mechanism to establish a board of directors. Legislation spelled out the board's composition: one member from each of the five mutual domestics, and that group would be part of the initial board until we could hold general elections. Among the five entities, there were 25 elected officials; the legislation called for a board of 5-7 elected officials so we asked each of the five entities to decide on their representatives. The easy way out for some of the entities was to appoint staff. However, our attorney recommended that we not have staff employees on the Authority's board, as there could be conflicts of interest. At least three individuals had to resign from the Authority's board, and the mutual domestics had to reappoint their replacements.

Another hurdle dealt with the transfer of water rights ownership from individual mutuals to the Authority. After sitting down with the local staff and staff from the Office of the State Engineer (OSE), the process was actually quite easy compared to everything else we had encountered. In August 2010, we completed the transfer of water rights to the Authority. The process did require an attorney who was familiar with the process. Four of the five mutuals had engineering firms on their boards so we had to coordinate their data. Also, not all individual mutuals had all the required information, so we had to rely in some instances on the data archived with the OSE.

We submitted a "Transfer of Ownership" to the OSE. However, wells still belonged to the mutuals so we had to pass resolutions authorizing the use of that water back to the mutuals; we have not received approval and a lot of discussion back and forth resulted in a couple months delay. One accomplishment since August has been the transfer of real property to the Authority.

A big piece of the legislation is the combining and commingling of water rights. This contains a fear factor with the potential that some water rights might not be recognized. We are looking at guidelines and working with OSE staff. We want to make sure we maximize all of the water rights available to us. One positive aspect of working with the OSE was that we discovered some water rights that had been lost in one of the systems, and they were recognized again. We now need to remove those water rights from their abandoned well site to another recognized well.

The RCAC governance documents were also completed in September. We had a legal review and some documents were approved as strategic and operational plans. The governance documents, charters, and bylaws for mutual domestics or co-ops are essentially set in stone so we needed to make sure that those were properly developed. We didn't want to have to go back and change the legislation. This required a thorough review by our attorney and some of the documents have been approved. The key to our existence is the governance document and it is now in place.

The biggest hurdle for our customers is financial. RCAC was charged with doing a rate analysis, basically taking five existing water rates and incorporating them into one. It may sound easy to look at expenses, divide them among users, and come up with a rate structure that is satisfactory. The twist in this case is that the individual mutuals and the Lower Rio Grande Mutual Domestics have about $12 million worth of ongoing infrastructure projects, so we had to incorporate all the different project budgets into these rates and had to be able to justify those proposed rates the funding agencies. Then we had to submit this not only to USDA, but to the Department of Finance and Administration for their approval. That, in itself, was a year-long process and in the end, the water rates will decrease for four of the five water systems. The fifth system, Mesquite, is the largest, and the rates will increase. So right off the bat, the economies of scale are going to pay off for us.

Another aspect of the legislation is our 40-Year Water Plan. Coordination with the state engineer is critical. A priority is the need to address return flow credits. A portion of Mesquite is "sewered" by our own facility, and 70 percent of our remaining customers are connected to the county's wastewater facility. We have a partnership with Doña Ana County to recover the return flow credits back to the Authority. Initial agreements between the state engineer and Doña Ana County had those return flow credits going to the individual mutuals. The 40-Year Water Plan has evolved but the board has not adopted it yet, but perhaps it will be adopted by January 2011. When water rights for Vado were recognized again, we had to re-edit the document and that has taken some time.

We worked with the Environment Department to obtain a Public Water System ID Number. The process wasn't simple because of the data collection method. The EPA and Environment Department track violations and operation based on a history of data collected from all five of the mutuals and there was an internal computer problem transferring that data into the single entity. Ironically, about a month ago, I got a call from the Environment Department asking if I remembered the number they had given the Authority.

A key to our operations was the hiring of staff. We were able to provide higher salaries and benefits to our employees, and the mutuals were no longer held hostage if an operator decided to take leave or move on. We were able to standardize our hours so that operators don't have to work weekends and overtime as they often did when they worked for the individual mutuals. Because most of our customers are from the Las Cruces and El Paso area and may want to pay their bill when they get off work, we have implemented on-call and after-hours operators to access staff.

Responsibilities accompany money. A small system like Vado had gross revenue in 2009 of about $10,000. Currently, combined revenue for all five systems is in excess of $1.5 million, and that is just from the water rate structure that we generated. To protect our customers, we have put in place policies and procedures for outside bookkeeping, internal bookkeeping, and internal controls and transparency. We have discovered that even our legislators want to know what is going on. You need to have balance sheets and income statements readily available. It was critical that we establish bank accounts for all monies. When I was with the Mesquite system, I was authorized to sign checks up to a certain dollar amount. Now I want to make sure there is a counter signer on checks and bank accounts. We are now recognized as a subdivision of state so we adhere to state procurement requirements. And we had to make sure that everybody paid their taxes; some of the mutuals had not been paying taxes, so we had to research whether we would inherited those taxes and we did. Some systems did not have enough insurance; some mutuals had made facility upgrades but did not include those upgrades in their insurance policy because they didn't want to pay higher premiums.

When we consider rates and fees, we look at the total cost of a project. Can we support our own infrastructure? We developed uniform rates making sure we didn't discriminate against any single user. We standardized all policies. The five systems had five different disconnect policies and five different late charge fees. In the small systems, staff knew everyone in the community and they didn't want to shut off their uncle's or aunt's water. We considered this when we developed transparency into our operations and policies.

Currently, one of our biggest hurdles concerns existing debt. We received a letter from USDA Rural Development indicating they no longer recognize any of the mutual domestics; they only recognize the Authority. In my opinion, this was premature because they wanted loans to be paid by the Authority but that couldn't be done because the money was still with the individual mutuals. But they no longer recognized the mutuals. Thus, a two-month battle started that involved U.S. Congressmen and Senators explaining that yes, legislation created the Authority, but it did not disband the mutuals. Eventually the mutuals will be disbanded but not yet. We had to look at how to get out from under the federal government for this purpose. We are working with the State to refinance already existing loans into the Authority. When we began this process, the Authority had no revenue base, the mutuals did, but not the Authority.

With the transfer and refinancing, we eliminated the need to have a large reserve. Previously, we had to have at least one annual loan payment set aside for each debt, which created a large reserve. That triggered customers to ask why we have so much money set aside and why we can't we use that money instead of increasing rates. We were able to get the feds to concur that the Authority was a successor to the mutuals and that the responsibility would be transferred to the Authority, which would assume fiscal responsibility. USDA attorneys and our attorneys went back and forth to get adequate documentation.

Then we had other liabilities, such as vehicle loans, maintenance contracts, small debts, and vendor obligations. Often one vendor had five different account numbers and five different state and federal ID numbers on record, so we had to consolidate them. Another problem was our assets. Some of the properties we thought we owned, we didn't own. "Ownership" had been based on a gentleman's agreement. For example, we had a well site at the old cotton gin in Mesquite that had no documentation. We discovered some very nice letters authorizing the well but the letters weren't signed. To make a long story short, in our discussions with the federal government, we had pledged assets we were not authorized to pledge, which stirred up other issues.

The transfer of the vehicles was another major problem. We now had to get state issued government plates. I never thought transferring an old '79 Ford pickup would be such a headache but some of the Board of Directors had really old vehicles that were recognizable by customers. Most of our pipe is underground and other than a water tank or a well house, people don't see anything out there except for the service vehicles that they recognize.

Other liquid assets were a big challenge. Some of the mutuals, in an effort to diversify their funds, would put money in Roswell and Albuquerque banks so we had bank accounts all over the state. We are still recovering some of that money. To make matters worse, many former board directors had moved money, and bankers want some kind of signed official document to release funds. Unless Governor Richardson can give us signed documentation , we have nothing other than the state statute. So there were problems with the consolidation of bank accounts and the Department of Finance and Administration wanted us to have all of money in one account before we could diversify it. Another kink occurred when the feds came in and said we had too much money in one account and they would only protected up to $300,000.

The legislation required us to determine who our constituents are. We had to define our membership by establishing eligibility criteria. Basically, property owners within our service area who receive our services are members. That excludes renters and other larger entities and corporations. We evolved from grass-roots small water systems and we do try to take advantage of that small-town feeling.

We have had problems with member documentation, for items like parcel ID numbers and map code numbers that do not match with county records. This means some people who thought they were members actually might not be. A lot of folks, especially in the colonias, don't own their properties. Many people, even if they paid off their land, have not filed the documents with the county. It is a big hurdle to overcome and we are required by July 2011 to establish boundaries for election purposes. Some existing water system boundaries must be cut up so we have an equal amount of representation. Some people don't want to switch from the Mesquite area to the La Mesa area or from the Mesquite area to the Vado area, but we are going to have to deal with these changes.

The county clerk's office has been very helpful in fitting us into a general election process and we are following the model that the Elephant Butte Irrigation District (EBID) uses for election purposes. We will need to deal with the whole procurement process of hiring election officials and entering into a contract with the county to run the election. Also, we will need to canvas elections.

We will have to go back and dissolve the memberships for the individual mutuals. Four of the five water systems have already gone through this process where they agreed to disband. But we must settle any outstanding liabilities with debt service or situations where individuals have filed suit against the mutuals for various reasons. Then we'll close out all of our agency information. Here we run into the problem of some money specifically naming a mutual recipient so we can't shut down the tax ID numbers or the federal ID numbers until we expend those funds. So even if a mutual isn't meeting anymore, a legal board must continue to exist. A whole gamut of documents must be closed, including approval and finalization of audits and budgets.

Our transition from individual mutual domestics to a single water Authority will allow us to rehabilitate and upgrade our existing system. We will be networking the large transmission lines. The Department of Finance and Administration folks asked us why we didn’t simply install a large waterline all the way around our area so we could connect to it wherever we needed, but that is easier said than done. We have interconnected the large transmission line to about a third of our system, so we are all physically interconnected at this point.

We need to establish adequate storage with larger capacity and perhaps install booster pumps. We are being approached by a lot of areas that are not currently being served and now want water from us. Some are colonias with the same issues in their systems. We are operating under three different billing programs and will need to integrate that entire operation and create an intranet in an area where some don't even get wireless service.

Exploring alternative water resources will be a priority. We are looking at the possibility of surface water facilities partnerships. We've been approached by another mutual domestic north of Mesquite that wants to do a physical interconnect for emergency purposes. And operators from another mutual domestic located in the mountains north of Chaparral have contacted us. We will continue to expand and cement ourselves as we grow. We are hesitant to take on any new members until we are actually established and that is a big challenge. We have a lot of interest by others to join the Authority, but we aren’t quite ready yet. We will be, but at this point, we are not.

Thank you.

Interbasin Transfer Projects: Impacts on Communities and Ecosystems

Bruce Thomson, University of New Mexico

Bruce is a Regent's Professor in the Department of Civil Engineering at the UNM and is Director of the UNM Water Resources Program. He has a BS degree in civil engineering from the University of California at Davis, and MS and PhD degrees in environmental science and engineering from Rice University. His recent research has included projects on water resources of New Mexico, leak detection from water distribution systems, customer willingness to pay for potable water, water reuse and treatment, and storm water quality-low impact development. He has recently completed a book chapter titled "Water Resources of New Mexico" that summarizes surface and groundwater resources, water quality issues, and water uses in the state. Bruce has served on numerous federal, state, and local committees involved with management and protection of water resources. He was recently elected by the public to the Board of Directors of the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA), the agency that deals with flood control issues in Bernalillo County. He is a licensed Professional Engineer in the State of New Mexico.

Introduction

Total annual withdrawals of ground and surface water in New Mexico for all uses are just under 4,000 KAF/yr (Longworth et al., 2008). Although this value has not changed in many years, increasing population and economic activity has resulted in increased demands for this water. This increased demand extends throughout the state and is most clearly described in the sixteen regional water plans submitted to the Interstate Stream Commission between 1994 and 2008. In spite of the large differences in hydrologic conditions in this state, a common thread in all of these plans is that all water resources in each region are over appropriated and the region must obtain new sources of water both to support the existing uses and to allow growth of population and economic development.

The challenges of meeting future water demands are further complicated by the likely effects of climate change. Hurd and Coonrod (2008) explored the consequences of a variety of future climate scenarios and estimated that a reduction in annual runoff of up to 29 percent might occur by 2080. The problem of reduced runoff volume will be exacerbated by earlier snow melt and spring runoff, as well as and warmer summer temperatures resulting in increased evapotranspiration.

In an inland state with an arid climate such as New Mexico, there are only two sources of water that may be considered to be new: transfers of water from outside the watershed (interbasin transfers) and utilization of previously unused and unappropriated water. Desalination of brackish and saline groundwater is an example of the second source. While much attention has been devoted to wastewater reuse, in New Mexico most dischargers of wastewater receive return flow credits that are factored in the community's water rights. Thus, municipal wastewater is not usually really an unappropriated water source (Thomson and Shomaker, 2008).

Upon initial consideration, interbasin transfer of water has enormous appeal. Indeed, many of the regional water plans offer vague references to receiving water from adjacent basins. However, a more thorough examination reveals that there are often few details to support these transfers and in most cases, there is no real wet water available.

It is difficult to find information on interbasin water transfers because they are usually kept secret to minimize the uncertainty that comes with public disclosure. Although the State Engineer must approve each transfer, application to this agency usually comes near the end of the negotiating process. For example, the Augustin Plains Ranch proposal drew over 450 protestants when the application to divert water was filed in 2008 (Augustin Plains Ranch, LLC, 2011). A summary of several high profile interbasin water transfers that have been proposed or are in place in recent years is presented in Table 1.

Table 1. Examples of interbasin water transfers that have been proposed, are in progress, or have been completed in New Mexico in recent years.

Applicant or Title	Description	Amount of Water (AF/yr)	Status
Augustin Plains Ranch LLC	Transfer groundwater from Plains of San Augustin to Rio Grande	54,000	Application Pending
Berrendo LLC	Pipe water from Pecos River near Ft. Sumner to Santa Fe	6,600	Application denied by State Engineer
Eastern New Mexico Rural Water System	Divert water from Ute Reservoir to communities on the eastern plains	16,450	Authorized by Congress, awaiting funds
Navajo-Gallup Water Supply Project	Pipe San Juan River water to Gallup and Native American communities	37,764	Funded at $180M of $870M total
San Juan Chama Project	Divert water from the Colorado River basin to Rio Grande basin	96,200	Diversion began in 1972
Sierra Waterworks LLC	Desalinate and transfer groundwater from Estancia Basin to Santa Fe	7,200	Inactive

The objective of this paper is to consider whether new sources of water are in fact likely to be viable and to discuss some of the issues associated with their development. The discussion is presented by considering two case studies, the Eastern New Mexico Rural Water Authority project known more commonly as the Ute Pipeline project, and the Sierra Waterworks proposal to desalinate brackish water from the Estancia Basin and pipe it to Santa Fe.

Eastern New Mexico Rural Water System

The Eastern New Mexico Rural Water System (ENMRWS) or Ute Pipeline, was a project conceived in the 1960s to provide water to communities in Quay, Curry, and Roosevelt counties (USBOR, 2011). Ute Dam was constructed in 1962 on the Canadian River and enlarged in 1986 creating a reservoir with a maximum capacity of 272,000 AF. Though the Canadian River subsequently flows into Texas and then Oklahoma, the Ute Pipeline project is possible because the Canadian River Compact gives New Mexico free and unrestricted use of water in the river as long as storage below Conchas Dam is less than 200,000 AF. Due to the presence of other lakes in the basin, 193,240 AF of water can be stored in Ute Reservoir before water must be spilled and delivered to Texas.

The New Mexico Interstate Stream Commission determined that the sustainable yield from Ute Reservoir is 24,000 AF/yr (USBOR, 2011). In its current form, the ENMRWS will transfer 16,450 AF/yr to communities participating in the project and 7,150 will be available to communities that are not part of the Ute Pipeline project (Table 2). The Ute pipeline will consist of a large pump station to lift water to the top of the caprock, a water treatment plant, and 151 miles of pipeline (Figure 1). The total cost is projected to be nearly $500M of which 75 percent is to be paid from federal funds, 15 percent by the State of New Mexico, and 10 percent from local funds.

Table 2. Apportionment of water from the Canadian River at Ute Reservoir

Participating Communities	Amount (AF/yr)	Existing Use (AF/yr)
City of Clovis	**12,292**	**6,453**
Village of Elida	**50**	**49**
Village of Grady	**75**	**21**
Village of Melrose	**250**	**143**
City of Portales	**3,333**	**2,149**
Town of Texico	**250**	**162**
Cannon AFB		**1,189**
Curry County	**100**	**714**
Roosevelt County	**100**	**140**
Nonparticipating Communities		
Village of San Jon	**150**	**55**
City of Tucumari	**6,000**	**1,208**
Quay County	**1,000**	**457**

Note: Water usages are 2005 values from Longworth et al. (2008). County totals exclude values for communities listed in this table.

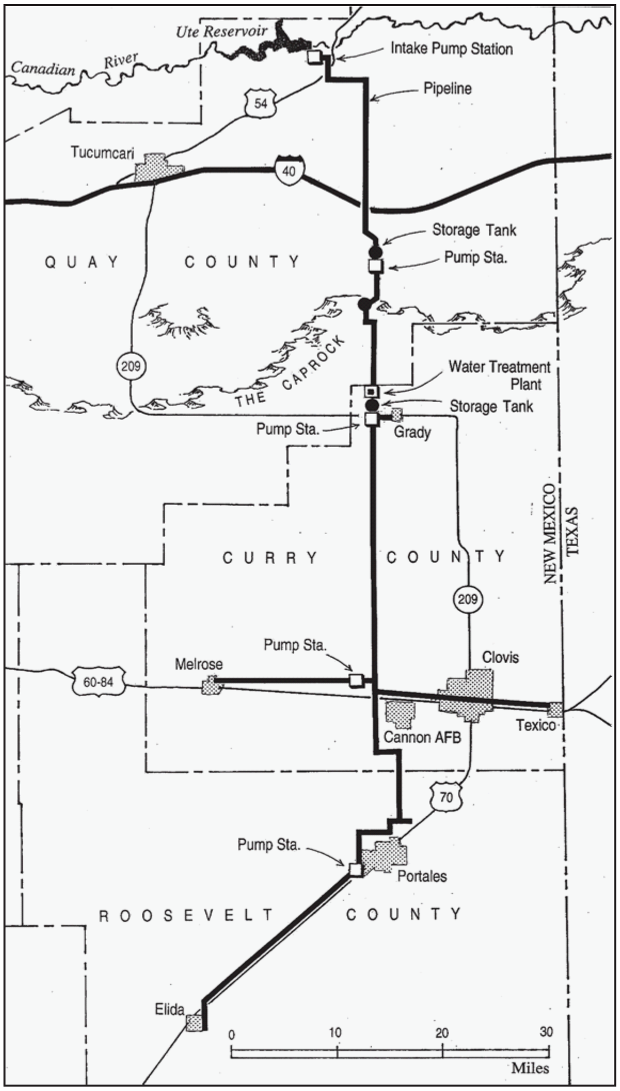


Figure 1. Eastern New Mexico Rural Water System (Utton Center, 2011)

The ENMRWS is justified because all of the communities in the region are entirely dependent on groundwater as their source of supply, primarily from the High Plains/Ogalalla Aquifer. Water levels in this aquifer are dropping rapidly due to extensive pumping, primarily to support irrigated agriculture (Table 3). This has placed enormous stress on public water utilities by forcing them to drill new and deeper wells and these wells are less productive because of the decreased thickness of the saturated zone. The experience in Clovis illustrates this; 62 wells were needed in 2010 to produce approximately the same flow as 29 wells did in 2000.

Table 3. Total annual water diversions in Curry, Quay and Roosevelt Counties (Longworth, 2008).

	Surface Water	**Ground-water**	**Total**
Commercial (self-supplied)	**0**	**820**	**820**
Domestic (self-supplied)	**0**	**1,031**	**1,031**
Industrial (self-supplied)	**0**	**0**	**0**
Irrigated Agriculture	**37,632**	**324,833**	**362,465**
Livestock (self-supplied)	**332**	**18,905**	**19,237**
Mining (self-supplied)	**0**	**143**	**143**
Power (self-supplied)	**0**	**14**	**14**
Public Water Supply	**0**	**11,889**	**11,889**
Reservoir Evaporation	**26,181**	**0**	**26,181**
Totals	**64,145**	**357,635**	**421,780**

There are three principal issues associated with this project: 1) sustainability, 2) environmental impacts, and 3) economic impacts.

Sustainability for the ENMRWS refers to the question of whether the source of supply can sustain the diversion. Average flow in the Canadian River at Logan, just downstream from Ute Dam since the reservoir was enlarged in 1985 is 25.5 KAF/yr, just slightly greater than the amount for the total project. However this average is skewed by very large flows exceeding 90 KAF in 1999, 1994, and 1987. If flows for these years are omitted, the average for the last twenty-five years is 14.8 KAF/yr. Of even more concern is the fact that the average flow in the river since 2001 is only 4.6 KAF/yr. Since the Canadian River Compact requires release of water when reservoir storage exceeds 200 KAF, it is not likely possible to store water from very wet years for multiple years.

Verhines and Gates (2008) report that dynamic simulation modeling of the reservoir shows a modest impact of the diversion on Ute Reservoir water levels. However, similar modeling done at UNM shows a ten-year sequence of dry years, as experienced since 2001, may cause lake volume to drop to less than 20 percent of its total capacity even if the total diversion is reduced to 15 KAF/yr.

The impacts of climate change will further diminish the amount of available water due to the effects of evaporation and diminished inflow. Pan evaporation at Logan is 84 in/yr. Modeling shows annual lake evaporation losses in excess of 20 KAF/yr when the reservoir is nearly full. This will increase with climate warming. Lake inflow from Ute Creek and the Canadian River will decrease due to increased evapotranspiration from the watershed and possibly decreased rainfall. These effects have not yet been modeled.

It is informative to consider the ENMRWS from the perspective of regional water use. While the projected safe yield of 24 KAF/yr will satisfy public water supply needs, it represents less than 6 percent of the total water diversions in the three counties (Table 3); virtually all of the rest of the demand is for agriculture and livestock watering. Thus, an obvious question is raised as to whether the water demand is justified in the face of inevitable declines in the agricultural sectors of the economy as groundwater resources are depleted. This is reflected in population projections for the region that show an approximate 10 percent increase over the next thirty years followed by a decline (Figure 2).

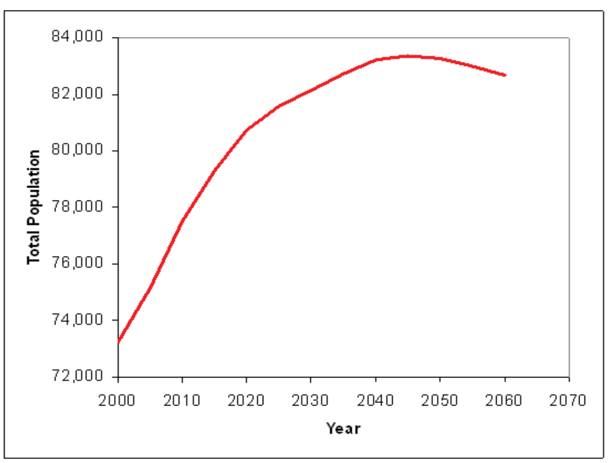


Figure 2. Population projections for Curry, Quay, and Roosevelt Counties (UNM Bureau of Business & Economic Research, 2008)

The economic consequences of the ENMRWS were discussed in the Environmental Assessment (USBOR, 2011). The principal impacts are the creation of jobs and construction expenses during construction of the project, and impacts on tourism and recreation in Ute Reservoir. Project water is to be used only for public supply and thus its economic impact is limited to that associated with replacement of dwindling groundwater supply with a presumably more sustainable surface water supply (USBOR, 2011).

Approximately 350 jobs would be created in the three counties during the five years of the construction phase of the project (USBOR, 2011). The completed project would produce few new permanent jobs, which would principally be associated with operation of the diversion, lift station, and water treatment plant. These jobs and the operating costs of the project would be paid for by increases in water rates for the utility customers, which are projected to range from $164 to $404 per year for each customer.

Perhaps the most uncertain economic impact of the ENMRWS is the potential negative impacts associated with tourism, recreation, and home ownership near Ute Reservoir. A sizeable economy has develop near the lake since it was formed that depends on maintaining a high water level in the lake. The spillway crest of Ute Dam is at elevation 3,787 ft. The USBOR predicts that lakefront and lakeview property premiums would drop 50 to 100 percent if water levels fall below 3,760 ft (USBOR, 20110), which corresponds to a total storage of 76 KAF. Dynamic simulation modeling of the reservoir done at UNM suggests the lake volume will drop to this level within ten years of operation if weather patterns of the past twenty years are repeated. The Environmental Assessment acknowledges that the impact of declining lake levels could be large but notes the difficulty in estimating the value. It is clear that more study needs to be done of this consequence.

Lessons Learned from the ENMRWS Project

The ENMRWS project has been evolving for over fifty years. The principal justification of this project is that communities in Curry, Quay, and Roosevelt counties are rapidly running out of water as water levels in the High Plains/Ogalalla Aquifer drop. The analysis described here identifies two questions regarding the project: 1) will the proposed project actually produce a sustainable supply of 24 KAF/yr, and 2) have the economic impacts been fully considered? Both are difficult topics to quantify and both have a high degree of uncertainty associated with them.

Brackish Water Development in the Estancia Basin

In 1962 then State Engineer Steve Reynolds estimated that 75 percent of the state's water resources were brackish (total dissolved solids or TDS concentration > 1,000 mg/L) or saline (TDS > 35,000 mg/L) (Reynolds, 1962). This estimate has not been quantified in part because this water was never considered to have any value. However, the combination of increased demand for water together with improvements and cost reductions in desalination technology has led to several proposed projects to use brackish water for public supply. Interest in brackish and saline groundwater resources was further increased by New Mexico water law, which did not give the State Engineer jurisdiction over deep aquifers (>2,500 ft) containing brackish water. This was changed by 2009 legislation but not before notices of intent to use 1.7 MAF/yr of deep brackish water were filed with the Office of the State Engineer (Utton Center, 2011).

The Estancia Basin is a 2,260 mi^2 closed basin located in central New Mexico east of the Sandia and Manzano mountains, which form the eastern boundary of the city of Albuquerque. The center of the basin is located in Torrance County but it extends into parts of Bernalillo, Santa Fe, San Miguel, and Lincoln Counties (Figure 3).

Most of the groundwater recharge in the basin is in the form of runoff from the Manzano Mountains to the west. There are six water bearing strata in the basin, however, nearly all pumping is from the shallow Valley Fill aquifer and the deep Madera Group (Table 4). Hawley (2004) studied this basin and published a series of geologic cross sections

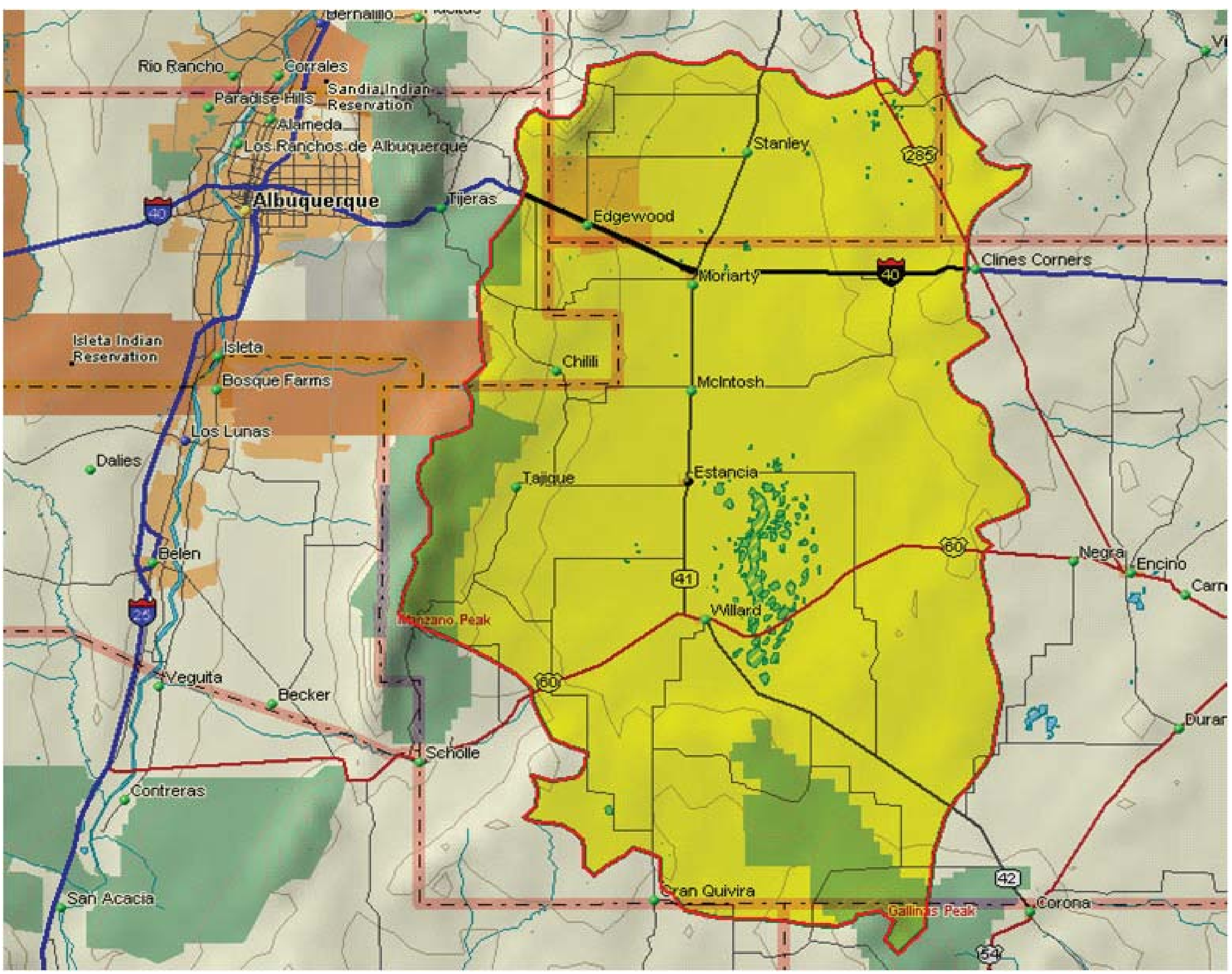


Figure 3. Location of the Estancia Basin (Thomas, 2004)

that identified a shear zone that is parallel to and a few miles east of State Highway 41. This shear acts to a large extent as a groundwater divide such that groundwater to the west has low TDS while that to the east is brackish with TDS values exceeding 3,000 mg/L in many wells.

Table 4. Principal aquifers in the Estancia Basin, the amount of water in storage, and their depletion rate (EBWPC, 2008)

Water Bearing Unit	Groundwater in Storage (MAF)	Depletion Rate (KAF/yr)
Valley Fill	6.58	52.1
San Andres Limestone	0.067	N/A
Glorieta Sandstone	5.85	N/A
Yeso Formation	23.8	N/A
Abo Formation	44.9	N/A
Madera Group	11.1	61.2

A proposal was made in 2005 to transfer 7,200 AF/yr of water from the east side of the basin to Santa Fe, New Mexico after desalinating it (Soussan, 2005). This constituted an interbasin transfer with a new twist that involved extraction and desalination of brackish water. It is informative to use this project to consider the impacts of this concept.

First, consider the impacts on groundwater resources. It is evident from Table 4 that groundwater resources in the Estancia Basin are all ready being depleted at greater than 110 KAF/yr. One of the consequences of this depletion is increasing salinity in public supply wells as shallow fresh water aquifers are depleted (White, 1994). The objective of the regional water plan was to reduce this overall depletion to 20 KAF/yr by 2040 (EBWPC, 2008). The proposed diversion is not consistent with this goal.

Thomson and others (2008) discussed development of brackish and saline water resources in New Mexico and surrounding regions and noted that, with few exceptions, these groundwater supplies are not sustainable. In most cases the water is very old and the high salinity is due to either concentration of dissolved minerals through evaporation or due to dissolution of soluble minerals present in the subsurface formation. In either case, the high salinity is evidence of very limited recharge, which would otherwise dilute the salt content. Thus, an obvious concern when considering brackish groundwater sources is its long term viability. Similar concerns have been raised regarding other proposals to develop brackish groundwater resources in New Mexico.

Introduction of desalination to the project adds a new layer of complexity. There are three concerns. First, desalination only recovers a fraction of the water that is treated. The Kay Bailey Hutchison Desalination Plant in El Paso, Texas treats groundwater with a TDS similar to that in the eastern Estancia Basin. It recovers 75 percent of the feed water. Thus, a plant to produced 7,200 AF/yr of water would have to pump 9,600 AF/yr of groundwater.

This leads to the second problem, concentrate disposal. A desalination plant produces a concentrate or brine that contains all of the salts from the desalination process. The Estancia Basin project would produce 2,400 AF/yr of salt water containing a TDS of approximately 12,000 mg/L, one-third the salinity of seawater. There are two options for concentrate disposal from an inland desalination plant: deep well injection and evaporation. Deep well injection as practiced in El Paso involves a 22-mile-long pipeline and three approximately 4,000 ft deep wells. Estancia is a bit unique because it is a closed basin with several salty playa lakes near its center. It might be possible to dispose of the desalination concentrate in these lakes, however, this would require a water balance study to determine its feasibility. Regardless, either disposal method would be costly and complicated.

The third challenge regarding the desalination process is the energy requirements. The energy required to produce 7,200 AF/yr of desalinated water was estimated at 11 Mwh/year for the desalination process alone. Concentrate disposal and pumping this water to Santa Fe would significantly add to this energy demand. Because New Mexico relies upon coal for electric power, the carbon footprint of the plant would be approximately 20,000 lbs of CO_2/d. It is clear that the power and environmental impacts of desalination projects are substantial.

Lessons Learned from the Estancia Basin Project

As with the ENMRWS, the fundamental issue of the Estancia Basin desalination and interbasin transfer project is whether the water supply is sustainable. Because the Estancia Basin project calls for development of a brackish groundwater source in a location with almost no recharge, this supply is not sustainable. The magnitude of the resource was not determined hence the lifetime of the project is not known. The fact that the groundwater resources is limited leads to another impact that isn't likely to be experienced with the ENMRWS, increased drawdown of neighboring wells and decreased water quality in them.

A second series of consequences of the Estancia Basin project are those related to the desalination process. One of the most significant is that desalination processes recover only a fraction of the water pumped, estimated at 75 percent. This means that a large volume of highly saline wastewater will be produced, which will require careful management to prevent environmental contamination. Finally, desalination processes require an enormous amount of energy that result in large emissions of CO_2. Although this factor is not considered in current interbasin transfer projects, it almost certainly has important environmental consequences and likely will be an important criterion in evaluating future projects.

Concluding Remarks

Interbasin transfer projects have considerable appeal as a means of increasing a community's or watershed's water supply. However, few resources are actually available. This paper examined some of the issues associated with interbasin transfers by considering two projects in New Mexico.

An analysis by the New Mexico Interstate Stream Commission shows that the Canadian River can provide 24,000 AF/yr sustainable supply to communities in eastern New Mexico. The Eastern New Mexico Rural Water System is a project to deliver 16,450 AF/yr of this total to Portales, Clovis and other communities in eastern New Mexico that has been approved by Congress but not fully funded. The analysis in this paper examines whether the watershed can actually provide this volume of water. A second concern regards the economic impact that the diversion would have on the economy of Ute Reservoir.

The second project considered in this paper is a project in which 7,200 AF/yr of water would to be pumped from the Estancia Basin to Santa Fe. This would entail pumping about 9,600 AF/yr of water from brackish aquifers in the eastern part of the basin and desalinating it. The issues raised in this paper deal with the long term sustainability of a brackish groundwater source, as well as the energy requirements and waste management concerns associated with the desalination process.

The issue of long term sustainability is a common thread in these and other interbasin transfer projects. Further concerns are the economic and environmental impacts. While environmental impacts appear to be limited for the ENMRWS, the economic consequences are substantial. For the proposed Estancia Basin water project, the principal environmental issues are centered around the impacts on the aquifer and other water users and those associated with concentrate disposal.

References

Augustin Plains Ranch, LLC. 2011. Water Resources Development Project, Cordova Public Relations, April 11, 2011. (www.nmlegis.gov/lcs/handouts/Augustin-Plains-Ranch-Water-FINAL-3-25-11.pdf). 10 p.

Estancia Basin Water Planning Committee (EBWPC 1999). Estancia Basin Recommended Regional Water Plan (Year 2000 to Year 2040), prepared by Corbin Consulting, Inc., Santa Fe, New Mexico. 142 p.

Hawley, J.W. 2004. Hydrogeologic cross sections of the Estancia groundwater basin, central New Mexico: New Mexico Water Research Symposium (N.M. Tech-8/10/2004), NM Water Resources Research Institute, New Mexico, Symposium Program and Abstracts, p. E-15. http://wrri.nmsu.edu/con/tc3/tconf.html

Hurd, B.H., Coonrod, J. 2008. Climate Change and Its Implications for New Mexico's Water Resources and Economic Opportunities, New Mexico State University, Agricultural Experiment Station, Technical Report 45, Las Cruces, New Mexico. 28 p.

Longworth, J.W., Valdez, J.M., Magnuson, M.L., Albury Sims, E., and Keller, J. 2008. New Mexico Water Use by Categories 2005, Technical Report 52, New Mexico Office of the State Engineer, Santa Fe, New Mexico. 111 p.

Reynolds, S.E. 1962. Twenty-fifth biennial report of the State Engineer of New Mexico for the 49th and 50th fiscal years July 1, 1960, to June 30, 1962: Albuquerque, The Valliant Company. 193 p.

Soussan, T. 2005. New Mexico Cities Covet Rural Water, Albuquerque Journal, Sunday, January 23, 2005.

Thomas, R.P. 2004. Estancia Basin Dynamic Water Budget, Sandia National Laboratories Report SAND2004-1796, Albuquerque, New Mexico. 19 p.

Thomson, B., Shafike, N., Hawley, J. 2008. Inland Saline Water Sources for Public Supply: Sustainable Future or Delayed Disaster?, Nonrenewable Groundwater Resources, conference sponsored by the National Groundwater Association, Portland, OR. Oct. 14, 2008.

Thomson, B., Shomaker, J. 2009. Municipal Water Reuse Isn't Necessarily Conservation, New Mexico Water Dialog, Santa Fe, New Mexico, *New Mexico Water Dialogue*, fall 2009 issue. pp. 3-4.

U.S. Bureau of Reclamation (USBOR). 2011. Eastern New Mexico Rural Water System Environmental Assessment: Quay, Curry, and Roosevelt Counties, New Mexico, Upper Colorado Region, Final Environmental Assessment, U.S. Bureau of Reclamation, Albuquerque, New Mexico. 144 p. (www.usbr.gov/uc/albuq/envdocs/ea/EasternNM/Final-EA.pdf.)

Utton Center. 2011. Water Matters! The Utton Transboundary Resources Center, University of New Mexico School of Law, Albuquerque, New Mexico. 90 p.

Verhines, S., Gates, G. 2008. Just Add Water: Eastern New Mexico Rural Water System Status Report, Surface Water Opportunities in New Mexico, proceedings of the Annual Water Conference, New Mexico Water Resources Research Institute, Las Cruces, New Mexico.

White, R.R. 1994. Hydrology of the Estancia Basin, central New Mexico / by Robert R. White, USGS Water-resources investigations report 93-4163. 83 p.

How Santa Fe Plans to Meet its Growing Water Demands

Claudia Borchert, Sangre de Cristo Water Division

Claudia has been working as a Water Resources Coordinator with the City of Santa Fe Water Division for over seven years, bringing her total years working in water resource management to sixteen years. Her main focus is implementing the City's Long Range Water Supply Plan, reviving a living Santa Fe River, managing the City's water portfolio, and developing a sustainable groundwater management program. Claudia received her MS degree from UNM's Department of Earth and Planetary Sciences in 2002, and a BS degree cum laude in geology from Amherst College in 1990. Her work passion is having 'difficult' conversations with various water users to find out-of-the-box solutions.

As I look around the room today and as I participate as an audience member, I'm always amazed at the vast amount of knowledge, the experience, the talent, and the good-naturedness of our audience. I am both honored and humbled to be able to speak to you today about our water picture. In most ways my presentation will be the same as lots of the other topics that are covered. Mostly what Santa Fe does is stretch available water resources, we protect and conserve our current supplies, our cultures, our environment, and our identity and quality of life; and we figure out how to accommodate for change such as growth, climate change, demographics, and often unknown change.

I am a firm believer that you have to look back in order to move forward; we have to be cognizant of our past. There is a quote on an old state archive building in Santa Fe that says, "Those who forget the past have no future." So today I am going to combine looking at the past and looking forward. I'll first cover some accomplishments, our plans for the next decade, and a little bit to address what I think is a very important question, the theme of this conference, which is how have institutions evolved and how they need to evolve.

Figure 1 provides our historical water use in Santa Fe. We are celebrating our 400-year anniversary this year, but this graph actually reflects usage from the beginning of a water utility. The city grew up around the Santa Fe River, which met the community's entire needs until it ran out by the 1940s and the city started using groundwater, which is true of most municipalities. In the 1990s, two-thirds of our water came from two groundwater sources, the city wells and the Buckman wells. Part of what I'll be talking about is just how dramatically that is changing for us in the future.

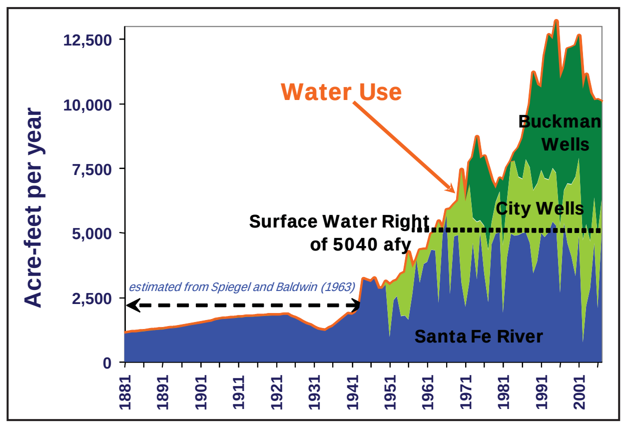


Figure 1. Historical water use in Santa Fe

Out of the vast uncataloged and mostly forgotten files that we have in our own organization, many of them inherited from the Public Service Company of New Mexico (PNM) or Sangre de Cristo Water Company, I looked at two documents that give a view of our past. One is, *People and Water*, 1984, and the other is from 10 years ago, the proceedings from this conference that was entitled, *Water, Growth and Sustainability: Planning for the 21st Century*. I looked at these references to see what kind of ideas people had suggested in the past. I sometimes get the sense that we are doing the same thing over and over again and ideas have been around for a quarter of a century and we are not actually moving forward. The handout that has been passed around (Appendix A) provides a tally of what we have accomplished in Santa Fe. I will also say that it is not that Santa Fe is in any way unique in what we have accomplished. Accomplishments have been made throughout the state and as you look at the handout, there are similar kinds of accomplishments that you can think about for your own organizations. We are also not unique in creating solutions by ourselves. Through collective efforts, we have made significant progress, both the City of Santa Fe itself and while working with others. I am going to highlight five that I think are our most important five accomplishments of the last ten years.

The first is demand reduction (Fig. 2). Everyone talks about the need to use water more wisely. I feel like we have done a good job of that. When we tracked our own numbers, we have gone from 168 gallons per capita per day (gpcd) in 1995 down to around 100 gpcd today. Using the Office of the State Engineer (OSE) methodology (which is in green), we started around 136 gpcd in 2003 and we are at around 109 gpcd now for total use. As you can see, our population continued to grow so we have been able to reduce our demand quite dramatically.

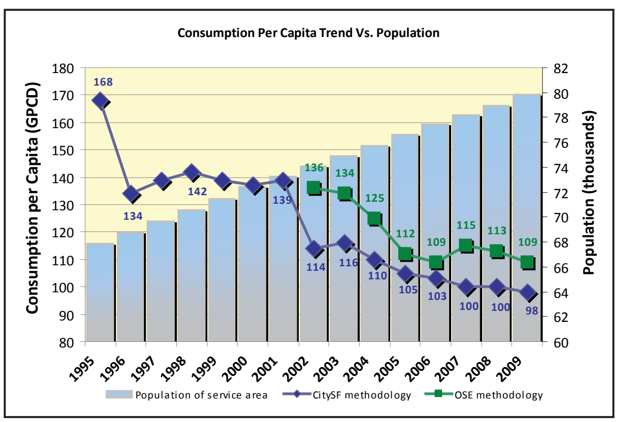


Figure 2. Demand reduction

Also, I feel that water supply planning is really important because you have to understand the beast with which you are dealing (Fig. 3). If you don't know what you are dealing with, you don't know how to solve your problems. We initiated a water supply planning process in 2003. Figure 3 is a chart from 2005 and shows our groundwater dependence and the transition zone between historical and projected use. First, you can see the huge amount of savings into the future that conserved water gives you. We will be bringing surface water online with our San Juan Chama water next year, and by using the Santa Fe River, we will greatly reduce our reliance on groundwater. We do still have a gap and I will talk a little bit about how we plan to bridge that gap. So water supply planning has been important for us.

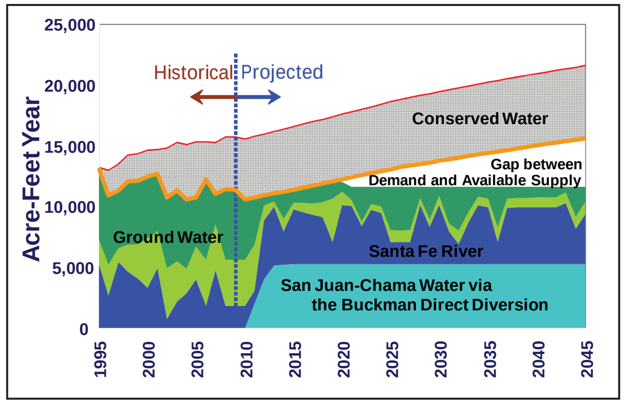


Figure 3. 2005 Water supply planning

The Buckman Direct Diversion Project, which many of you probably already know about, will allow us to use our 5,230 acre-feet of San Juan-Chama Project water. What's really key here is that right now, in a good year, we can use up to 50 percent surface water; next year and for the next ten years, we will be able to use, in an average precipitation year, around 90 percent surface water. That will be a huge change from our heavy reliance on groundwater. The other accomplishment that I feel makes a big difference for us is the management of our upper watershed. Together with the Forest Service, we thinned over 7,000 acres through mechanical and hand-treated fire reduction methods. We have reduced tree density from about 1,000 trees per acre to about 60-100 trees per acre. Obviously the reason we do that is to help protect our water supply from the vulnerability of fire. We have adopted an Upper Watershed Management Plan, received $1.3 million from the Water Trust Board to implement the Plan over the next three to five years. Part of the implementation is to look at "ecosystem services" as the mechanism to help pay for the continued maintenance of that watershed.

Finally there is stewardship of the environment, particularly, in our case, the Santa Fe River. It was declared "America's Most Endangered River" in

2007. For the last 3 years, we have been releasing or bypassing water from our water supply to the Santa Fe River (200-800 acre-feet a year). I don't know exactly where this will lead. I don't know what kind of river we may get with that amount of water, but our mayor, in particular, and elected officials and the citizens of Santa Fe, are committed to trying to keep the Santa Fe River from going dry.

So what are we going to do next? Figure 4 is a chart similar to what we saw earlier, although Figure 3 was done in 2005 and I have updated this one for 2010. We are in a very fortunate position now because of our planning work, especially the Buckman Direct Diversion coming online. Our gap as I project it, now doesn't appear until about 2030. The gap in Figure 3 was actually appearing in 2015, but the gap has now been pushed out another 15 years because of our continued conservation. It speaks so much to the value of conservation. We have the next 10 or 15 years to continue to decide on our plan. We also have breathing room to decide to do the kinds of things that we know are of value in progressive resource management, such as conjunctive use. We can use the surface water when it is available, and save our groundwater for drought and for climate change emergencies, for example. We have the luxury of looking at what we can do for our ecosystem.

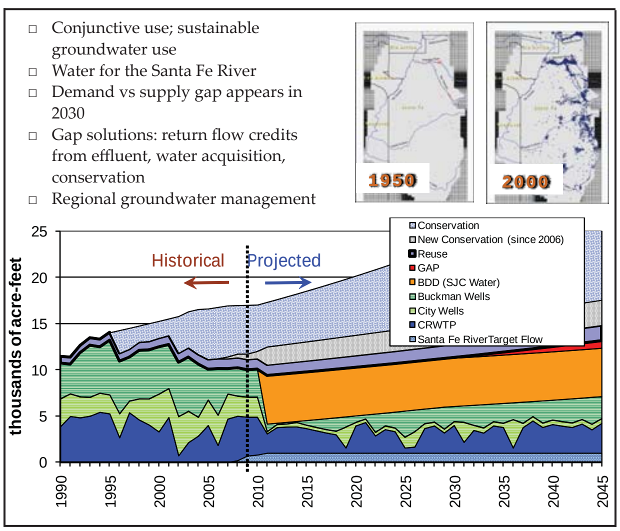


Figure 4. 2010 Water supply management

We have time to decide what the best thing is to do with our gap. The current thinking is that we can get return flow credit for some of our wastewater by sending it back to the Rio Grande and divert an equal amount. We also have a water acquisition program but it is fairly modest I think.

And we can do more conservation. Something we do have to start working on right now is regional groundwater management. The maps at the top right of Figure 4 are from our regional groundwater model and they show the amount of domestic wells that were in this basin area in 1950 versus the amount of domestic wells now in 2000. If Santa Fe and our regional partners are going through the great expense of preserving the aquifer for future use or for emergency use and drought use, then we have to figure out how to incorporate domestic wells in regional management.

We have talked about additional conservation (Fig. 5). We are considering trying to have targets of either reducing one or two gcpd targets per year over the next ten years. Storm water hasn't been discussed too much here today but obviously, it is still a resource that we need to look at and will be discussed later in this conference. A vast amount of water flows from a given thunderstorm, a circumstance that is supposed to be exacerbated by climate change conditions. Figure 6 is the Santa Fe River flowing at probably 100 cfs, 10 times its average during this period. On the right is a local arroyo that has an outfall from the arroyo Mascaras where there has been some work where the water jumps around from pool to pool, slowing it down, and allowing it to infiltrate. It is a small example of what we need many, many more of throughout the basin.

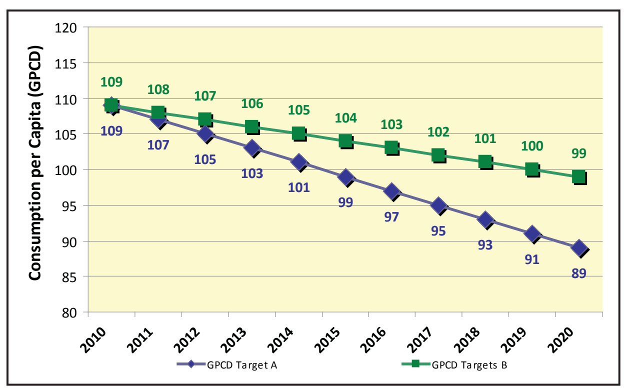


Figure 5. Possible City of Santa Fe gcpd targets

Figure 6. The Santa Fe River flowing at about 100 cfs

Another thing we have to work on now since we aren't in crises mode is to secure our water rights. I feel it is easier to plan and share if you know how much you have. We are particularly working on securing our pre-basin city groundwater rights of 4,865 acre-feet. We are participants in all kinds of settlements and agreements and want to do more of that because we feel like that is the way to go. It's been a theme you've heard here this morning. Adjudications are not necessarily the most effective way to work things out. We also monitor local water right transfers and protest as necessary.

We will continue to have and put effort into the Santa Fe River. Maybe you heard about the event that was held the Saturday before Thanksgiving called "flash flood." It was an action using art as a way to highlight the dire needs of the Santa Fe River. A couple thousand people lined up in the river and at some given cue they flipped over their cardboard from brown to blue. The photo in Figure 7 is what it looked like from satellite images, a small token of water for the river.

Figure 7. Satellite view of "mimic hydrograph"

We are currently trying to figure out how to put more water into the Santa Fe River and elected officials are considering allocating 1,000 acre-feet to the river. The tricky thing is 1,000 acre-feet does not create a sustaining living river, any more than what the art activists did. With the 1,000 acre-foot budget, we have to figure out if we want year-round flows for a short distance, do we want to have larger flows throughout the downtown but only during the summer, do we want bi-monthly pulses that allow the vegetated corridor to become more riparian, and how does the idea of mimicking a hydrograph fit into all that?

Then there is climate change: assessing, adapting, and mitigating. We need to evaluate our supply vulnerability. We acquired a 700+ year stream flow record reconstructed from tree ring data and we need to figure out how we can use that in our water planning, as well as reasonable consideration of climate change models. We need to consider how to use dual supply systems of surface and groundwater, and we need to go green. We need to reduce our own emissions. We are working on how to use our wells and our energy efficiently. I think the Albuquerque Authority has a program like that. One-third of the Buckman Direct Diversion Project electrical needs will be supplied by a nearby solar PV array. We are installing hydroelectric generators in some of our transmission lines. We need to continue our efforts to go greener with our energy supplies and use.

The last concept here is the idea of institutional evolution. How has our institution evolved in the last couple of years to accommodate our current conditions? A big one was that the City purchased the utility from a private entity, PNM, in 1995. Publicly owned water supply was a reoccurring theme that, as I look back in the documents, has been important since the 1880s when the utility was first established. Throughout Santa Fe's history, the city council and the people of Santa Fe tried to get local control of their water.

We have also set up a water bank that allows water conservation and acquisitions to go into the water bank and then either be applied toward development or resold. The City of Santa Fe is buying some of those water rights. We feel like markets are important for being able to have the water go where it needs to go, provided that growth is linked to a sustainable supply. But that is a whole other topic that I won't go into today.

So what is it that I feel the City needs to do in the future? We need to make local decisions in the context of the whole. I think Bruce Thomson talked about this too, earlier. We need to consider the concept of cradle-to-grave, which means going beyond only the cost of a project. Decisions need to consider energy impacts, economics, the food production impact, the efficiency impact, the social, the cultural, the ecosystem, and the sustainability impacts of any project or action. And it is really hard to incorporate all those considerations into making a decision.

We also need to increase intra- and inter-agency conversations. I am amazed about how often I found out about a project that's going on by the engineers who work down the hall from me, where a little bit of a conversation could provide mutual benefits. Another example is the shift at the OSE these days to have stream gaging become more of an OSE function as opposed to a USGS function. Traditionally stream gaging has been under USGS domain, but if we could all get onboard and have all stream data go to one place and have it managed collectively, I think we could all benefit.

I think we are in an era where we have an obligation to the community to include them more and to be more responsible and transparent to them. That is sometimes hard. All these things I'm suggesting take time and we all know that we are strapped for time, but we really need to evolve. We excel at technical solutions, but I think now it is the human solutions that we need to move toward. Part of that is also encouraging creativity and entrepreneurial opportunities.

Here is an excerpt from the 2000 proceedings from Nelson Cordova who gave this quote at the end of his talk. "How water problems created by generations of confrontations are addressed will depend on the ability, the vision, the compassion of persons given the awesome responsibility of coming up with solutions, but they must be resolved if we wish to live in harmony." I would just add to that part of how we do that is having those hard conversations that people don't like to have. I'm working for a municipality and we will need more water. I feel like we have been very responsible about managing and stewarding the resources we have, and if you have suggestions on how we can continue to grow and meet your needs too, we need to have that conversation. It is not about giving and taking. It is about finding the solutions together.

Thank you.

APPENDIX A

WATER-RELATED ACCOMPLISHMENTS FROM THE PAST DECADE CITY OF SANTA FE AND COLLABORATORS

Supply Management

- Provide safe, reliable drinking water supply
- Drilled additional Buckman wells to match production capability to groundwater right (3)
- Secured permanent City SF San-Juan Chama contract in 2005; previous expiration date of 2016 (3)
- Maximize San Juan-Chama surface water use via a surface water division structure, online in April 2011 (2) (3)
- Leased 3000 acre-feet/year of Jicarilla Apache tribal water rights (4)
- Initiated water acquisition program
- Cooperate with local pueblos and acequias (1) (4)
- Treated 6,000 acres of forest in the Santa Fe River Upper Watershed to reduce risk of catastrophic fire in SF Upper Watershed
- Monitor water right transfers; intervene if necessary to protect City's or the region's senior water rights; eg. Anaya, Aamodt, Hyde Park Estates (1); (4)

Demand Management

- Reused water demand (e.g. conservation, emergency and drought management ordinances) (1)
- Adopted tiered water rates

Ecosystem

- Provide for ecosystem needs: Santa Fe River, Buckman Direct Diversion operations, Santa Fe River Upper Watershed (5)
- River restoration projects

Green

- Designed and installing a 1 megawatt (mW) solar facility at the Buckman Direct Diversion
- Designed and installing a 100 kilowatt (kW) hydroelectric within the City's gravity transmission lines, which will generate about 400 kW of electricity annually

Future Supply

- Purchased water utility (1)
- Linked growth to water demand (1) (3) (5)
- Established water bank
- Completed Jemez y Sangre regional planning process (2) (3) (6) (7)
- Plan for ways to meet gap between existing supply and future needs (return flow credit, stored San Juan Chama water, relinquishment credits, water acquisition)
- Adopted Upper Watershed Management Plan to continue progress made

Fiscal Responsibility

- Received $60M from state and federal sources for water projects (1) (3)
- Adopted tiered water rates
- Increased water rates
- Cost Share with US Forest Service on maintenance of upper watershed

Measurement and Water Resources Science

- Increased understanding of water resources in our basin (OSE, USGS, NMBGMR, CitySF, SFCounty, NMED, USFS, Reclamation) (1) (3)

Sources:

People and Water, 1984 (1)

Proceeding from NM Annual Water Conference, 2000: (2) Eluid Martinez, (3) Tom Turney (4) Fidel R. Lorenzo, (5) Nelson J. Cordova, (6) Peter C. Chestnut, (7) Stan Bulsterbaum

City of Santa Fe Water Division 12/01/2010

The Future of Our Water Agencies: Do We Have the Right Agencies Doing the Right Things?

Bill Hume, journalist and formerly with Governor Richardson's staff

Bill was born in Albuquerque, raised and graduated from high school in Socorro, and is a U.S. Army veteran (three years). He began working at the Albuquerque Journal in 1966, and worked there until the end of 2002, at which time he joined the staff of Governor Bill Richardson as director of policy and issues. In Bill's tenure on the governor's staff, his primary areas of responsibility were water matters, Mexican affairs, and Native American issues. Other than service on the Governor's Blue Ribbon Water Task Force, the New Mexico-Chihuahua Commission, and the Commission on Indian Affairs, he has been in retirement since late 2009. Bill has agreed to help out in the final two months of the administration at the New Mexico Border Authority, headquartered in Santa Teresa, NM, but intends to go to full retirement status with the onset of the new year. He is married to Elizabeth G. Hume and they have two adult children, a son and a daughter.

Greetings to you all. It is always my pleasure to be in a concentration of New Mexicans engaged in water law and policy. There is no more important–or stimulating–group in all of New Mexico government and society

I should by rights be intimidated at the thought of talking water issues to such a learned assembly. But, three decades in the ivory tower of a newspaper–topped by seven years among the learned, and less learned, staff of Governor Bill Richardson–have cured me of any virtue of knowing my own limits.

Now, when I agreed to undertake this conversation about the coming evolution of our water institutions, I envisioned comments about lists of record for water rights, mandatory disclosure of appurtenant water or lack thereof in records of land ownership, the continuing saga of adjudication. In other words, my thoughts about the things you all had been wrestling with for years, with greater or lesser progress recorded.

Then, virtually on the eve of this event, the New Mexico Court of Appeals rendered two water matter decisions that work significant change on sections of our water law. I refer, of course, to Tri-State–the ruling on Active Water Resource Management regulations, and to Bounds–the ruling upholding the constitutionality of the Domestic Wells Statute.

I am not a lawyer, so my thoughts that follow are but the musings of a somewhat informed observer, perhaps somewhat hyped by the habits of an unrepentant newspaper editorialist. But looking at those two decisions, in summary, I think the court may have accomplished more than it intended.

As you all know, priority of appropriation is the gold standard of water rights characteristics. The more senior the right, the greater the assurance of access to water. The power of that protection depends on at least the threat of priority enforcement.

However, Tri-State says that the engineer may enforce priorities based only on water rights that have been adjudicated by a court, or licensed by the State Engineer. All others are immune to priority enforcement–which as I read it means there can be NO priority enforcement in any but fully adjudicated basins. How can you enforce priorities when some classes of users are exempt from the process?

But in Bounds, the court finds that the Legislature may instruct the State Engineer to issue domestic well permits without regard to senior water rights, because, as the court put it, priority of rights is only a broad principle.

It seemed to me that the two decisions are contradictory in some respects. The court in Tri-State said that since the Legislature didn't specifically say the State Engineer could enforce priorities in the manner he wished, he didn't have that power. Yet, in Bounds, the court said that "the priority doctrine is but a broad principle."

"Although priority calls have been and continue to be on the table to protect senior users' rights, such a fixed and strict administration is not designated in the Constitution or laws of New Mexico as the sole or exclusive means to resolve water shortages where senior users can be protected by other means."

Where the apparent conflict between priority enforcement and domestic well permits is concerned, "We further must presume that the Legislature has determined that it sees the hydrological expertise of the State Engineer as the preferable, IF NOT THE ONLY REASONABLE WAY to attempt to reach the right balance of priorities and needs."

So, the Appeals court has left us with the seemingly inconsistent duality that the State Engineer can use his hydrological expertise to protect the senior agricultural water users from the encroachment of tiny domestic wells–but that protection from the gargantuan Johnny-come-lately municipal and industrial users must await the completion of basin-wide adjudications. The sum of those two approaches provides scant protection for those seniors.

If a water right that hasn't got a priority date blessed by an adjudication or a State Engineer license cannot be considered in a priority call, is it even a water right under New Mexico law? Could the State Engineer enforce priorities among licensed rights holders in an unadjudicated basin, and move all others to the back of the line?

Pre-1907 water rights are deemed valid by the 1907 Water Code. But, if the determination of their pre-1907 status is dependent upon a priority date, which can only be determined by an adjudication or a license, what is their status before that determination?

What legal force or protection may be ascribed to water rights declarations?

The truth is that Tri-State appears to neutralize the authority to protect senior users in unadjudicated basins. Certainly a senior user with the resources to hire a lawyer could ask a court to limit a more junior user from impairing his right. I leave it to the courts to determine whether a court has the authority to do that which the Appeals Court has said can only be accomplished by adjudication or licensing.

Does the State Engineer now have the authority–or perhaps the duty–to refuse any priority call entered in a basin, which is not yet adjudicated?

Given the relative rarity of priority calls, does this change make any difference anyway?

On the other hand, might some behaviors change for the worse if indeed it became clear that no priority enforcement were possible–or at the very least, water uses that were not adjudicated or licensed were immune from priority enforcement? Think growing communities with lagging water rights portfolios.

And what of federal water rights in unadjudicated basins? The water rights of tribes and pueblos? Can protection of their priority be dependent upon an adjudication or a State Engineer license? If not, how are they to be protected from all state-based water rights claimants in a non-adjudicated basin?

How does the State Engineer or the Interstate Stream Commission act to enforce compact deliveries downstream from basins in which there is no authority to enforce priorities?

It appears to me that the Tri-State decision opened more questions than it answered. How the Legislature, the courts, and the State Engineer deal with this in the year ahead could well be the dominant factor in determining how our water agencies do the right thing in the future.

But Bounds and Tri-State aren't the only items on the agenda for our water agencies.

Water rights adjudication, that necessary prerequisite to priority enforcement, is the complex, cumbersome and hugely expensive process that has been much talked about but little changed over recent years.

I participated in discussions of water rights adjudication reform with representatives of the Administrative Office of the Courts and the Office of the State Engineer. In my mind, the problem of reform boiled down to the fact that most changes that increase efficiency of adjudication either shift the burden of acting to the water user or increase the water user's responsibilities. I refer to the claims-based process used in some of our other Western states. Traditional small water users in New Mexico are having no part of that, however. So it is my personal opinion that any substantial streamlining proposals will founder in that opposition.

Licensing–the second leg of the two-legged Tri-State priority stool–is an interim alternative to full-dress adjudication. But, there is opposition to that as a strategy. Certainly, Tri-State would seem to give some additional strength to the State Engineer's concept of the legal sufficiency and utility of the licensing process.

One question that arose in my mind out of those adjudication reform discussions was the one of who–or what–is the keeper of record for the master list of water rights?

If they are licensed, the record is in OSE files. If an adjudication has been completed, there is a final decree in a court file that provides a snapshot of adjudicated rights at one point in time. But what is the best place, and the best procedure for maintaining the list of lists from an adjudication?

It seems less than efficient to require a court proceeding to alter the list every time Smith sells his water right to Jones. The Office of the State Engineer has long operated under the assumption that OSE is the primary repository for recording changes. I agree. It is the actual list for water rights prior to an adjudication. Post-adjudication changes in ownership, location or use of rights could be recorded there. The court would retain the authority to settle differences.

I think the public interest would also be served by imposing some duties on water rights holders in the system and records of land ownership as well. I haven't thought this through in detail, but I think that it should be required to note on any recorded deed the presence or absence of water rights. Or, in the case of residential properties, the source of domestic water–municipal system, mutual domestic, domestic well, and so on. And, in the case of a domestic well, the new owner would have to affirm that a transfer of the well to new ownership had been accomplished.

Deeds should reflect the presence of acequia water rights. I have heard stories of land buyers clashing with their fellow parciantes over ditch access matters or water use because they don't know–or don't choose to respect–the rights and obligations they acquired along with their land.

The deed description of a farm should not be legally complete without information about its access to water. We make point of diversion and place of use an integral part of a water right; we should make water rights information an integral part of the land record as well.

It must be noted that adjudication reform is likely a dead issue for the immediate future. It can be expected to be one of the processes that ends up largely on the cutting room floor in the budget making process we face in January. Given the dire shortage of funding, things that can be postponed will be.

Another State Engineer function vitally necessary to the smooth functioning of our water allocation system is the efficiency of the water rights transfer system. Additional resources have been allocated in recent years to the State Engineer's processing of transfers, protest hearings, and so on. But the number, complexity, and protests of transfers have grown at a greater rate.

Delays in protested transfers are usually the fault of the parties. But, I fear delays in the processing of all transfers will grow as budget-cutting digs into this area as well.

Help for the thousands of small water systems and mutual domestics across the state never seems to quite keep up with the problems. It, too, depends upon funding–and it will be another place where tightening of budgets will have negative results. In this case, however, failure to perform by the state agencies will be directly reflected in hardship and health risk to New Mexico families.

Another issue that was gaining momentum even while budgets were fat is the issue of dam safety. New Mexico has a daunting number of flood control dams built mostly about 40-50 years ago with federal funding, and designed to protect agricultural lands.

Today too many of those dams are past their useful design lives, were built to more lax engineering specifications than those of today–and are now protecting vast acreages of urban development instead of alfalfa fields. Again, staffing and funding are the keys to progress against this backlog–and neither is likely to be even maintained at current levels in the budget drought ahead.

As the budget makers turn to their splitting-the-baby task, the human services areas–schools and healthcare at the top of the list–have the highest public and legislative priority.

Colorless, bureaucratic functions like water rights administration, and adjudication, become ripe targets for reduction or elimination. It is difficult to make a life-and-death situation out of whether an adjudication case is completed in five years or twenty. And things that aren't life and death will likely get short shrift in the next few years of New Mexico budget making.

I hope the water agencies will be able to at least maintain efforts in keeping their myriad functions from losing ground. But I am not optimistic. The stresses on agency people and the frustrations of their client group will rise in direct proportion to the cuts in funding.

I don't know which I would least rather be in the years ahead: a customer service person in the Office of the State Engineer, or a member of the Legislature trying to make ends meet.

I am not optimistic about the outlook for the capabilities of our water agencies.

As to the current configuration of the various responsibilities for water-related matters, I think the current system is generally appropriate, with one observation for change.

I think the diverse and specialized nature of the various water agencies makes their separation of functions appropriate. The State Engineer shouldn't be determining the environmental parameters of dairy farms and the Environment Department shouldn't be ruling on changes of point of diversion and use of water rights. The Game and Fish migratory bird expert shouldn't be determining the water needs of pecan trees.

However, institutionalized cross-discipline communication on state water activities is very beneficial. The strengthening of the Water Cabinet would provide the framework and mechanism to accomplish that. Established by executive order, the Water Cabinet is a sub-cabinet of all the department heads concerned with water issues. The goal was to impose top-of-the-silos coordination on all water projects and policies.

Environmental considerations would be considered from the beginning in water use and delivery system planning, for example.

We got the Water Cabinet up and running, and it was instrumental in bringing some standardization in the treatment of applications for water project assistance. But we never got much beyond that initial project.

I think the Water Cabinet approach could superimpose the necessary interagency coordination over all aspects of water policy and implementation, without materially restructuring the existing agencies.

There are more problem areas than bright spots in the outlook for water policy in New Mexico. The backlash from some of the more controversial environmental initiatives of the outgoing administration, coupled with the stands on many of these issues advocated in the campaign, set the stage for some potentially bruising struggles in the Roundhouse come January.

But again, for the immediate future at least, it will be the availability of resources, rather than the structural organization and statutory authority of our water agencies, that will be the primary determinant of future success. I fear it ain't gonna be pretty.

Permanent Storage at Elephant Butte: Meeting the Needs of Recreationists

Neal B. Brown, President, Lago Rico, Inc. and Operator of Marina Del Sur, Rock Canyon Marina and Damsite Resort

Neal is President of Lago Rico, Inc. and Operator of Marina Del Sur, Rock Canyon Marina and Damsite Resort. Originally from California, he has lived in New Mexico since the early 1970s and has been at Elephant Butte Lake since 1994. Neal's interests include restoring wetlands and fresh water ecology.

There is a story of a man who was traveling across the southwestern desert when his car overheated. In need of water, he walked to a nearby ghost town and found an old hand pump. Under the hand pump there was a jug of water with a note instructing him to pour the water into the pump to prime it. The note further instructed him to refill and then replace the jug. I ask the question: should he just take the jug of water and use it up? Or should he follow the advice of the note and use the jug of water to prime the pump? You have heard the expression "have your cake and eat it too." It's just not possible with most commodities to have something, enjoy using it, and then still have it to be used again. But that is the scenario of recreation on the lakes and reservoirs. People enjoy the water, use the water, and we still have the water to be used again. As a matter of fact, recreation, because it does not consume the water, is the most profitable water user. And going to the lake is just plain fun.

Standing just over 300 feet tall and more than 1,600 feet long, the dam at Elephant Butte is a phenomenal structure. The dam was built for water storage to be used primarily for irrigation. In addition to water storage, it provides flood protection to cities and farmlands downstream and it generates electricity. The reservoir provided by the dam has been used for recreation since the completion of the dam back in 1916.

Prior to that time, the Rio Grande was just a great big arroyo. Snowmelt and rains would fill the channel and it would run unchecked—destroying homes and farmlands and sweeping away livestock. Flash floods were a common occurrence with the unharnessed river. During hot times in the middle of the summer, or during droughts like we are experiencing now when the water was most needed, areas of the river would be completely dry. For hundreds of years, people living along the river would try to build dams either to keep water around a little longer or to divert it into irrigation canals. These dams had to be rebuilt at least annually because of flooding and were difficult to use given the diversity of flow rate and unpredictable volume and frequency of water flow.

Around the turn of the century when the civil engineers started looking at the project of building a dam, it was a monumental task. Its completion resulted in the world's largest man-made reservoir of that time. The idea of building a dam was that it would hold enough water in the "good times," or wet years, to sustain farmers in the dry years. The dam also provided safety so people could build homes near the river and their farmland would not be threatened with washing away. Having a dam allowed water to flow at a regulated rate over a greater period of time, which is a huge boon to civilization. People were no longer victims of the river but rather partners with the river. This partnership works really well, most of the time.

With the water came recreation. In the 1930s and 40s, less than 20 years after the dam was completed, the United States government used the Civilian Conservation Corps for lake improvements. The Corps was put to work to make the lake more usable. Usable for what? Recreation, of course. Cabins, an RV park, and a restaurant were built along the old railroad bed. A boat repair shop was built along with a gas station, a hotel, and a number of other buildings. Several homes were also constructed.

Just as the dam was built to hold water, the U.S. government had recreational structures built to capitalize on the water that was being held. They recognized the importance of recreation so they poured money into some infrastructure. Private enterprise also capitalized on the water. A marina facility and boat moorings were built. People's interest in recreation motivated these structures. After all, going to the lake is fun. Swimming, boating, fishing, and camping around the lake were a major draw to people. In the early 1940s, the water went over the spillway and the lake was the place to be. Houses dotted the hillsides around the dam site area. It was a great time and a great place to live. The dam site area was a thriving community. Enough children lived there that they filled the school bus every morning. Farmlands downstream were fully developed and being irrigated and they received full water allocations. Boats on the lake were getting bigger and faster. About 70 rental boats were available along with rooms to rent and places to eat. On weekends they were all full. An observation deck was built on the roof of the restaurant to watch the boat races. The recreation at the Butte was in full swing. The water in the reservoir made it all happen.

Then things changed. The upper Rio Grande Basin went into a drought in the late 1940s. The drought intensified in the 1950s. The full irrigation demand was more than the Rio Grande could deliver. Allocations were cut and farmers had to adapt to get their fields irrigated. The lake was spent. The water level reached its lowest point in 1954. Recreation was gone. People's lives changed and they moved away. Stories from people living out there at the time recount how miserable things were. They tell how the lake bed was covered with dead fish and rotting algae. The smell was horrible and parents would not let their children go out there because they were afraid they would catch some disease. People left the area and they never returned. The whole community disappeared. In spite of the dam, there was just not enough water to carry irrigation through the drought. Although the dam had immensely improved the farmers' ability to have water, it was not a guarantee to always have water. The lake elevation vacillated but remained low for a number of years.

As a matter of fact, it was 25 years before the storage in Elephant Butte Reservoir was able to recover so that farmers could have full allocations again for irrigation. Even though the lake came back, the dam site recreation area never returned to the bustling community it once was. There were no children to ride the school bus. When the precipitation came, we saw the wettest period in the lakes history. The lake came up 70 feet in one year. This wet period started in the late 1970s, went through the 80s, and into the mid- 90s. It was in 1985 that for just the second time, the water went over the spillway. It remained full and spilling through 1988. After a short dry period, Elephant Butte Lake filled and spilled again in 1994 and 1995. There were over 16 years of abundance. There was a feeling of comfort and well being; a feeling of prosperity.

Then came the poor runoff in the late 1990s. It was a precursor to the tremendous drop in the first few years of the new century. The fact that the water was dropping was discouraging. The discouragement was made worse by negative publicity. Morale was shattered, any feeling of security or optimism was gone. I know the farmers felt it just like those of us in recreation did. There was a push to get the pumps running to save the crops. With the drop in water came a drop in visitation to Elephant Butte. Visitation dropped to only 800,000 visitors—half of what it used to be. Most other parks would brag about 800,000 people coming, but to Elephant Butte it meant a real hardship. Numerous businesses closed their doors or sold out.

Since then, the area has been in a drought. It appears that we will be starting on our fifteenth year of drought. This will be another year of reduced allocations. Only three out of the last 14 years have had above-normal spring runoff measured at San Marcial at the north end of Elephant Butte. The battle to have a business has been a long one and it's one battle we have had to work together to win. Fortunately, we have been able to overcome the bad press and the fears that were prevalent in the first half of this decade. Visitation has increased to over a million again and the trend is moving upward. With the state and national economic situation depressed, people are in need of a recreational outlet. Elephant Butte is on the increase because it fills this recreation need. It is inexpensive, wholesome fun.

The lake went from being full in the 1980s and 90s to short allotments a few years later. The great dam has improved life for all of us in the Southwest. It has given us quite a bit but it is not big enough to average out the water flow over the length of a drought. If it were twice the size, it still would not be big enough. We need to exercise wisdom and prudence in using this resource. In the past, prolonged drought has been the primary threat to the lake. That is not the case anymore. There are new issues attacking the reservoir.

Some people feel that the river should be kept running all year long. Others would remove the Dam. There are concerns that if the lake fills up, a few of a certain species of bird believed to be endangered will be displaced. Current law may be interpreted such that preserving salt cedars (the new found habitat for the willow fly catcher) may be more important than water storage; more important than the people who use that water.

These factors will determine how much water is available for irrigation. In other words, they will determine when the lake is full or when it is empty. Remember, the reservoir was built primarily for irrigation. Farmers are the ones who create the financial economy that the rest of us are trying to spread around. Anything that is going to be done that impacts the farmers needs to have the farmers' input taken into consideration; the impact on farmers must be accessed before it is implemented. All too often, decisions are made based on false science spewed out by eloquent orators. We are all aware of ridiculous laws that have been passed that are impractical and regressive. These decisions are frequently made by well-meaning but disconnected government officials and result in huge expense and misery for mankind. There is a fable about a chicken who was hit on the head by an acorn. The chicken then gathers as much support as it can from the other animals and gets them all stirred up in a frenzy in its cause to save the world. Just like in the story of Chicken Little, there are times when someone has a perceived issue (such as the sky is falling) and they are willing to sacrifice the well-being of everyone else to solve their imaginary problem.

In these cases, the solution is to the detriment of mankind. We need to get rid of these ridiculous laws and we need to be careful not to write or allow to be written any more ridiculous, unreasonable laws. People will—and do—suffer the consequences of these bad laws. With all that said, right now, in our community, there are people using good judgment in preserving the reservoir. We applaud the efforts and wisdom in channeling the north end of Elephant Butte. Another great idea to support is water banking. The eradication of water-wasting salt cedar trees has been profitable and should continue, especially along the Rio Grande corridor. Can you see how recreation fits into all of this? Just like the farmers, recreation is impacted by the amount of water available.

When the lake is full, there are no water costs for recreation. All that is needed for recreation is water to play on. As I said before, people who play at the lake use the water but they don't consume it. Only when the lake is at its lowest point is there a cost associated with the water to play on. That cost is minimal and it is worth it to keep some water in the lake. Recreation allows us to make money on the same water twice. This means more businesses in our community, more people working, more money in the economy, and an improved quality of life. There are a lot of benefits manifest by people coming to the lake.

Did you know that tourism is the number one employer in the state, providing more jobs than any other industry? After oil and gas extraction, the tourism industry is also number one in bringing in revenue.

As a recreation destination, the Rio Grande corridor has millions of visitors each year. Elephant Butte Lake is by far the most visited state park in New Mexico. With between one and two million people coming annually, Elephant Butte makes up almost 25 percent of all of the visitors to the state parks. In other words, almost one fourth of the state park visitors throughout the whole state visit Elephant Butte Lake. Consequentially, Elephant Butte generates more money than any other State Park. Elephant Butte provides more than 20 percent of the revenue that State Parks take in statewide. Money derived from Elephant Butte helps support the rest of the state park system. In addition to fishing and water sports, the lake is used for numerous other activities such as biking, hiking, bird watching, and camping. Locals are not the only ones who use the lake. We see people from around the world. It draws people from all over the Southwest who make regular visits.

Remember, going to the lake is fun. It lifts your spirits. There are a lot of reasons why people go to the lake but underlying all of them is the fact that it is enjoyable and affordable for everyone. And it just makes you feel good.

In addition to all of the people, the lake area is visited by about 300 species of birds, some of which are waterfowl that depend on Elephant Butte for a winter home. Because the Rio Grande corridor is in a principle route on the central migratory flyway, it provides a safe stopping point for waterfowl and other migrating birds traveling across the continent. Additionally, the lake is an ecosystem that supports numerous species of fish and animals in the area.

Keeping water in the lake makes sense, economically and environmentally. Like keeping water around to prime the pump, having water around also keeps the economy primed.

Let me share a couple of analogies of what happens when the lake is drained to its lowest point. In relationship to the environment: You can compare running all the water out of the lake to driving your car until it runs out of gas. It may be very inconvenient, but you can go get a gas can, put gas in the car, and get down the road. Other than the trouble caused by the inconvenience, it is an easy fix. If the water is drawn out of the lake, most of the pelicans and other birds will go somewhere else, but they will probably survive as a species. Some of each of the species of fish will survive to repopulate and those that don't survive can always be restocked. Although a lot of plants will die, there will still be a seed base. Even though it will be a stinking, rotting mess of algae and fish, nature will take care of it. Although it will take years and it won't ever be quite the same, environmentally speaking, the lake can be environmentally fixed by simply filling it back up with water when the drought is over.

Now consider the economic consequences. Draining the lake is like driving your car and running out of oil. It is not only inconvenient, it is very, very expensive. Putting oil back in the car will not fix the engine. Economically speaking, pulling all of the water out of the lake is much more difficult to fix. First, there is the loss of millions and millions of dollars that have been invested by small businesses in the area. There is the huge loss of revenue to the state through taxes and fees. Think of all the boat and RV dealers in the Southwest who will be negatively impacted. The marinas and many of the motels, restaurants, gas stations, boat dealers, and boat repair shops will go into bankruptcy and lose their businesses. It will be a catastrophic event to the cities of Elephant Butte and Truth or Consequences just like it was to the dam site area 60 years ago. The impact on the state in lost revenue and increased unemployment will cost every one of us. The negative effect on the millions of visitors who have fun there is harder to measure. The more than 400 people who have boats moored on the lake will certainly be put out. Losing the destination place for all of the people and families that vacation there will be very significant. Morale was low six years ago but it will really be bad if the lake is allowed to dry up. A minimum pool could have a predetermined elevation that would keep the lake viable for recreational activities.

Another factor that affects allocations is who owns the water. Right now I believe about 200,000 acre-feet of water in the reservoir are promised to someone and are not available for irrigation. That amount of water can vary up or down. Having a predetermined elevation would minimize storage capacity impact and allow us to take advantage of that stored water. When you go to the bank and open an account, they ask you to put a hundred dollars in your account. That hundred dollar deposit won't make or break you. Put that hundred dollars in the hands of the bank and it gets invested and benefits the whole community. It may help your kid buy a car or your neighbor buy a house. A permanent pool of water for recreation is only a bucket full of water to irrigate each field. It is not going to make or break anyone, but in the hands of recreation it will provide hundreds of jobs, bring money into the area, and provide recreational services to everyone. Having a minimum elevation point means greater stability and sense of security for the whole Southwest.

It is easy to avoid running your car out of gas or oil. It is just as easy to keep from running the lake out of water. Remember, the man who was stranded in the desert? I ask the question again, do we just use up the last of the water? Or should we use the water in the jug to keep the pump primed?

For the benefit of all, we need to establish a minimum pool or minimum water elevation—before the water is gone.

The Benefits of Restoring Our River Ecosystems

Beth Bardwell, Audubon New Mexico

Beth is the Director of Freshwater Conservation of Audubon New Mexico. She has an MS in biology from NMSU and a JD from the University of Oregon School of Law. Beth has eight years of experience working on natural resource management and water resource policy at the local, regional, state, and federal level. She has served as a member of the New Mexico Water Dialogue, the Governor's Blue Ribbon Task Force on Water, and Lt. Governor Denish's 2009 Transition Team on Energy and the Environment.

The residents of New Mexico derive a whole host of benefits from their state rivers, from drinking water to food and fiber production. The purpose of my talk today is to emphasize additional and significant benefits that arise when we conserve and restore the health and ecosystem function of our state's rivers.

A major river restoration effort on the Middle Pecos River is a good illustration. The Pecos River restoration project (Fig. 1) was funded by the State's River Ecosystem Restoration Initiative in 2007. The project's objectives were to restore an active floodplain and create quality habitat for native fish, birds and plants. The state's restoration funds leveraged significant federal funding and employed private sector contractors. The project enhanced the Pecos River through the Bitter Lake National Wildlife Refuge, which draws 150,000 visitors annually to Roswell. Post-project monitoring suggests a positive response in the abundance of the federally threatened Pecos Bluntnose Shiner, which can help to reduce the likelihood of federal intervention in water management on the Pecos River. The restoration project accomplished all of this without increasing the net depletion of water.

Figure 1. Pecos River Restoration Project-reopening a historic meander and closing a channelized reach (2009) © Ken Stinnett

One of the least recognized but significant benefits of restoring New Mexico's rivers are the jobs and revenue they generate from tourism. Tourism is the world's largest industry. Here in New Mexico, nicknamed the "Land of Enchantment," tourism is our second largest industry, bringing in more than $5.7 billion annually. Within the tourism industry, ecotourism or nature based tourism is the fastest growing segment. Americans love nature. Wildlife viewing, and that includes birdwatching, is the single largest national recreational activity. For example, one in every five Americans watches birds—that is twice as many golfers and five times as many skiers. In New Mexico, nature based tourism accounts for more than half of the tourism industry's revenue. Sixty-six percent of the state's tourism dollars are generated from fishing, hunting, and outdoor recreation. There is a positive correlation between wages in rural counties and recreational tourism. Wage earners in rural recreational counties earn on average $2,000 more per worker.

One of the ecotourism success stories in New Mexico is the Bosque del Apache National Wildlife Refuge. The refuge is located on the Central Flyway, a major migratory thoroughfare for ducks and cranes and songbirds; the equivalent of an I-40 for birds. The refuge is located in Socorro County, the second poorest county in New Mexico. Local economic effects associated with recreational visits to the refuge totaled more than $13 million annually from non-residents across the three counties of Socorro, Bernalillo, and Sierra. More than $2 million is derived just during the six-day Festival of the Cranes.

If wildlife is the cornerstone of the tourism industry here in New Mexico, healthy rivers keep that industry thriving. Our state's rivers are an important source of the state's biodiversity. Although rivers, lakes, and wetlands comprise a tiny percentage of the earth (one percent of the land), they play an essential role in supporting life on earth. Species richness per unit area is greater in freshwater than marine or terrestrial habitats. In New Mexico, riparian ecosystems support a greater diversity of plants and animals than the state's upland habitats. Eighty percent of all sensitive vertebrate species in New Mexico use riparian or aquatic habitats at some time during their life cycle. When it comes to New Mexico's bird life, two-thirds of the state's Important Bird Areas occur at freshwater sites. Important Bird Areas are Audubon designated sites that provide essential breeding, migrating, or wintering habitat for one or more species of bird. They are generally discrete sites that support one or more high-priority species, large concentrations of birds, exceptional habitat, and/or have substantial research value.

Restoring the state's rivers promotes long-term sustainable economic growth that extends beyond tourism. Targeted investments in river restoration improve New Mexico's quality of life, which in turn attracts new businesses to the region. With increased mobility of today's businesses, entrepreneurs often decide to locate their companies in areas with high quality of life such as places rich in natural amenities. The same qualities that attract businesses also attract retirees and people with investment income.

River restoration also creates jobs for New Mexicans. The Department of Interior estimates that for every $1 million invested in restoration, an average of 30 jobs are created—largely in the private sector. During the first two years of the state's River Ecosystem Restoration Initiative, the state's investment of five million dollars created hundreds of employment opportunities over seventeen counties. A total of 222 full-time, part-time, or temporary restoration-related jobs in the private sector were documented.

Restoration also leverages federal and private funding and services from which New Mexico would not otherwise benefit. Grantees of the state's River Ecosystem Restoration Initiative reported more than a two-to-one match from other private, state, and federal funding sources and in-kind services. Twenty-seven river restoration projects matched the state's five million with three million in other funding and three million in in-kind services.

Healthy, functioning river ecosystems also provide ecosystem services that help to sustain and fulfill human life. Figure 2 is a list of commonly recognized ecosystem services. The services listed below are so fundamental to life that they are easy to take for granted, and so large in scale that it is hard to imagine how human activities could disrupt them. Most importantly, these services are performed free of charge. The cost of providing these services through man-made technology would be staggering. And yet, rarely do we acknowledge the value of these ecological services in decisions about water allocation, management, and development.

- Generate and maintain biodiversity
- Source of genetic and biochemical resources
- Purify water
- Retain water and recharge groundwater
- Buffer droughts
- Regulate flood peaks and flow velocity
- Cycle and move nutrients
- Moderate weather extremes

Figure 2. List of ecosystem services provided by rivers

A good example is New York City, which derives most of its drinking water from reservoirs in the Catskill Mountains. As development pressures increased in the Catskill region, water quality began to deteriorate. New York City residents were faced with building a new filtration plant that was estimated to cost $6 to $8 billion to construct and over $300 million annually to operate. Instead of the infiltration plant, the residents passed a $1.5 billion dollar environmental bond to restore quality to the City's drinking water. The bond proceeds were used to acquire lands, improve local sewage treatment, and pay farmers to forgo streamside production of crops and forage. In this case, investing in the natural asset and paying rural communities to help secure this service, was cheaper than providing the same service using man-made technology.

One ecosystem service in particular, moderation of weather extremes, warrants additional attention. Increased greenhouse gas emissions are projected to increase the temperature of air and surface water, and change the patterns of precipitation and run-off. A recent publication in Ecological Restoration concludes that restoring rivers can help humans and animals cope with increased climate variability. According to the authors, river ecosystems are naturally resilient to disturbance like droughts and floods and have a high rate of recovery. This resiliency can promote ecological resiliency to increased variability both within and beyond riparian zones. As the physical environment changes, species will adapt better if they can move between systems and elevations. Rivers by their very nature provide natural wildlife corridors and habitat connectivity for movement and dispersal. Riparian areas also provide thermal refugia as air and water temperatures rise. Water absorbs heat and is a buffer against higher air temperatures. Riparian vegetation provides shade helping maintain cooler water temperatures and blocking searing winds.

As the preceding paragraphs demonstrate, healthy, functioning rivers can reap big benefits for New Mexicans. Unfortunately, evidence suggests that the health of our state's rivers is declining. The greatest stressors to our state's rivers are over-allocation of water, regulated river flows, channelization, and invasive species. The rate of loss of freshwater species in North America is comparable to species loss in tropical rainforests. Here in New Mexico, significantly larger numbers of amphibians (58%) and crustaceans (91%) are recognized as "species of greatest conservation need" than other taxonomic groups. More than half (55%) of New Mexico's native fish species are threatened, endangered, or already extinct. Almost one third (31%) of New Mexico's assessed stream miles have water quality impairments. Habitat conversion along our river corridors is substantial. Ninety percent (90%) of New Mexico's and Arizona's original riparian forests are gone. One-third of the wetlands that existed in New Mexico no longer exist. The state's Comprehensive Wildlife Conservation Strategy identified the state's freshwater habitats as key areas to focus conservation efforts because they contain key habitats, high diversity of species of greatest conservation need, are subject to ongoing habitat alterations, and lack legal constraints or long-term management plans to protect them from future modification.

This brings us back to the central theme of this conference: "How will institutions evolve to meet our water needs in the next decade?" If we hope to continue to derive benefits from healthy living rivers, our institutions will need to address the water needs of rivers. Rivers need water. A river's natural ecosystem function is strongly dependant on the ability to protect or restore a natural flow regime or key attributes of a natural flow regime. Riparian ecosystems are a flood-driven environment, dependant on surface and subsurface stream flow as well as seasonal flows for plant recruitment, growth and maintenance. The importance of natural flow is recognized in the state's Comprehensive Wildlife Conservation Strategy and the New Mexico's Statewide Natural Resources Assessment, Strategy and Response Plan.

New Mexico has lagged behind other western states in dedicating water to rivers, but in the last decade New Mexico has embraced new legal and policy tools for dedicating water to our state rivers. As early as 1998, the New Mexico Attorney General opined that the New Mexico constitution, statutes, and case law afford legal protection to instream flow for recreational, fish or wildlife, or ecological purposes. (AG Opinion No. 98-01, March 27, 1998). In 2005, the State Engineer amended the regulatory definition of "beneficial use" to include "the use of water . . . for fish and wildlife" (NMAC §19.26.2.7(D)). Currently, there are at least three approaches that are being utilized or proposed to restore some component of natural flow regimes and/or irrigate off-stream riparian habitat in New Mexico.

The first tool is the Strategic Water Reserve, NMSA § 72-14-3.3. Enacted in 2005, the Strategic Water Reserve authorizes the New Mexico Interstate Stream Commission to acquire water or water rights for the benefit of threatened and endangered species or to avoid additional listing of species. To date, the Interstate Stream Commission has used the Strategic Water Reserve to acquire groundwater rights to enhance flows on the Pecos River for the federally threatened Pecos Bluntnose Shiner.

The second tool is a provision under the state's forfeiture statute that was enacted to remove the perverse incentive of using water to avoid losing it. Under NMSA § 72-5-28(G), forfeiture of water rights is tolled during periods of nonuse when rights are placed in a state engineer approved water conservation program. Recently, the Office of the State Engineer authorized a water conservation program of the Gila National Forest on the Mimbres River to allow placement of private, corporate, and federally held water rights in a program, indirectly preserving instream flow for the federally threatened Chihuahua Chub (Cause 6326).

The third tool is a market based environmental water transaction program that Audubon New Mexico, the Elephant Butte Irrigation District, and the U.S. International Boundary and Water Commission are implementing in the Bureau of Reclamation's Rio Grande Project below Caballo Reservoir. Under this initiative, water rights or water could be acquired or leased and transferred with District Board approval to benefit streamside restoration. Application of water to these sites would be considered an agricultural use of water; for example, growing a crop of cottonwoods or wild millet. A more far-reaching proposal would be to utilize the Miscellaneous Purposes Act under federal Reclamation law to release a periodic environmental peak flow from Caballo Reservoir to enhance connectivity between the river and the floodplain at restoration sites. This would require the consent of both irrigation districts within the Rio Grande Project and the Bureau of Reclamation.

Although these tools each have their limitations, we are in a better position today than we were a decade ago to address the water needs of our rivers. Audubon believes the opportunity exists to do more and is working to advance more tools for environmental flows benefiting our river ecosystems in New Mexico.

A related question to meeting the water needs of our rivers is how will our institutions evolve to meet the restoration needs of our rivers? Currently, there are no dedicated reoccurring funds in New Mexico available for river restoration. But public opinion is in support of the state's investment in restoration and conservation. In a survey conducted in 2004, 61 percent of New Mexicans believed that a permanent, stable source of public funding should be set aside "to protect unique natural lands, wildlife species and drinking water sources." In an earlier poll conducted in April 2002, 84 percent of New Mexicans strongly favored "preserving land that protects water quality in aquifers, rivers and creeks." From 2004 to 2010, the state legislature appropriated annual funding for conservation of natural lands and river ecosystem restoration. Those yearly appropriations have accomplished great things for New Mexicans and the state's rivers and natural heritage. During the four years of funding, the state's River Ecosystem Restoration Initiative awarded over $8 million in grant funding to 47 community-based restoration projects. In just the first two years of funding, the initiative benefited over 2000 riparian acres and restored 30 river miles in 17 counties.

There are numerous opportunities at the federal and state level to enhance our ability to restore New Mexico rivers. Here are a few recommended approaches.

- Provide dedicated, recurring state funding for the River Ecosystem Restoration Initiative and the newly enacted Natural Heritage Conservation Act (NMSA § 75-10-1 et al.);
- Reauthorize and secure federal funding for the Army Corps of Engineers Rio Grande Environmental Management Program, Sec. 5056 of the 2007 Water Resource Development Act;

- Update regional water plans to quantify and address the water needs of the region's streams and rivers and how proposed regional water supply solutions will impact the ecological health of these stream segments;
- Coordinate and prioritize river and flow based restoration projects across the state's six natural resource agencies through the New Mexico Water Cabinet;
- Increase Water Trust Board funding for river restoration projects;
- Reauthorize the Middle Rio Grande flood control projects for the multiple purpose of ecosystem restoration and flood risk reduction; and
- Submit a state proposal to the Bureau of Reclamation under the Secure Water Act to develop strategies to address future water shortages and impacts to the environment from climate change on the Rio Grande.

Sources:

Daily, G.C., et al. 1997. Ecosystem services: Benefits supplied to human societies by natural ecosystems. Issues in Ecology-Ecological Society of America, Number 2, Spring 1997.

Colorado Water Conservation Board. 2005. Decades down the road: An analysis of instream flow programs in Colorado and the Western United States. Denver, CO: Charney, S.

MacDonnell, L.J. 2009. Environmental flows in the Rocky Mountain west: A progress report, Rocky Mountain Mineral Law Foundation Journal, 46(2).

New Mexico Department of Game and Fish and New Mexico Energy, Minerals and Natural Resources Department. 2004. Funding conservation for New Mexico: Providing for future generations. Santa Fe, NM.

New Mexico Department of Game and Fish. 2006. Comprehensive Wildlife Conservation Strategy for New Mexico, Santa Fe, NM.

New Mexico State Forestry Forest and Watershed Health Office. 2010. New Mexico statewide natural resources assessment & strategy and response plans: A science-based process for identifying, prioritizing and conducting natural resource management and restoration activities. Santa Fe, NM.

Postel, S. & Richter, B. 2003. Rivers for life: Managing water for people and nature. Washington, DC: Island Press.

River ecosystem restoration initiative: Community partnerships restoring New Mexico rivers. 2010. Santa Fe, NM: Audubon New Mexico.

Seavy, N.E., et al. 2009. Why climate change makes riparian restoration more important than ever: Recommendations for practice and research. Ecological Restoration 27(3).

The economic benefits of Southern New Mexico's natural assets. 2010. Bozeman, MT: Headwaters Economics and Santa Fe, NM: Audubon New Mexico.

U.S. Department of the Interior, Fish and Wildlife Service. 2009. Birding in the United States: A demographic and economic analysis, addendum to the 2006 national survey of fishing, hunting and wildlife associated recreation. Report 2006-4. Arlington, VA: Carver, E.

U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2006. 2006 national survey of fishing, hunting, and wildlife-associated recreation.

Sustaining Rivers through Instream Flows

Steve Harris, Far Flung Adventures and Rio Grande Restoration

Harris of Pilar, NM, has been a student of the history and natural history of southwestern rivers since 1975. He is president of a river outfitting business, Far-Flung Adventures, and executive director of the basinwide streamflow advocacy group, Rio Grande Restoration. His decades of practical experience on the river include work on complex issues such as diminished stream flow, riparian ecology and watershed restoration. Steve participates actively in regional and state water planning forums and has served on a number of public water resource programs, including the New Mexico Soil and Water Conservation Commission and the Middle Rio Grande ESA Collaborative Program's Water Acquisition and Management subcommittee. A single father of three, he now speaks and writes from his riverside home in rural Taos County on river issues, including water policy, ecological restoration, river and flood rescue/mitigation, and eco-adventure travel.

Rivers occupy a unique position in the long-running public conversation about natural resource conservation and the question of who, exactly, has responsibility for the condition of ecosystems. The truth is that New Mexico has no policy, or only a de facto policy, to guide the future condition of our rivers. That there is no single agency or institution, no "Department of Rivers" or "Bureau of River Management," may be attributed to the fact that rivers are our primary source of water, a commodity with particular importance to both the economic aspirations of the human species and the survival of every other living thing.

Rivers have real economic value, too: they supply water to cities, industries, and farms. In their natural channels, they perform environmental services: transporting sediments and contaminants, cycling nutrients to nourish the agro-ecosystem, and recharging aquifers. Such services have tangible benefits to New Mexico, determinable as the dollar-cost of replacing these river services.

But I want to suggest that what is most important about rivers, what should command our greater attention to their condition, is deeply intangible. Rivers like the Rio Grande, the Pecos, the San Juan, and the Gila are icons in our home landscape. They are the bedrock of indigenous cultures, a miraculous treasure of water coursing across rich valleys and stark canyons, flowing through our interior lives. We find in rivers the peace and beauty of natural processes expressing themselves to our senses, adding value to our lives.

Perhaps New Mexico might make greater progress in protecting rivers if we could simultaneously embrace the notion of water as a private good, alongside the notion of a public interest in water, rivers as "hydrologic commons." I'll talk about two projects I'm engaged in to try to advance the cause of environmental flows in this state.

Statewide Assessment of Hydrologic Alteration

In the 2008 Legislative Session, House Joint Memorial 3, sponsored by Rep. Mimi Stewart, directed the water cabinet agencies, that is, Game and Fish, Environment, Agriculture, Energy and Natural Resources, and the State Engineer/Interstate Stream Commission to cooperate in a study of the effects of flow alteration on various ecosystem values, explicitly including agriculture. Its final form and eventual unanimous passage by the State House of Representatives owes a great deal to cooperation from agricultural leaders. In addition to requesting a study that would assess New Mexico Rivers' vulnerability to streamflow alteration, it made the following policy statement:

"NOW, THEREFORE, BE IT RESOLVED BY THE LEGISLATURE OF THE STATE OF NEW MEXICO that the policy of the state of New Mexico be to use scientifically derived information appropriate to each stream system in managing stream flows so as to protect the environmental integrity of its rivers and riparian areas while maintaining the viability of the surrounding agricultural lands and compliance with legal mandates."

Unfortunately, the legislative session expired before the Senate could consider the measure, but it unanimously passed the Senate Rules and Conservation Committees on its way to the floor. After the session, the agencies agreed to cooperate and make the relevant data available to project proponents, which included the Wildlife Federation, Audubon, Nature Conservancy, and the Santa Fe Watershed Association, if these private parties wished to conduct the called-for assessment without fiscal appropriations from the state.

This past March 15, a one-day workshop sponsored by the UNM-Utton Transboundary Resources Center, Nature Conservancy, Conservation Voters New Mexico Educational Fund, Tetra Tech Center for Environmental Studies, Trout Unlimited, and Rio Grande Restoration convened to explore alternative approaches to the issue of Environmental Flow protection in New Mexico. The 125 participants, including legislators, water users, and agencies, heard from water administrators in Texas and Colorado about their recently implemented programs to appropriate or acquire rights to water for the benefit of their states' river environment. A proceedings of that conference will be published in the near future.

A dozen or so participants volunteered to serve on a NM Environmental Flows Technical Team, to complete the HJM 3 study. Significantly, the Environment and Game and Fish Departments and the Interstate Stream Commission remain engaged in this work. Essentially, the Tech Team will conduct Index of Hydrologic Alteration analyses on some 30-40 U.S. Geological Survey stream gauges, representing a long history of streamflow data in the Rio Grande, Pecos, San Juan, Gila, and Canadian Rivers and some other key tributaries, in an effort to compare pre-development flows with the present, developed condition.

The IHA index was developed by the Nature Conservancy's Freshwater Conservation Initiative and has been used widely as a building block to restoring key elements of the natural flow regime of rivers. This model uses mean daily discharges and calculates 32 indices that describe the hydrologic regime for that station. The thirty-two indices generated by IHA consist of five major categories: (1) magnitude; (2) magnitude and duration of annual extreme conditions; (3) timing of annual extreme conditions; (4) frequency and duration of high and low pulses; and (5) rate and frequency of changes in conditions. In essence, the model evaluates changes in both minima and maxima, and also synthesizes and groups these two extremes over several temporal scales (1-day, 3-day, 7-day, 30-day, and 90-day).

As many of you may know, environmental flow science has been advancing over the past 30 years, so that it is now possible to link the river ecosystem's biological and geomorphic responses with these larger departures from a stream's "natural hydrograph." IHA can help to discover the critical elements that might point to the presence of factors that indicate risk of the kind of ecological collapse that has afflicted many rivers.

For example, a 30 percent loss in average flood peaks could indicate that a river might have become disconnected from its floodplain. Similar-scale changes in the timing of the large flood events might indicate loss of reproduction opportunities for native riparian or aquatic species, even to the peril of indicator and keystone species. Loss of 2-3 year reoccurrence interval flows could lead to a river being unable to transport effectively its sediment load and, in the extreme case, a river might fail to maintain its channel. And so on.

And consequently, water managers might be positioned to recreate these keystone processes, using reservoir releases and/or water acquired from water rights holders. And the cost in water to human water users might be quite small. Efforts to ensure river flows in other states and countries have demonstrated a wide range of policy options which, it is hoped, can help inform New Mexico decision makers to consider new river protection measures here.

So, for the Statewide Assessment, an Index of Hydrologic Alteration will be compared, geospatially, with existing or obtainable inventories of observed conditions in: Aquatic Species of Concern, Water Quality, Riparian Condition, Upper Watershed Condition, Geomorphic Alteration, Groundwater to Surface Water Connection, Agro-Ecosystem Health and so forth. Some of the data sources to be used include: magnitude, magnitude and duration of annual extreme conditions, timing of annual extreme conditions, frequency and duration of high and low pulses, and rate and frequency of changes in conditions.

The product will be a report, hubbed by a series of maps, which will be circulated to policy makers to suggest river reaches or regions with significant problems with or opportunities for Environmental Flow enhancement. The U.S. Environmental Protection Agency has pledged initial funding for the project, under their new "Healthy Watersheds Initiative."

During the vetting of HJM 3, Tanya Trujillo, the ISC's General Counsel asked us, "Why not conduct a test case on a stream to demonstrate the viability of the concept in New Mexico?" Thus was conceived…

The Rio Chama Flow Optimization Project

The Rio Chama is one of only two National Wild and Scenic Rivers in New Mexico and a sparkling gem in the crown of outdoors New Mexico. The Wild and Scenic segments comprise about 30 river miles from the outlet of El Vado Reservoir, whose principal purpose is to store and release irrigation water at the call of the Middle Rio Grande Conservancy District, to the head of Abiquiu Reservoir, whose authorized purposes are flood water retention and water supply storage for the Albuquerque Water Utility Authority. This thoroughly plumbed river system offers a near-perfect opportunity to release water from El Vado for some instream purpose and capture it at Abiquiu for its primary offstream use.

Unlike many another dam-controlled rivers, the Chama has the benefit of substantial tributary inputs of sediment. It also receives that rarest of attributes for a southwestern river, augmented flows. The Chama receives a 50 percent bonus of water, 100,000 acre-feet diverted through the Continental Divide from the San Juan River, into Heron Reservoir, where it is regulated for the use of contractors, which include the cities of Albuquerque and Santa Fe as well as the Conservancy District and several tribes.

Since the construction of El Vado in 1936, the Chama has adjusted to reduced peak flows and increased base flows, which has changed the river dynamics that form and maintain in-channel and riparian habitats. The macrophytic food base that supports fish and bird populations has apparently declined in richness and abundance. Nevertheless, it remains a lovely stream, much prized for river boating, a pursuit available whenever El Vado is releasing water.

Water releases, of course, do not always occur at the times and in the amounts desired by the pre-dam fauna and flora or even by the boaters. And the tailwater fishery promoted by the clear cold releases of other dams like Navajo are, on the Chama, much less productive of big trout.

All in all, the Chama is a prime candidate for improved management: lots of controls, an enhanced water supply and economic importance to residents, visitors, distant water users, and a small hoard of resource managing authorities including the BLM, Forest Service, Bureau of Reclamation, Corps of Engineers, the State of New Mexico, several large cities, irrigation, and conservancy districts. It is subject to the terms of the Rio Grande Compact, water rights administration by the State Engineer, Indian Prior and Paramount claims, and the Congressional authorizing mandates of several reservoirs.

If this welter of users with claims on the Chama seems to be inevitable competitors, they are also cooperators who have acquired some sense of balance between their own desires and entitlements and those of others. They communicate regularly, formally through the Upper Rio Grande Water Operations Review process and the Bureau of Reclamation's Annual Reservoir Operating Plan, and informally in phone calls and a process akin to family wrangling. The principal constraint on cooperation to achieve a proverbial win-win situation is patently psychological: the desire of water suppliers to hurry "their" water into storage, and gain the highly desired feeling of security in their property, as if any party could be truly secure in the desert Southwest. The requisite cooperation is not impossible but does promise to be hard-won.

A few weeks ago, a partnership among the BLM, ISC, Rio Grande Restoration, and some concerned ecologists, fluvial geomorphologists, hydrologists, engineering modelers, and university scholars, received word that the Rio Chama Flow Optimization Project had been awarded a River Ecosystem Restoration grant from the state.

The stated goal, "Optimization," is something a bit different from "Restoration." The Chama project is an attempt to improve irrigation storage and delivery practices while achieving some explicit ecological goals, enhancing fishing, whitewater recreation, and maybe even hydropower.

To get to an end game of changing Chama river management, we perceive a need to systematically accomplish certain markers of progress.

- Understand the present workings of the system: a conceptual model of the physical system and a parallel assessment of the management practices and legal constraints and the choices that they suggest.
- Acquire baseline data on the macroinvertebrates, sediment flux, geomorphology, groundwater and populations of higher order biota, linking these data to flow regimes.
- Use the data to model ecological flow criteria.
- Engage all the stakeholders: a series of meetings with the interests to "take their pulse" on how much cooperation they can safely offer and arrange a series of workshops to bring together the interests to grapple with a common understanding of Chama realities.
- Let each stakeholder set their own rules. Mediate resulting conflicts.
- Use optimization modelling to integrate the several parties' desired outcomes.

Last, vet the modelled hydrograph to determine whether the suggested regime can be accepted.

After all, a system that functions more effectively in accommodating many values benefits everyone. My hope is that by these means, New Mexico may be able to sustain its legacy of living rivers, while continuing to protect water rights holders.

Environmental Flow Issues and Science

Tom Annear, Wyoming Game and Fish Department

Tom is the water management program coordinator for the Wyoming Game and Fish Department. He has worked for the department since 1981 and helped establish their instream flow program. Originally from Iowa, he has a BS degree in fisheries and wildlife management from Iowa State University and an MS degree in aquatic ecology from Utah State University. He has conducted over 100 instream flow studies for the state of Wyoming; written numerous scientific reports, publications, and popular articles on river management; been an invited speaker at international symposia, and has been invited to help address instream flow issues on a variety of projects in the U.S. and Canada. He is a co-founder of the Instream Flow Council and served as that organization's first president. Tom is the senior author of the book Instream Flows for Riverine Resource Stewardship and is a co-author of the book Integrated Approaches to Riverine Resource Stewardship: Case Studies, Science, Law, People, and Policy.

The really great thing about talking about a subject like instream flows is that there are so many experts on the subject. However, one of the things I've found having worked in this area for 30 years is that not all experts are working from the same data set. There is a tendency no matter where you are, whether you are in Oregon or Montana or Nebraska or New Mexico, to try and simplify this really complex subject. I think my responsibility or role today is to try and provide some background and understanding of instream flows so that we can be on the same page when we are talking about the subject. I am going to cover a lot of ground and will start out by providing some perspective and looking at some of the issues without going into great depth. At the end I'm going to wind this up and look at some of the challenges and opportunities and make a pitch for why instream flow legislation is really an important tool in the state's toolbox.

As with any natural resource management issue, we manage water within the constraints of laws, the public input, and science. It is important to involve all three of these elements in decision making in order for us as a society to shape the outcome of our decisions. The extent to which we involve these three elements determines what the world looks like and how well we live.

One of the many messages in Figure 1 is that when you look at population growth in the lower Colorado River basin and plot it against the ability to meet the demands of a growing population, the reality is you don't expect those lines to keep going at the same rate in the same direction. Something has to give. The reality is that we can't figure out where we're going in the future by looking in the rear view mirror; what has happened in the past has been great, but it is not going to be that way in the future. There is a tendency to think that the way things are today is the way things always have been and always will be, but the fact is that is not the case. We are in a situation where we have opportunities today to take care of some things that in the future will be much more difficult to take care of, and if we don't take care of those things today, or even if we do, we are going to have to change how we approach the water management business in the future. This is just a fact of life that some of us have a harder time coming to grips with than others.

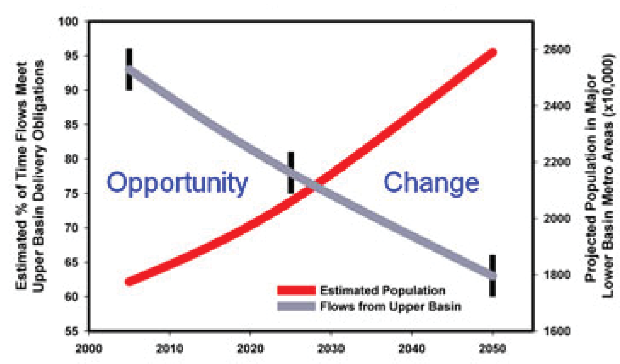


Figure 1. Projected upper Colorado River flows vs. population growth in major lower basin metropolitan areas

When natural resources are abundant, as they have been throughout history, it is easy to look at them as a commodity: what is the economic value that I can get from a buffalo hide or a passenger pigeon or a gallon of water? As natural resources become less abundant, we can no longer look at them as commodities, we need to look at the full range of values of a resource. Water is certainly no exception. There is no one best use of water, it provides an awful lot of uses or services to society. In combination, these are broadly termed ecosystem services. I'll refer to that term from time to time today and it's important to distinguish that these aren't environmental services. Ecosystem services include not only benefits for fish and wildlife, but benefits for irrigation, industry, and municipal uses as well. We as humans are part of the ecosystem and water provides us ecosystem services.

The issue or challenge then becomes one of finding balance and that's where things get difficult because when you have more than one person in the room and more than one value with a resource, you can run into a fairly contentious situation. What makes it even more difficult is that our values are always changing. Our values today are much different than the values 100 years ago when water laws by and large were written. We are now trying to address the public's needs and values based on an old system of law. It's unrealistic and unnecessary to think about a major overhaul of existing law, but we all know it could be tweaked a bit.

It has always struck me as to how much controversy there can be over instream flows. Instream flows provide for ecosystem services both directly with water in the creek, and indirectly in terms of conveying water to people who use it for different human-based needs. No matter what state or country you're in, you hear a lot of reasons why instream flows won't work and a lot of arguments against it. The following is a list of the many claims I've heard over the years. The reality is that these reasons are essentially all false or rhetorical red herrings with no credible basis made by people or groups who are just opposed to environmental use of water.

- Water needs to be diverted
- Costs too much to measure
- Will cause streams to go dry
- Will impact interstate compacts
- Will stop economic development
- Need dams to get an instream flow
- A government plot to take back water rights
- That won't work in (fill in state name)

To provide some perspective on this, I'll talk a bit about Wyoming's history with instream flows. We've had 41 years of history with instream flows so you'd think that if any of those claims were valid, we would have seen proof by now. The debate in Wyoming began long before 1986 when we finally had an instream flow law and used that law to begin protecting water around the state.

Let's look at what has happened in the last 24 years since we've had an instream flow law. To begin, we've protected habitat for game fish species on over 100 different stream segments with current day priority dates without injuring or taking away anybody's water rights. We also found that instream flow legislation has been critical for the permitting process of new dams and the ability of the state to control the amount of water coming out of reservoirs under a state system of law and administration. We've used the instream flow law to protect habitat for the four native cutthroat trout species in the state, all of which have petitioned for listing as federal threatened or endangered species. Our state instream flow law has been critical for keeping state ownership and control over habitat for those organisms and the lands through which those streams pass.

We've also found that it was useful to have a state mechanism to help quantify federal water rights in one Wild and Scenic River segment. We're working on a second quantification process on the Snake River right now, again under state authority.

The list of things that haven't happened in Wyoming is probably longer than the things that have happened. Nobody lost a water right in spite of all the claims that instream flow was a threat to private property owners. We still haven't protected most of the streams in the state and I'm not sure we ever will. But what we have seen is that once an instream flow application has gone through the system and been approved, it just hasn't been a big deal.

Let's dig a little deeper into what is an instream flow and talk about some of the definitions and concepts that I think people a lot of times know but may not realize they know. We'll begin with the question of "what is an instream flow?" At the most basic level, it can simply be water in the creek from a natural source or maybe the water is kept in the river as part of an informal agreement.

In other situations when you talk about instream flow, you are talking about getting a water right or some form of legal or regulatory authority. It's possible to get an instream flow water right on streams that are already depleted, but that doesn't put any water back into the stream.

Or, you can have a combination of these two aspects - water in the creek that is protected by some legal mechanism or permit or right.

When you are talking instream flow, there is also the question of how much you need. It could be a little water, that's an instream flow. It could be all the water, that's an instream flow too. Or it could be a seasonally appropriate flow regime. Each of these flow levels or patterns has different consequences and different issues associated with them.

When talking about the purpose of an environmental flow it's also important to distinguish between whether we are trying to protect part or all of the flow regime that's still available or if we're trying to restore some measure of flow regime to a stream that experiences some level of depletion. There can be a big difference between these two concepts depending on the desired outcome. When we talk about flow protection, you already have water in the stream and you are trying to figure out how much you can take out and still maintain whatever ecological function water managers have set for the stream. In Wyoming, these usually are public lands. Protection typically is not a private lands issues but it could be if there is still water available to protect. It doesn't mean you are protecting the entire river; it is a flow level to meet a specified objective.

Flow restoration is the more traditional view of instream flow management. When restoring flow and riverine function to a stream, almost any level of increased flow will be beneficial for environmental purposes. These situations typically exist on private lands where water has been allocated for consumptive human uses and involve finding ways to put water back in the stream – either by creative management plans or redirection of existing water rights or permits. Because most of the streams and rivers in need of habitat restoration are on private lands, it's important that private landowners be able to have a role in this flow management strategy. It's also important that they have the flexibility to do this on a temporary basis and not be forced to give up existing water rights permanently, unless that is their sincere intention.

Instream flow isn't just about the science either (Fig. 2). If you are going to have an effective instream flow capacity in a state or country, you need to have trained staff and a budget to do the work. You must involve the public and you need to have laws and policies that provide for and regulate the instream flow. Today I'm going to talk about the science, but I want you to realize that I'm only talking about one leg on the proverbial stool.

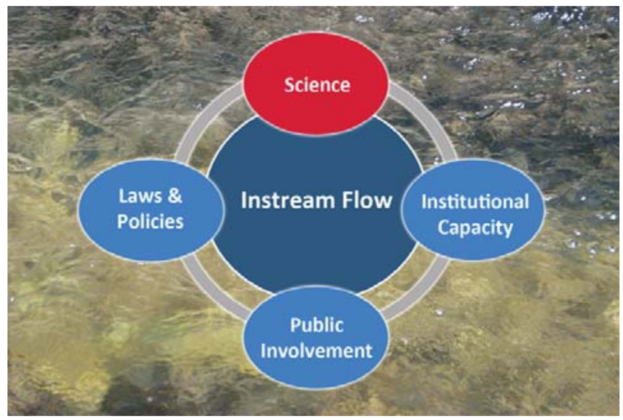


Figure 2. Instream flow is a product of the combined interaction of four primary components

The science is clear that rivers change over their length spatially, and over time. As you proceed down a river, the habitat changes and the organisms that live in each progressive segment of the river system change as a function of flow and a variety of other variables. To describe the conditions in a river and the ecological characteristics, there are five main elements that biologists and instream flow practitioners consider.

- **Hydrology**
  - Short and long-term water availability
- **Biology**
  - Short-term physical habitat availability
- **Geomorphology**
  - Long-term trends of channel conditions
- **Water Quality**
  -Short and long-term
- **Connectivity**
  -Multiple elements and concepts

Models are used to deal with the uncertainty associated with instream flow issues, but they don't always tell you everything you need to know. In spite of that limitation, there's a tendency among some managers to expect models to do the heavy lifting for them when it comes to decision-making. Unfortunately, models provide limited information about the relationship between flow and a particular environmental condition and considerable professional judgment is usually needed to apply the results.

It's also important to understand that sometimes more is not better, and the flow/habitat relationship is hardly ever a straight line. It's important to realize, too, that a flow that is good for one species or life stage of fish in one river can't be used in another segment or another river. Each river and river segment is unique so site-specific studies are needed for each situation. Another critical fact is that in most cases, a single flow at all times of the year will not maintain the ecological characteristics of a stream. If you are looking at restoring or protecting an ecological function, you need to be talking about an instream flow regime.

Interpreting the output from models to come up with recommended flows is handicapped by our limited ability to define nature. The way we define nature is based on our ability to perceive it. A 1998 paper by Kull talks about four "faces of nature" that relate to our association with the world we live in (Fig. 3). We often come up with recommendations that look good to us – and may be fine – but that perform much differently than we intend simply because we don't fully understand the complex interactions of natural, ecological form and functions. Laws and policies typically lag scientific knowledge and probably place the biggest limitation on our ability to achieve more natural conditions.

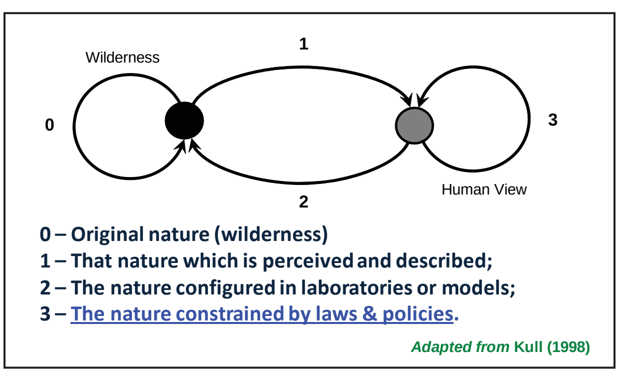


Figure 3. Defining nature is a major limitation

The message here isn't necessarily that you want to move all the way back to wilderness times. The reality is that we are human and we are going to use water so the goal with defining and managing nature is to maximize ecosystem services by maintaining healthy ecosystems, which are linked to healthy economies. We achieve this by fine-tuning our legal system, though that is a very challenging process with imperfect results.

Those five elements I talked about earlier aren't stand-alone elements, they are interrelated in complex ways. In essence, you can't do one of these things or one kind of study and get the complete answer you're looking for.

When talking about hydrology, we discuss the pattern and process, the way water flows through a stream, with each level of flow having a different ecological function. High flows are just as important as low flows; you don't want a low flow all the time and you certainly don't want or need a high flow all the time. These different flow levels need to come at a seasonally appropriate time, amount, and rate of change. We hear a lot about the "minimum flow," though this term is slowly disappearing from flow management conversations. The problem with minimum flow is that you are allowing water to be depleted down to some minimum level. But once that happens, the minimum flow becomes the maximum flow. A more appropriate question or perspective is how much water is needed at each time of the year and how that will relate to maintaining the environmental qualities that are desired by water managers.

Some of the key points to keep in mind with hydrology models are that they are typically based on analysis of flow statistics. They aren't capable of providing information about incremental trade-offs in terms of benefits for organisms or processes and aren't directly tied to any other riverine processes. These models can tell what kind of flow is needed for things like channel maintenance flows, but there are strict limitations to the information you can glean from hydrology models. That's why you typically don't just use hydrologic statistics to set instream flows.

The majority of instream flow models address only fish. But biology relates to all of the organisms that are associated with a river and help define it, including fish, aquatic insects, and vegetation along the banks. These combine to define the face of a river and how a river functions. Remember that biology models primarily look at habitat, they don't typically address how many fish will result from a particular flow regime. You can't make this jump from habitat to fish because fish populations are dynamic – they fluctuate over time for a variety of reasons. However, the inability to quantify organisms is not a failure. Rather, the goal is to look at habitat and consider relative changes in habitat as opposed to some absolute number. And again, you need other models to address other elements of the stream ecosystem – like geomorphology, which is the study of how sediment moves through a stream channel.

Basically, three factors go into geomorphology models. These include the amount of flow, the amount of sediment addition or removal, and the shape of the channel. For example, if you change the depositional processes, the habitat changes and you will almost certainly have different animals living in a straightened channel than you have in a natural channel. Geomorphology models are designed to look at long-term processes, not instantaneous goodness or badness of a flow. Professional judgment also is needed to determine when a particular flow is needed, the ramping rate, and the duration of this flow.

When we look at water quality models, the tendency is to think about pollutants. Certainly there are a lot of models that deal with water quality. But temperature and dissolved oxygen are also important water quality factors, as are ice forming processes. The point to make with water quality is that not every species sees any one attribute the same. What is good for one species may not be so good for another species. Again, you are left to rely on professional judgment to decide what species or communities of aquatic organisms you are managing.

An important consideration regarding water quality models is that they look mostly at threshold flow, and minimum flows, but they don't identify ecological trade-offs of how much better the stream will function with more or less flow. Again, you must integrate water quality models with other models.

The last of the five elements is connectivity. In many ways, it is possibly the most complex because we tend to think of connectivity as just the ability of fish to swim up and downstream unencumbered by dams and diversions. Instream flow also relates to the connectivity of groundwater to flow in the stream, the ability of the stream to connect to the floodplain (lateral connectivity), and connectivity over time. It may be important for streams to flow all the time, but in some streams, temporal disconnectivity in the form of seasonal periods of no flow actually favor some native species. Connectivity isn't just about fish. It also relates to connectivity patterns that provide energy, sediments, and chemical cues to organisms throughout the stream system. Connectivity to the flood plain also recharges water tables in the riparian areas adjacent to the streams and where bed-load comes from that helps maintain the channels. Connectivity can be really complex. The problem is there aren't many good models to address connectivity needs in freshwater streams. Most connectivity models are designed for estuaries and so to address connectivity issues in streams, we usually use other models that relate conditions of stage and flow. Again, connectivity flow needs rely on professional judgment to decide when and how long it's needed, what species you need it for, or if you need it at all.

The last group of models I want to talk about are holistic models. These models integrate many of the five riverine elements we've talked about previously. Examples of holistic methods include: downstream response to imposed flow transformation (DRIFT), demonstration flow assessment (DFA), Bayesian probability models, and ecological limits of hydrologic alteration (ELOHA).

I want to talk about the Bayesian probability models because they are not only intriguing but offer a lot of potential (Fig 4). They basically function by identifying the probability of an outcome of a certain action, and from that action, there are probabilities associated with the next outcome and so on and so forth. Instead of coming up with an amount of habitat, you come up with a probability that a certain condition will result. These can get messy in a hurry. Anytime you model ecosystems, there are more things to model then you can credibly account for in a mathematical model.

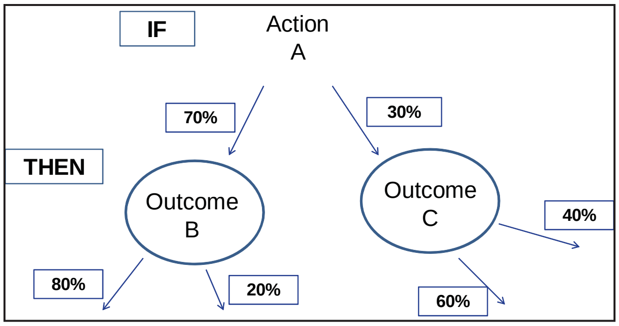


Figure 4. Bayesian probability models

Figure 5 is a construct from a project I helped the USGS with on the Flint River in Georgia. This is a simplified version of the model we started with. The initial model had a lot of lines and pathways that aren't shown. We left the main pathways, but you will see we still included hydrology, connectivity, geomorphology, habitat, and water quality. We came up with the desired outcomes where we wanted to know something about the animals in the stream. We also identified an outcome for water quality.

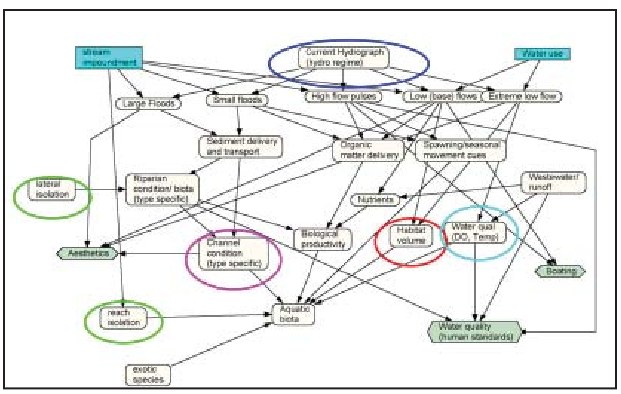


Figure 5. Ecosystem modeling can be complicated

The problem with holistic models is that they still address a limited range of elements and inputs and the outcomes are still relatively imprecise. But again, the goal here isn't to achieve precision as much as it is accuracy. If you can accurately predict the relative goodness of a certain flow regime on the organisms or habitat in the stream that you are trying to manage, that is an acceptable goal. When you get hung up on precision, you are dooming yourself to failure because you are almost always going to be wrong.

To wrap up this talk, I want to discuss some of the challenges and opportunities faced by states today. I worked on a project with the Instream Flow Council (IFC) to assess many of the trends and activities of state fish and wildlife agencies. We surveyed all 50 states and six of twelve Canadian provinces and territories. The participants were instream flow or water management specialists with state and provincial officials in fish and wildlife agencies who are the members of the IFC. Thus, the results may be skewed a little by that group's perspectives and knowledge of water management. We wound up with a great big report that is posted online. You can download the report by visiting the Instream Flow Council website at www.instreamflowcouncil.org.

This study looked at a variety of things including the top things that state agencies feel they need in order to deal with instream flow issues. The top need in nearly every region and almost every state was the need for better laws and policies to deal with environmental flows. The next most important need was improved institutional capacity. Agencies need formal commitment to protect and restore environmental flow, well trained people, and financial support to conduct instream flow studies. Right now, New Mexico is losing instead of adding staff that can do instream flow work.

The other thing that participants said was needed was a more informed and active public. Oftentimes the public is supportive of environmental flows, but they aren't active in their support. In essence, the public isn't very vocal, and everybody here knows that it is only the vocal advocates who usually are heard in a public forum.

Interestingly, one item that didn't rise to the top was better science. You always need the best possible science, but when it comes to states addressing instream flow issues, it just didn't make the top of the list.

Lastly, we did a ranking in 2008 of the capacity of the western states in terms of their ability to address instream flow issues based on four elements: legal opportunity, institutional capacity, public involvement, and the status of stream protections (Fig 6). We found that while every state is challenged to do instream flow work, Alaska, not surprisingly, was top of the list and New Mexico is wagging the tail on the list of western states.

Alaska
Colorado
Washington
Oregon
Montana
Wyoming
California
Hawaii
Idaho
Utah
Arizona
New Mexico

Figure 6. Ranking in 2008 of capacity of the western states in terms of their ability to address instream flow issues based on legal opportunity, institutional capacity, public involvement, and the status of stream protections

So what's the take-home message? There are probably several messages. One of the things that strikes me is the importance of keeping conversations realistic. We need to at least try to stay away from the rhetoric and if you are going to make a claim for or against instream flow, make it a valid one based on defensible fact.

It's also important to be specific when we are talking about instream flows so that we are at least talking about the same thing. It's important to know if we are just talking about naturally flowing water in the creek with no legal protections or if we are talking about an instream flow water right. These are both legitimate definitions but very different aspects of instream flow.

Let's use all the words when having these conversations. We need to say, "instream flow regime," when we're talking about managing for ecosystem form and function. Just saying, "instream flow," leads many of us to think we're talking about a single year-round minimum flow that may work in some settings but typically won't maintain a fully functional aquatic environment.

We also need to be very specific about whether we are talking protection or restoration. In Wyoming, we have an instream flow law, but about all we can do with that law is protect whatever flow is still unappropriated. It's virtually impossible to use our law to restore flow in streams even when there are willing parties who would like to do so.

Another of the several take home messages here is the importance of using the right tools to obtain needed answers or recommendations. There is no one way to do an instream flow quantification study. Every stream is unique and every situation is different. You may not need to look at all five of the riverine elements I talked about earlier, but you still want to acknowledge that you considered them all so you are able to say whether each one is a legitimate issue or not when designing and conducting flow studies. Be specific and use the right tool; don't think you can just slap the same method on every stream and get the answers that you want or need.

One last critically important thing to understand is that instream flows really are an important state tool. It is very unfortunate that there is this "us" versus "them" notion on instream flows. Every state in the country that has had this instream flow discussion has experienced this great debate of whether instream flows are good or bad or are needed or not. But at the end of the day, an instream flow water right is just another water right. But they are really important when you think about the fact that supportive instream flow laws are a needed way to affirm states rights over the administration of water, especially in the face of many federal water-related mandates. When states are faced with federal laws such as the Endangered Species Act (ESA) and Wild and Scenic Water Management River initiatives, it is often better to manage water administration with a state mechanism rather than a federal mechanism. If you don't have a state mechanism for formally administering instream flows, the feds will have one for you.

Instream flow capacity provides ecosystem services and benefits for the public because water is owned by the public – not by any one person or one agency. So in some settings these are private property rights issues as well in the sense that if legislation is provided effectively, instream flow opportunities can add flexibility, value, and opportunity to an existing irrigation right without taking away any of the other important values associated with existing uses of water or water rights.

Thank you.

Innovations in Rural Wastewater Management - Decentralized Approach

Graham Knowles, New Mexico Environment Department

Graham Knowles oversees the New Mexico Environment Department's (NMED), Community Services Group (CSG). The group's primary focus is on assisting communities to fund the development of sustainable water, wastewater and solid waste infrastructure solutions. For more than a decade, he worked with the U.S. Environmental Protection Agency directing decentralized wastewater infrastructure demonstration projects nationwide. Subsequently, he directed both the National Environmental Training Center for Small Communities and the National Small Flows Clearinghouse at the EPA sponsored National Environmental Services Center. Graham attended Plymouth College in the UK and holds a bachelor's degree from the University of South Africa. He also has graduate degrees in public administration and political science from West Virginia University. Graham is also a certified ISO 14000 Environmental Management Systems international lead auditor.

Good afternoon, I want to set the stage about innovations in rural decentralized wastewater management by looking back in order to move forward (Fig. 1). In the early 1990s, the United States Environmental Protection Agency (EPA) initiated a demonstration program to encourage the utilization of alternative, decentralized wastewater treatment technologies in an effort to better protect public health and the environment in small and rural communities. In 1996, Congress charged the EPA with developing a report focusing on three core concerns.

1. The ability of onsite/decentralized systems to make more efficient use of the limited funding available for wastewater infrastructure;
2. Whether or not these systems were appropriate alternatives to centralized treatment, and if so;
3. What actions EPA would take to implement the alternatives.

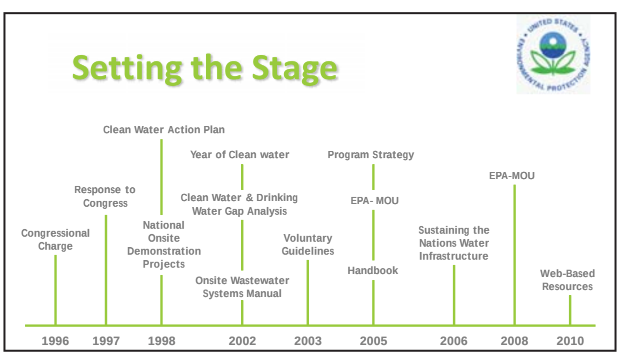


Figure 1. Federal timeline for wastewater management since 1996

A year later in its Response to Congress (1997), EPA concluded that onsite/decentralized systems could protect public health and the environment and that such systems typically tend to have lower capital and maintenance costs for rural communities. The report also noted that onsite/decentralized systems are appropriate for varying site conditions and are suitable for ecologically sensitive areas when adequately managed. However, EPA identified several barriers to the improved performance of onsite/decentralized systems. These included the lack of awareness about system maintenance requirements along with public misperception regarding system performance and capability. Other concerns centered on regulatory and legal constraints along with the lack of management and liability fears coupled with financial constraints. In conclusion, EPA observed that until significant progress toward eliminating these major concerns was made, it was likely that onsite/decentralized systems would continue to cause health and environmental problems, and would not be recognized as a key component of the nation's long-term wastewater infrastructure.

In 1998, states and tribes reported in their Clean Water Act section 303(d) reports that designated uses (e.g., drinking water, aquatic habitat) were not being met for more than five thousand water-bodies as a result of pathogens. It was also reported that almost five thousand water-bodies were impaired by nutrients. State and tribal reports clearly indicated that onsite systems were a significant contributor of pathogens and nutrients to surface and groundwaters. Onsite wastewater systems were also contributing to an overabundance of nutrients in ponds, lakes, and coastal estuaries, leading to overgrowth of algae and other nuisance aquatic plants.

These threats to both the public health and water resources clearly underscored the importance of enabling onsite/decentralized wastewater management programs with both the authority and necessary resources to oversee the full range of onsite system activities—planning, siting, design, installation, operation, monitoring, and maintenance. This along with the Clean Water Action Plan was in harmony with an evolving decentralized wastewater infrastructure agenda in terms of the Clean Water Act (CWA) goals. In fact, throughout the 1990s this emerging research program saw several initiatives gathering data and conducting analytical studies focusing on onsite/decentralized wastewater issues.

In 2000, EPA published a draft version of its Guidelines for Management of Onsite/Decentralized Wastewater Systems as a practical reference for tribes, states, local governments, and community groups to strengthen their existing onsite/decentralized programs. These guidelines included a set of recommended program elements, activities, and model approaches that program managers could refer to in evaluating their management program.

Within two years EPA published a revised Onsite Wastewater Treatment Systems Manual (2002) to both complement as well as update the design manual published two decades earlier. The publication provided information for wastewater treatment professionals in both the public and private sectors and further explored developments in treatment technologies, system design, and long-term system management. In addition, the growing national emphasis on management programs that establish performance requirements rather than prescriptive codes for the design, siting, installation, operation, and maintenance of onsite systems underscored the importance of revising the manual to address these emerging issues in public health and water resource protection. In 2003, EPA published the Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems bringing to the forefront that the performance of onsite and clustered (decentralized) wastewater treatment systems was indeed a national issue of great concern. Finally, it seemed EPA was acknowledging that onsite and clustered (decentralized) systems were a permanent component of the country's wastewater infrastructure.

During this period, EPA also clarified what was meant by decentralized wastewater treatment systems and defined them as managed individual onsite or clustered wastewater systems (commonly referred to as septic systems, private sewage systems, individual sewage treatment systems, onsite sewage disposal systems, or "package" plants) used to collect, treat, and disperse or reclaim wastewater from individual dwellings, businesses, or small communities or service areas. That said, EPA indicated that many of the systems in use were improperly managed and did not provide the level of treatment necessary to adequately protect public health and surface and groundwater quality. Noting that proper management of decentralized systems involves implementation of a comprehensive, life-cycle series of elements and activities that address public education and participation, planning, performance, site evaluation, design, construction, operation and maintenance, residuals management, training and certification/licensing, inspections and monitoring, corrective actions, recordkeeping, inventorying, reporting, and financial assistance and funding.

In a nutshell, the underpinning premise of the guidelines was simply that, adequately managed decentralized systems that protect the environment and public health can provide an alternative to centralized wastewater treatment systems. Noting that against this backdrop, EPA supported the most sustainable approach to implementing protective water pollution control solutions whether centralized or decentralized. The guidelines were simply a framework within which state, tribal, and local authorities along with other applicable federal requirements, may better meet water quality and public health goals as an integrated component of a comprehensive watershed approach at the state, tribal, or local government level.

EPA noted that the benefits of an adequate management program include: protection of water quality and public health; protection of consumers' investment in home and business ownership; increased onsite system service life and replacement cost savings; avoidance of transfers of water away from the source by conserving groundwater; and negates the need to use a community's tax base to finance sewers. As a result, EPA continued to strongly encourage communities to consider the voluntary guidelines as a template to strengthen an existing management program or implement a new program. Along with these efforts, in 2005 EPA developed a specific program strategy through its Office of Water.

Evidently, the Agency wanted to improve the performance of these systems in terms of the EPA strategic plan and wanted to move forward by integrating appropriate and affordable technologies with sustainable management strategies to bring about viable community solutions. Unfortunately, more than a decade after the initial congressional mandate there seems to be a continuing lack of awareness, and that is really where we are today in terms of diffusing the innovation of rural infrastructure management. Public misperceptions continue concerning the systems and their capabilities, as well as other legal and regulatory constraints in terms of responsible management entities and oversight.

In 2007, EPA's Office of Water came out with a collaborative approach to sustainable water, which was something new to a bifurcated and fractured set of government agencies and the internal politics among divisions within agencies. The approach advocated sharing information, developing best practices, and introducing inventive new technologies. A research and development agenda was set forth.

The approach was underpinned by four pillars: 1) better management, 2) full cost pricing, 3) water efficiency, and 4) a watershed approach. I've selected these today to put into context the evolving agenda, and how ultimately the watershed approach is connected to decentralized wastewater infrastructure management. Simply stated, decentralized wastewater infrastructure management is a subset of the watershed approach, and is one of the four pillars, which when they work together in an integrated and holistic fashion results in sustainable community outcomes.

When we look at management we view it as a continuum. In Figure 2, we look at personal accountability, individual responsibility, regulatory compliance, and system integrity. At one end, it means that individual users are responsible, while at the other end, a management entity takes full turn-key responsibility.

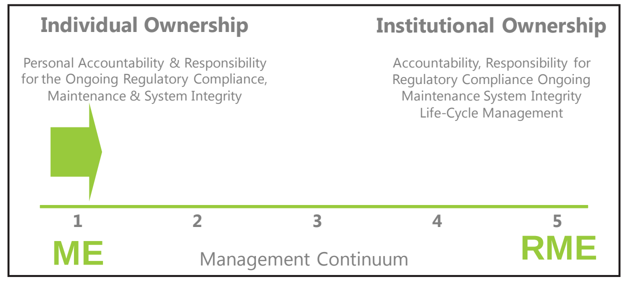


Figure 2. Management continuum

I want to briefly look at three community initiatives in New Mexico (Fig. 3). The figure shows a parallel path that I want you to follow. Peña Blanca a small community north of Albuquerque began their effort in 1990, predating EPA's congressional mandate to examine this institutional option by six years. By 1996, Estranosa Water & Wastewater Cooperative also took action independently. Three years later Willard became an EPA demonstration project. Let's look at these community initiatives briefly.

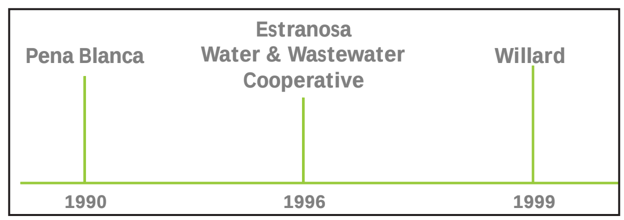


Figure 3. Community initiatives in New Mexico

The basic driving forces in Peña Blanca were failing systems. The systems were malfunctioning, dysfunctional, or nonexistent; they were noncompliant with regulatory requirements. The net result was potential public health challenges; we had multiple residents who were served by overloaded and overburdened systems. In other words, we had too many people too active in too small of a space. The systems had also affected high groundwater, and inadequate leech fields served these overburdened systems. The recommendations were for a small diameter pressure collection system with an estimated cost of over $3 million. The connection cost was $16,800 to $18,300 per 1,000 gallons of waste treated. We had to utilize these systems because we weren't going to get a big pipe. We installed appropriate systems to get the right kind of disposal and dispersal in place. We could protect public health and enhance water quality by putting in onsite systems at a total cost of less than $1 million. That was a significant savings over the earlier recommendations. The

Water and Sanitation District that was designated as the lead agency became responsible for maintaining the systems to ensure proper operation and management for the life cycle of the systems. Outcomes included biannual pumping services for a monthly fee of $10.64 for a 1,000 gallon tank and sampling of private wells in the area found nitrate nitrogen levels below 1 mg/l.

Estranosa is another case study and the driving force was pretty simple: protect the groundwater and put a management program in place. The recommendation was to initiate a septic tank management program. Actions included efforts to provide an operation and maintenance certification programs, instituting a voluntary program to provide discounted septic tank pumping at a three-year interval, and revising bylaws to make the program mandatory for all new and transfer memberships. The outcomes: first membership organization to institute a septic tank maintenance program in New Mexico and it provides service to an area approximately 20 miles east of the City of Albuquerque, known as the East Mountain Area. Initially, there were seventy members signed up for the voluntary program at a cost of $5.00 per month. By 2005, over 1,100 households were served by the septic tank pumping program and the rate increased to $5.50 per month.

Willard is another example of driving forces, actions, and outcomes. The driving forces were the lack of adequate septic tanks and surface contamination with rising levels of nitrates in the village communal well. The recommendations were to demonstrate the viability of the centralized management of affordable, decentralized wastewater systems within New Mexico. Our actions included providing higher levels of treatment by linking conventional septic tanks to re-circulating textile media filters. The village also took legal and administrative steps to operate the system, including holding a Wednesday night meeting in a little town hall where we were able to get some resolution to move forward. The outcome is that today, Willard has a centralized management of decentralized systems.

So what do we take away from all of this? Fifty-two percent of all housing units in New Mexico are served by decentralized systems. We continue to have growth and some new homes will not be served by the big pipe systems. Today there is increasingly less funding available for the big pipe infrastructure solutions because we are busy retrofitting the existing aging infrastructure. The reality is that we know that we need to manage decentralized systems properly. One institutional consideration that you might take back to your communities today is this: there are mechanisms in place, there are institutional options that you can consider, and it behooves us all to consider those alternatives and options. Consider cost efficient, economically viable institutional options for alternative onsite technology management, so that we can protect the scarce water resources of our beloved New Mexico. Move forward knowing that decentralized wastewater infrastructure solutions have been done and are being done in New Mexico. Building on these early efforts coupled with federal guidance documents and resources along with the experience of others, this approach continues to gain momentum. We are now looking to move that groundswell forward to a more elevated level and to continue the momentum.

Good work has been done in the state by forward thinking well-intentioned innovative community leaders. Management approaches tailored to meet local needs are in place, they are working and based on experience are increasingly becoming more efficient and effective in meeting the needs of communities in New Mexico.

Thank you for your time.

Increasing Institutional Resilience for Water Conservation

Frank Ward, Agricultural Economics and Agricultural Business
New Mexico State University

Frank is an NMSU professor in the Department of Agricultural Economics and Agricultural Business. His recent work has looked at conservation and economically efficient use of water resources with special emphasis on irrigated agriculture. It also includes policy planning, program formulation for water resources development, analysis of water resource systems, and institutional strengthening. Frank has conducted integrated hydrologic-agronomic-institutional-economic analyses to support sustainable river basin management and flood policy analysis. His recent work has been applied to the Rio Grande Basin of North America and to river basins in Afghanistan, Iraq, Egypt, Jordan, and Turkey. He received BS, MS, and PhD degrees all in economics from Colorado State University.

In March 2010, Karl Wood organized a group to prepare a proposal for the NSF on connections between water and climate change. We debated mechanisms to promote institutional resilience in water institutions for encouraging water conservation; none of us really knew what institutional resilience meant, but we still sent the proposal off on April 15. We discovered a short time later that the proposal would not get funded for various technical reasons. Several of us thought it was is a merciful end to a very ambitious program, and that surely no one would ever bother us again about institutional resilience in water conservation. However, about three days later Cathy Ortega Klett said, "Frank, how would you like to give a talk on institutional resilience for water conservation?" But that was back in April, and I thought that December 3 wouldn't come for a long time. I would have plenty of time to learn something about institutional resilience. So I committed back in April, hoping that I could somehow get it finished. Well here it is, December 3rd, and institutional resilience still presents all the challenges that it did back then.

As I think about what it means to have institutional resilience for water conservation, I am reminded of a photograph of Dulles International Airport. Many of you may have flown into that airport recently, and you will notice that although it is a very beautiful place, it sits out there in an isolated way; it looks like a loaf of bread. If you study the history of that airport, you will discover that they built it to be able to expand to growing demand if that demand happened, or to shrink in case demand disappeared. So the Dulles people built what you could call structural resilience. As we think about institutional resilience, that airport would be an analogy to sharpen our thinking. Institutional resilience is what we need to set up against a background of growing evidence of water shortages in many regions of the world, with the need to insure food and water security for growing populations.

If you are looking at ways for any river basin to adapt to climate variability and climate change, you need to know something about that basin's resilience to unexpected changes in demand or supply. Yet, there is little knowledge of measures to improve water institutions that could in fact bring about the increased economic and ecological resilience to an unexpected future.

So with that in mind, my mission here today is to at least try to do three things. I would like to characterize what we mean by resilient water conserving institutions. I'd like to talk about some criteria for how we can identify resilient water institutions. Finally, I'd like to apply some of these principles to four or five well-known water institutions in New Mexico's Rio Grande Basin.

So what do we mean by water institutions? We could talk about an institution as a rule that affects the development of water, the allocation of water, or the use of water. So we are looking at rules. What kind of rules or social/legal structures might we have to live with that are very important? Certainly international treaties would be a good one, for example, the 1906 U.S.-Mexico treaty that promises and delivers 60,000 acre-feet of water per year to Mexico at the U.S.-Mexico border. It is a great example of an international treaty or institution that is important to our lives.

Certainly the Rio Grande Compact as well as the other compacts in other states like the Colorado River Compact and the Pecos River Compact are all important. There are 22 compacts in the western U.S., and we live in our immediate area with the Rio Grande Compact, a very important set of rules for allocating water and water shortages as the case may be.

Any kind of trading arrangement would be an important institution. These include things like water trading, water rights markets, water leasing, inter- or intra-basin transfers, renting of water, which is any sort of process to move water from where it is to where it needs to be based on economic ideas of need.

Legislation is a very important institution. The Endangered Species Act has an immense influence on water allocation. It is an important rule governing how water is used. When you look at things like the Rio Grande silvery minnow that requires a certain amount of flows for survival, the Endangered Species Act is a way that legislation has a lot of influence in setting rules on how water is used.

Plain old private water rights are a very important institution. We routinely talk about water rights in our part of the world, but when you look at other parts of the world such as Afghanistan and Iraq, there is no such thing as a water right. So when a drought occurs or other terrible shortage, there is a mad scramble for water; no one knows who has a senior right, no one knows who has a junior right and thus there is massive over-watering in the basin because there is no legal authority to enforce those rights in that part of the world. Water rights and their adjudication are a very important institution.

Adjudications, which state how much water you have a right to, and how that right to use water varies under various water supply conditions, its seniority, is very important. Shortage sharing agreements are important. We are finding in our work in Afghanistan that when supplies fall off in dry years, the question of who has to bear what part of that shortage and how that is enforced has a great influence on food security, water security, and farm income, all important to that part of the world. For our own part of the world, the Rio Grande Compact is an important shortage sharing agreement. Project operation rules like the Rio Grande Project are another example. All of these are important institutions, and since these institutions are designed and influenced by people, they are certainly not acts of God. They are adjustable and controllable and can be used to deal with future climate change and climate variability.

What might a water conserving institution look like (whether or not it is resilient), as opposed to a water hogging institution? Water conservation is itself a very tricky idea to define, but I would think that any institution that promoted a reduction in use over time, not just less use physically, but less productive use economically, where the benefits exceed the costs of reduced use, could be considered a water conserving institution.

What do we mean by resilient? You might have 120 definitions if you counted up everyone's definition in this room; but I would view a resilient institution as something that has built-in flexibility, something that can adapt to changes in demand for water from things like population, changing values, and changing uses. So when demand changes, the institution would adjust to reduce the suffering caused by unexpected shortages. Of course maybe supply is the bigger force, so when the supply of water changes, we would like our laws or institutions to be able to adjust or adapt to it; supply because of climate change, supply because of drought or flood. Pakistan has much infrastructure, but very few institutions for adapting to recent floods.

Resilience has to do with flexibility and has to do with adaptation: How are we going to evaluate whether or not some particular institution really is resilient? I'm not sure if there are any well-accepted standards out there, but I for one would like to see it be economically efficient in the sense of having the benefits be larger than the cost. I'd also like it to be just and fair. It would be even better if our institutions could be sustainable, if they could last; and it would be nice if they could protect water security and food security, though that's a bigger problem in some developing countries of the world. Certainly protecting water from out of state or out of nation encroachers or demanders would be very important here in New Mexico as other states and other countries are certainly looking at our water.

As we pursue this quest for these institutions, we are looking for measures that adapt, not just to changes, but to unexpected changes, that is, unexpected demand changes or supply changes or quality changes. The emphasis here is not just adapting, because you'll always adapt, but it would be nice to adapt with minimum economic loss. We are looking for flexibility so that people don't suffer as part of these changes.

My wife, Erin, found this nice photo last night of an efficient structure (Fig. 1), a classic picture of Hoover Dam. The dam is presumably efficient, it only cost $44 million to build the thing back in the 1930s; it has certainly produced 100 times that much in benefits. So that passes the test of an economically efficient structure. The benefits far exceeded the costs. But what might an economically efficient institution look like? I've looked at my old photo files, and I've driven around the state of New Mexico in this quest after Cathy put me on the hook here six months ago. I went looking for some economically efficient institutions. I found no signs saying that this was an economically efficient or resilient or any other kind of institution. So it's not easy to see an economically efficient institution. Even though you cannot see them, we can define them as a set of rules that produces high economic benefits from the supplies we have. Maybe benefits for irrigation, maybe benefits for urban use, benefits for environmental use, energy use, whatever kind of use we have for water.

Figure 1. Hoover Dam, an economically efficient structure

And, of course, in economics we always love the idea of avoiding using high-cost water for low-valued uses. So a good institution should discourage scarce water from being thrown on non-productive uses. Better yet, it would encourage ways to get scarce water moved from low-valued uses to high-valued uses. We would like to promote orderly development. When you think about the Colorado River Compact, the Rio Grande Compact and other compacts, those were developed many years ago so each state would know how much water they had coming to them. This helped each state with orderly development of farms and factories and apartments.

As for an equitable institution, Figure 2 is a photo that my wife and I took in Valencia, Spain last June; this is the water court of Valencia. This court convenes at noon every Thursday, at which time it tries to resolve local irrigation disputes. This is a fine and distinguished group of men who normally hang around in jeans, but at the appointed hour, they toss on those hoods to give them a look of distinction so they can debate and deliberate. It is a pretty impressive body and we thought that would be a good example of an equitable institution because it promotes social justice and it promotes fairness. I don't know that they promoted equal opportunity for access to water, but it would be nice if they did. So if our institutions are truly resilient, we want our institutions to be equitable and just.

Figure 2. The Water Court of Valencia, Spain, ranks as one of the oldest democratic institutions in Europe. The Court convenes at noon each Thursday in the center of the city, where farmer-elected judges hear and resolve local irrigation disputes.

For sustainable institutions, Figure 3 is a photo of a gentleman standing by his canal and one would think that he is going to sustain his water right. I'm not sure if that is a shotgun or a shovel that he has in his hand, certainly if that were in the Rio Grande Basin, there would be a

Figure 3. Gentleman protecting his water supplies

shotgun. He is forcing his sustainable institution with a shovel in this picture. What do we want sustainable institutions to do if resilience is going to mean sustainability? We certainly would want to keep our aquifers from being depleted; we would probably want to encourage institutions to use only renewable supplies of surface or groundwater but certainly we think of surface water as a more common renewable resource, although some aquifers are rechargeable. We would like our institutions to last for many generations. Eleanor Ostrom who won a Nobel Prize a year ago in economics, did lots of writing on institutions. Her work is relevant to our part of the world. If you like an institution and it is truly resilient, it will probably be lasting for a long time. I like the looks of the Rio Grande Compact; it has been around since 1936, it has a pretty good chance of being sustainable, and we'd want our water supplies to be sustainable and we would want the human right to water.

How would we score water institutional resilience? I have three or four rather interesting examples of great local importance. I looked at some important local institutions: the Rio Grande Compact; the U.S.-Mexico treaty of 1906; the U.S.-Mexico Groundwater treaty, which as you know doesn't exist yet; domestic well development that's being debated in the courts right now; and stream and aquifer adjudication.

The emphasis of table (Table 1) is on how all these institutions, existing or proposed, would be altered if you allowed water trading; without trading versus with trading. Generally, the message of this table is that with trading, it certainly gives rise to greater efficiency; water has a greater chance of moving from where it is to a higher valued use. Water trading can promote equity, although it is less likely to than without trading in some cases. And aquifer sustainability is another piece of the criteria. This table emphasizes lots of things, but probably any institution with trading has a greater probability or likelihood of passing the test of resilience.

Table 1. Impact on efficiency with and without trading

	Efficiency	Equity	Sustainability
Rio Grande Compact			
without trading	medium	high	low
with trading	high	medium	low
U.S. Mexico Treaty 1906			
without trading	low	low	low
with trading	medium	medium	low
U.S. Mexico Groundwater Treaty			
without trading	medium	high	high
with trading	high	medium	high
Domestic Well Development			
no offsets required	medium	high	low
offsets required	high	medium	high
Steam/Aquifer Adjudication			
without trading	medium	high	high
with trading	high	medium	high

What are my concluding points? Identifying resilient and water conserving institutions is complex. It is very important that even if you can't see them, they are pervasive, affect our lives, and they are mired in controversy. Good institutions will complement good infrastructure. Afghanistan has no institutions and no infrastructure for sharing shortages. So building great institutions with no structures won't help much. Any search for resilience should be open and debated and transparent. I like watershed policy models, so I would say the discovery of good institutions could be informed by hydrologic and economic models. Models force you to confront your assumptions.

Thank you.

Agriculture in New Mexico

Aron Balok, Pecos Valley Artesian Conservancy District

Aron has been the Water Resource Specialist and registered lobbyist for the Pecos Valley Artesian Conservancy District for about a year and a half. He came to the district from the New Mexico Farm and Livestock Bureau, where he was the South Eastern Regional Director. Aron has a passion for New Mexico's agricultural heritage and a deep appreciation for the complexity of the water issues that face the state. He has been professionally involved in water related issues for the past seven years. Aron was raised on a small cattle ranch in northwestern New Mexico. He attended New Mexico State University, and in 1997 graduated with a BS degree in agriculture, extension, and education. He and his wife Hayly and their three daughters live in Roswell, New Mexico.

I was asked to prepare a presentation about the relationship between agriculture and water. In particular, what the future may hold for the two.

Having said that, I am almost sure that you think you know what I am going to say: "Agriculture is good," "If you eat, you're in agriculture," "Don't take all the water away from ag." Well, you are sort of right. All of that is true, but the problem that agriculture (ag) faces regarding water is far more complex than just a simple line or phrase, and it has ramifications that reach far beyond the borders of New Mexico or even the United States. We all know that agriculture is the largest consumer of water; we all also know that urban development is the fastest growing consumer of water. It makes sense that ag is going to lose some water to urbanization. But I am here to offer a word of caution. There are some effects of fallowing farmland that often go unseen until it is too late.

So what am I hoping to accomplish here today? Am I hoping to get you to actively oppose any water transfer that might take ag land out of production? No. The fact is I am hoping that the next time you go for a drive through the valley, you might look out your window and say to yourself "hum." That's right, I want you to say hum — "How will our great grandchildren get their food?" If that happens, I will have done my job here today. While I am at it, I would like to try to dispel a few myths that are out there about agriculture.

The United States has always grown more food than we as a country could eat. The U.S. exports around 24 percent of our annual crop. American farmers grow about 42 percent of the world's corn and 20 percent of the world's beef, and that is where New Mexico farmers and ranchers come into play.

Let's start close to home. Figure 1 is the face of agriculture in New Mexico. Ok, maybe not, but Figures 2 and 3 are. New Mexico's top three agricultural commodities are dairy products ($1.36 billion per year), cattle and calves (nearly $1 billion), and hay (over $225 million). With an economic multiplier of seven, that's about $17.5 billion of economic activity per year! And it is all because of the cow's four-chamber stomach, or maybe more specifically, it is because of the lowly rumen microbe that resides in the cow's stomach. It is what allows us to raise cows here in the desert, feed them nothing but dry grass, mesquite, and sand and still send a healthy calf to market. This microbe allows us to unlock the food value of woody plants that have no food value to humans. It is because of this little bug that we are able to use such low quality forage to raise a healthy calf. We can then feed that calf some corn and hay and end up with a top quality protein source. So when you are driving home and you go past those alfalfa fields and think to yourself, "they are using all of that water to grow hay, and NOBODY eats hay," remember that hay is what allows us to raise cows; and those cows, along with dairy products from cows, combine with the hay to generate about $17.5 billion in economic activity every year!

Figure 1. Agriculture in New Mexico

Figure 2. Agriculture in New Mexico - chile field

Figure 3. Agriculture in New Mexico - alfalfa field

We grow a lot of pecans here in New Mexico. In 2009, New Mexico sold about $133 million worth of pecans. That's money that went directly to the growers and was more than any other state. And with the U.S. ranked as the top pecan growing country, that makes New Mexico the best place in the world to grow pecans.

Let me give you a little background on New Mexico's farmers. New Mexico farmers are in the business of selling what they can grow. The farmer first looks at what can be grown on his land. He factors in soil conditions, climate, and his own expertise along with the water he has available. Next he looks at the economics of growing a specific crop, and that means looking at the crop's commodity price and factoring in the inputs. You can look at it like this: irrigated agriculture sells inches of water. The farmer looks at what crop he can water that will cost him the least amount of additional money and yield the most money. Quite often alfalfa best fits the bill.

I'd like to talk a little more about today's farmer. The perception of the land rich, dirt poor rube still exists. I have a story that helps make my point. After a failed four-year campaign to rid the Navajo Reservation of ignorance as a teacher, I took a job on a large ranch west of Albuquerque. One of the goals I set for myself and the ranch was to increase the deer and elk population. One way to help accomplish this was to decrease the predator population. So I spent a considerable amount of time and money hunting, trapping, and generally harassing the coyote population. As a result, when someone asked if they could come to the ranch to hunt coyotes I had to tell them that while there were still plenty of coyotes left, I had already taken care of all the stupid ones. The only ones left were survival experts, with senses so honed, that a mere mortal had little chance of catching them out in the open. Today's farmers have something in common with those coyotes; the free market has weeded out all the dumb ones. Those left are businessmen who not only understand economics and trading on a global market, but they have also somehow learned to survive in a business environment where even if you do everything right, Mother Nature can still pull the rug out from under you.

Most people also fail to recognize how technology has impacted agriculture. Today's farmers rely on state-of-the-art technology; from the water delivery systems that use satellite or radio telemetry for turning pumps on and off and for monitoring water use, to high-tech equipment to harvest and process their crops. I'd like to use a farmer who I know as an example of this new way of doing business. He is a hay grower in the Pecos Valley. If you look at any of his fields, you will notice immediately that there are conspicuously few weeds. That is a feat in and of it self. If you look into any of his hay barns you can't help but notice how green and lush the bales of hay look. An experienced hay buyer would tell you that it's been "put up right." Obviously this guy knows how to grow hay, but there is more. If you ride around in the truck with him, you can't go five minutes without being interrupted by a cell phone call. He'll talk to a buyer just down the street, or across the country who wants four or five bales, or four or five semi-truck loads. The buyer is a customer that he may have done business with for years or someone who just found his website. In one of his hay barns, you will find what he calls "the hay plant." This is where they take big 1,500 lb square bales and cut them into small bales. These small banded bales are then stacked on a pallet and shrink wrapped. The bales can be loaded on a truck with a forklift and shipped across the state, or be loaded into an air-tight sea shipping container and shipped anywhere in the world. This can all be done by a two-man crew. He and his son run a very efficient and successful farming operation.

Today's talk provides me with an opportunity to do a little myth busting. People tend to believe that most farms are in the hands of some big multinational corporation. The truth is that 82 percent of all agricultural products are sold by family farms. And by family farms I mean this: individuals, family partnerships, and family corporations. Ninety-eight percent of all farms in the U.S. are family owned. Yet we are losing farmland at an alarming rate.

Now we get to the heart of the problem—the loss of farmland, or more specifically, the loss of irrigated farmland. It seems to be the natural progression of land ownership: land begins as wilderness, it then becomes pasture, followed by cultivation, growing hay and grain crops. Next you see a transition to row crops, like vegetables, cotton, and chile. Then you start to see trees growing in those fields, fruit or nut trees. Before you know it, houses start growing on this same land. The late Paul Harvey once called attention to this fact when he said, "There is no more farmland and every year there is less, we're paving it, flooding it, leaching it, and building buildings on it." In the past decade, we have lost about 32.6 million acres of farmland in the U.S. That's about five times the size of Yellowstone National Park. And 11 to 12 percent of that loss is from irrigated agriculture.

If you go to Germany and decide to buy a farm, you can do that. If you decide you want to tear the old farmhouse down and build a new one, you can do that too. But if you decide that you want to take that farm out of production and build houses on it, you cannot do that. They have laws in place to protect the existing farms from development. If you ask them why, they will look at you like you are stupid, then tell you that a country must preserve its ability to grow its own food.

Many would argue that we need laws like that in our country. And while it sounds like a good idea, I couldn't disagree more. If you passed a law such as that, you would, in one fell swoop, remove most of the value of that farmland. So a farmer who has been counting on the value of his farm for his retirement and has worked all his life to build a nest egg, would have it taken away. I believe he has the right to sell his land and water out of production. The choice is his. Here is where many think that conservation easements are the silver bullet that we have been looking for. For those of you who aren't familiar with conservation easements, that is where a deed restriction is put on the property that limits how the land may be used or developed in the future. A conservation group may buy an easement on a farm for, say, a quarter of its appraised value. That farm may then be sold to someone else, but the new owner cannot develop it. Often the problem is that a group may be able to afford a quarter of the value of the land, but as a result, the land may be de-valued by more than half. These types of easements are only effective when the price paid is enough to cover the loss of value. Another shortcoming of conservation easements occurs when the seller is required to forfeit some management rights in order to sell the easement. In other words, the buyer will get some input as to how the farm can be run in the future. So while conservation easements will play a role in the future, they are not the total solution.

Today we set out to discuss the future of water. All our lives we have been misled about what the future holds; from the Jetsons to Space Odyssey 2001, we have been unable to foretell what to expect. So first let's talk about what we know. Less than 2 percent of our population produces our food. That means that each farmer or rancher produces enough food to feed 155 people. Every year there are fewer farms and fewer farmers. Bear in mind that in the next nine years, agriculture must produce as much food as it has in the last 6,000 years.

A lot of people believe that we can meet our growing demand with supply from other countries, and to some extent, we can. As efficiencies in other countries improve, supply will increase to feed a growing world population. But this is one area that becomes tricky. Today at the grocery store, you can buy food from around the world, often cheaper than the same product grown here. I don't have a problem with the availability of food from other countries, but I see a very slippery slope that can lead to a dependency on foreign food, and if you have enjoyed being dependent on foreign oil, you are going to love being dependent on foreign food. Food grown outside of the United States does not always meet the standards that U.S. food is required to meet. For example, there are pesticides that have been banned from use on food crops here in the U.S. that are used in other countries. Now you may be thinking, "but in order to enter this country, they must meet our standards." You are right. Sort of. I guess you could say, "They should meet our standards for production and processing. It's hard to tell given that only about one percent of the food that crosses our borders into the country actually gets inspected by the U.S. Food and Drug Administration. And if foreign processing plant inspections continue at the current rate, they should finish inspecting them all in about 1,900 years.

What about the environment? It is estimated that about 80 percent of the wildlife and 75 to 90 percent of the endangered species in the country live on privately owned lands depending on where you are in the country. Wildlife depends on agricultural land for both food and cover. Thanks to the Endangered Species Act (ESA), wildlife has been put at odds with agriculture, often with dire consequences for both. The biggest problem with the ESA is not its intent, which is to protect endangered species, but the fact that it has been used as a club to beat people over the head to promote an agenda. If you talk to a wildlife biologist, they will tell you that when legal action forces compliance, the endangered species rarely reaps the benefits. In California, they had a problem with a little creature, the Delta Smelt, which is a small 2- to 3-inch minnow that lives in rivers in southern California. In 2008, it was determined that the pumping in the San Joaquin Valley was causing this endangered fish greater peril and the courts ordered the irrigation pumps to stop. Prior to the order to stop pumping, Berkeley Economic Consulting, using a model from the U.S. Forest Service known as IMPLAN, calculated that "720 jobs will be lost in the San Joaquin Valley as a result of the Interim Order. The large majority of these farm jobs are held by low-wage workers living in economically depressed areas." The pumps did stop, and since then economists have been struggling to calculate the actual impacts. Job loss estimates vary wildly from somewhere over 1,400 to 95,000. Despite noble efforts to counter the negative impacts, the economic impacts are disastrous. Positive effects on the Delta Smelt have been hard to determine.

Where are we headed? As E.M. Tiffany once wrote, "I believe in the future of Farming." I love the productivity of American farmers! I think Dr. Lowell Catlett from New Mexico State University's College of Agriculture put it best when he framed it like this: There are about 77.5 million dogs in the U.S., and they are the most well fed dogs in the world! There are about 90 million cats in the U.S., and guess what? They are the best fed cats in the world! I believe that New Mexico farmers, just like farmers all around the country, are going to keep doing what they do best, producing more for the many—with less.

Agriculture has been counted out every few years since the beginning of the industrial revolution. I still hear it from time to time—"agriculture is on its way out." You would think that after 10,000 years people would come to believe that agriculture is here to stay. But many insist that it is on its last leg. I think they are wrong. Much like the coyotes I told you about earlier, farmers have learned to adapt. I would argue that you won't find a more flexible and adaptive business plan in any other sector of business or industry. I think that farmers will continue to increase per acre yields; I think we will see more genetically modified crops that are more drought and heat tolerant; we will see better delivery systems that allow for less waste, maybe something like the device shown in Figure 4. It is called an "in-line processor." It is thought to be capable of striping electrons from water as it flows through the water. By doing this, the water is unable to bond with impurities like salts. If it works, this would allow the plant to absorb a higher percentage of the water.

Figure 4. In-line Processor

I also see people placing a greater value on food grown here. That can be seen today with people willing to pay more for produce grown locally. I think that if society as a whole is willing to pay a premium for water that does not come at the expense of farms, farmers will be willing to help fill in the gaps. An example of this can be found in west-central Oregon. Oregon's salmon runs were suffering during times of drought. So while some environmental groups sharpened their pencils and talked to their lawyers, others took a different approach. They leased some water rights from working farms. The farmers were able to change their farming practices and did not water during the times of greatest need, and they still stayed in business. The fish got the water they needed to spawn, their farms still produced a crop, and all this was done at a fraction of the cost that would have come about from a court ruling.

The real solutions to our water and food problems, I think, will come from where they have always come from: scientists in big laboratories, and handymen in their garages, and farmers in the fields. There will be concepts so foreign that most will scoff and say it will never work, or be so simple and obvious that we will all collectively slap a hand to our forehead and say, "Why didn't I think of that?"

If people like you and me put our minds to it, I see no reason why urban growth must come at the expense of agriculture. It will take better planning, and great ideas, and it may be harder. I also think that is fitting. It should be harder. Nothing worth having comes easy.

Rainwater Harvesting and Recharge Techniques for Flood Control and Improved Stormwater Quality

Vaikko Allen, CONTECH Construction Products, Inc.

Vaikko is the Stormwater Regulatory Manager for CONTECH Construction Products Inc., where he assists regulators, engineers and environmental organizations in the development of regulations that are clear, implementable, and protective of our public waters. Throughout his 14 years of stormwater management experience, he has managed BMP testing programs, new product development initiatives, and been involved in numerous work groups providing technical guidance on TMDL implementation, hydromodification planning, and low impact development. Formerly, Vaikko served as Technical Manager of Vortechnics, Inc., a rapidly growing stormwater BMP provider that was acquired by CONTECH in 2004. He holds a BS degree in environmental science and policy from the University of Southern Maine with a concentration in water resources. He also holds patents for several stormwater BMPs.

The following is a transcript of an oral presentation given by Vaikko Allen.

Good morning. I'm glad to be here today and I've enjoyed meeting a few of you here as I spend some time in New Mexico. What I want to spend most of the time talking about is rainwater harvesting and infiltration and capturing water that might otherwise be lost to the atmosphere and perhaps using it for something useful, thereby reducing potable water demand. That water is needed for all kinds of things here, farming for example, and it is also over-allocated if you are look at the Rio Grande or other water systems.

I want to zoom down to the micro level, the site level. What do you actually do on specific projects and what are some of the techniques? But before we look at that, I thought it would be wise to take a macro view and ask ourselves what is our goal and what are we trying to do here. I think as you back up further and further, you eventually reach a point where nobody can disagree, which is to say, sustainability is really the important strategy or endpoint that we are all trying to reach. It is where you have some kind of a balance between extraction of resources and the natural replenishment of the resources so that you can provide for the needs of the present without compromising the ability of future generations to satisfy their needs.

Back in 1987, the World Commission on Environment and Development came up with a definition that is one of the first widely referenced definitions of sustainability. People usually quote the beginning part, but the more interesting parts **follow in bold**. The commission recognizes that it does imply that there are some limits, particularly to resources and how much of them you can use, but they also point out an important point, which is that those limits are a function of the technology and social organization that exists at the time. To the extent that we can improve on those two things, we can actually increase our ability to use our resources, and we can use more of them some of them perhaps.

> Humanity has the ability to make development sustainable to ensure that it **meets the needs of the present without compromising the ability of future generations to meet their own needs**. The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of **technology** and **social organization** on environmental resources and by the **ability of the biosphere to absorb the effects** of human activities. (WECD, 1987)

The report included some simplistic math and maybe it applies to water resources; the more we extract that isn't replaced or the more we degrade what is remaining there, the less we have to use.

- Water Resource Impact = Resource Depletion + Resource Degradation
- Resource Depletion = Resource Use – Regeneration Rate
- Resource Degradation = Pollution Inputs – Assimilative Capacity

For those of you who are visual learners, about the most macroview that you can have puts this in perspective (Fig 1). What we see is obviously the earth in two views, but you are seeing a representation of the total amount of water on earth as compared to the earth itself and the total amount of air in the atmosphere. That is a pretty small drop in the bucket so to speak, about 1.4 billion cubic kilometers of water we have on earth. As you all probably know, of that water, 97 percent is in the oceans. What we are left to manage is really a very small amount. We need to be exceeding careful and deliberate about how we use it.

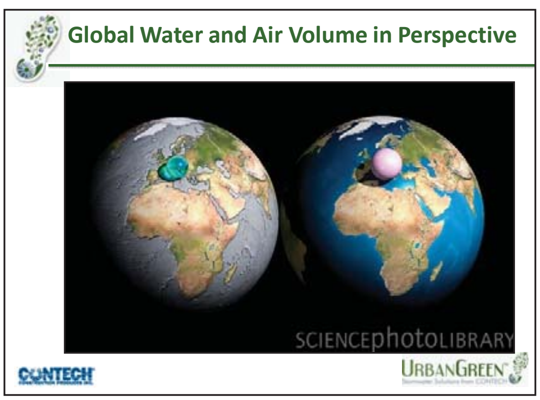


Figure 1. Total volume of water on earth (left) and total volume of air in atmosphere (right) [Credit Adam Nieman/ Science Photo Library]

Getting a little bit closer to where we are now, and looking at what the future holds for us, we can talk about the next ten years perhaps and water policy decisions and management decisions that need to be made (Fig. 2). If you look at New Mexico specifically, in the next ten years between 2010 and 2020, we are expected to have a little more that 100,000 additional people move here. It may be a less dramatic increase than some of the surrounding states, but it is still pretty important when you do the math as far as water demand. A 150 gallon per day (gpd) per capita target is not something that we are at right now but it is set as a realistic goal for us in the next few years. We are at about 155 or 160 gpd. When you do the math, there is 17,500 acre-feet per year in additional demand that has to be coming from somewhere. Where does it come from? I don't know the answer to that question, but I think as we go through the rest of the presentation, we'll see some places where we may be able to salvage a bit of water that otherwise may be a loss.

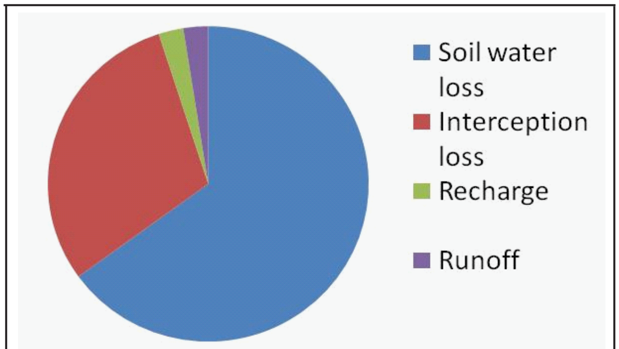
The biggest thing to focus on when talking about water or energy or many other utilities is efficiency improvements. That's kind of like a free additional source or supply. To the extent that you can be careful with what you are using, there is more of it to go around. Desalination projects around here use pretty deep groundwater but sure enough, people are extracting it, and of course you look to the extent to which you can bring water in from outside, although I think around here it is usually the case that more people are trying to take the water from here and export it outside the state than the other way around. A lot of those avenues are either expensive, as with desalination, or they are often tapped out at this point.

Region, division, and state	Numerical change 2000 to 2010	Numerical change 2010 to 2020	Numerical change 2020 to 2030	Numerical change 2000 to 2030	Percent change 2000 to 2010	Percent change 2010 to 2020	Percent change 2020 to 2030	Percent change 2000 to 2030
United States	27,513,675	26,868,965	27,779,889	82,162,529	9.8	8.7	8.3	29.2
Colorado	530,293	447,313	513,490	1,491,096	12.3	9.3	9.7	34.7
New Mexico	161,179	104,116	15,367	280,662	8.9	5.3	0.7	15.4
Arizona	1,506,749	1,819,067	2,255,949	5,581,765	29.4	27.4	26.7	108.8
Utah	361,844	395,081	495,273	1,252,198	16.2	15.2	16.6	56.1
Texas	3,797,068	3,986,008	4,682,848	12,465,924	18.2	16.2	16.4	59.8

U.S. Census Bureau, Population Division, Interim State Population Projections, 2005.
Internet Release Date: April 21, 2005

Figure 2. Project population growth for western states

I thought it was interesting to look at the dryland range water balance (Fig. 3). I know you are a sophisticated audience and we don't have to look at the whole water balance graphic, of which there are many pretty pictures: the rain falls, some of it evaporates, some of it infiltrates, some of it runs off, and so on. If you look at this on dryland range, similar to what you would have in places in New Mexico, you see that the actual run-off percent and the recharge percent are very small and in most cases will be substantially less that 10 percent of the total rainfall. In a lot of these cases, the water falls and is absorbed in the top layer of soil and then it evaporates over time, some of it is directly intercepted by vegetation just falling on leaves and such and evaporating directly. That water doesn't go anywhere in terms of improving your water supply; it isn't available to you. It falls, goes back up into the atmosphere and is lost; thus the water is unavailable.



- 30-80% Soil water loss
- 20-40% Interception loss
- <5% Runoff
- <5% Deep Recharge

Figure 3. Dryland range water balance. Wilcox, B.P., D.D. Breshears, and M.S. Seyfried. 2003. Water balance on rangelands. In *Encyclopedia of Water Science*, Marcel Dekker, New York, 791-794

Think about the way urban development works: you come in and build houses, you pave areas, and you turn the landscape runoff, which has a natural sponge that may be taking up 80+ percent of your precipitation. The runoff piece of the pie dramatically increases in these cases, especially as imperviousness increases. What can we do with that water? How can we use that? That leads me to the rest of the presentation on is rainwater harvesting; getting water into the ground in such a way that it could potentially be useable or recoverable later on.

Conservation has been outlined a bit today, but who has heard of green infrastructure and low-impact development as a terms being thrown around, especially as terms in the stormwater world? It is kind of a buzz word this year. I know U.S. EPA has been through this region conducting green infrastructure workshops. I'm going to trace through a couple of developments that are happening at a national level and you can see a direction where things are headed from a stormwater management perspective.

Green infrastructure and low-impact development action plans have been developed. These plans make it very clear what they are trying to do. They are trying to build in such a way that they preserve that sponge, that evapotranspiration, and that natural functionality of our landscapes even though you are putting in buildings, parking lots, and roads.

An interesting piece of legislation is the Energy Independence and Security Act. This applies to federal facilities and from a stormwater perspective, it contains an important short paragraph, Section 438, and a guidance manual published in 2009. It basically says that for a federal facility, to the maximum extent technically feasible, you can't have any increase in the post-development run-off duration, magnitude, temperature, or volume. That is a pretty difficult thing to calculate and to prove what you've done, but they said that instead of doing all those complicated calculations, you can just retain the 95th percentile store on site by design. In most cases that works out to one or two inches. You must take the rainfall and not let it leave your site. That applies to federal facilities, so those working on military bases and would have to follow this, too. In 2010, EPA published the MS4 Permit Guidance that applies to municipal and separate storm sewer systems. It is expecting that as permits get renewed, they will basically do the same thing, retain the 95th percentile design storm on site to the maximum extent technically feasible. So you can see the direction EPA is pushing things as stormwater permits are updated.

I live in California, and it has been a pretty interesting and tumultuous couple of years as we have had eight or nine municipal permits being renewed in places like Orange County, San Diego, San Francisco Bay, and other places. Figure 4 is my attempt to summarize and homogenize all relevant requirements into a handy table. Basically what it says is that you have a hierarchy of management techniques that you are expected to use when it comes to managing stormwater. If you start at the top, source control and design techniques are things to preserve that natural sponge that exists or to just use less impervious materials. If you can't do that, then you need to infiltrate that water at the surface via retention. If you can't do it at the surface, then dry wells or something similar is used. If you can't get that done, you can use rainwater harvest to keep that water from running offsite. If you can't get the job done through any of those techniques, which actually retain the water onsite, you need to go to the next step, which is to do some sort of flow-through treatment. Before you get there, you must do a feasibility test, basically to prove that it is technically infeasible, not financially infeasible to hold that water onsite. As you can imagine, the development community thinks it will be difficult if not impossible as well as extremely expensive and all the details are settling out. I think this framework is what we are moving toward everywhere in the U.S. Right now the EPA is engaged in a rulemaking process and they expect that in 2012 they will have a new stormwater requirement that will apply universally and which will be patterned after this kind of approach.

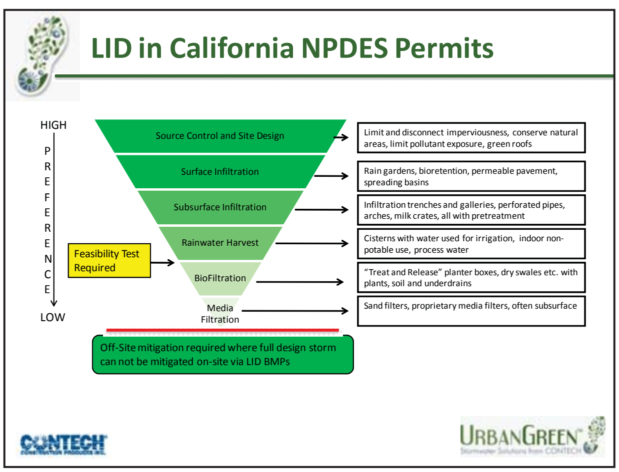


Figure 4. Hierarchy of management techniques used when it comes to managing stormwater

For the rest of the presentation, I want to talk about these controls: what they look like physically, how they are designed, and what we need to think about. First, for the infiltration part, there are some very obvious things like if water goes in the ground you need to think about where it is going. You don't want to put it in the vicinity of contaminated soils, contaminated groundwater plumes, or building foundations. If you are going to be doing infiltration, you need soils that are permeable; obviously you can't permeate if you have bedrock or clay or anything else impermeable. And, wherever the water goes, things that are soluble are going to go with it, so you must pay attention to what is located in the area like gas stations. You don't want to be doing infiltration and later end up with problems created as a result.

There are lots of ways to do surface infiltration. Figure 5 addresses permeable pavement. A lot of options are out there; this is basically used exactly the same as regular asphalt or concrete would be, they just remove the fines from the mix and you have a relatively porous top surface. Below that, there is a bed of washed stone that has a 30-40 percent void ratio and usually a fabric liner underneath that, which acts as a reservoir. So when it rains, it acts like a permeable surface, the water goes into the ground and is able to percolate into the native soil. This is not accomplishing much as far as water supply, but it will satisfy stormwater requirements. There are also plastic grids that are sometimes used with turf on them. However, around here let's avoid turf if at all possible in light of our conservation goals. You can use gravel with the idea that essentially you are reinforcing the driving surface so that it can support much more load; it is like a snowshoe, it supports a load over a wider area so you don't destroy the driving surface. Also, if it rains, it is a much more durable surface because the water can flow through and you don't end up with ruts.

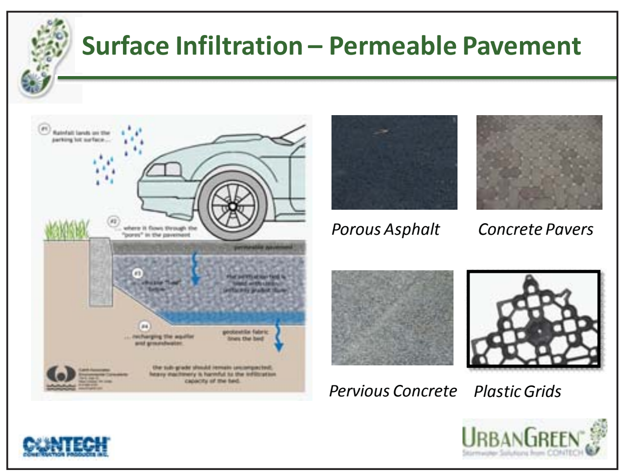


Figure 5. Examples of permeable pavements

The other way to get water in at the surface is by retention and Figure 6 is an example of a typical one in San Diego. Essentially what you are doing is taking sheet flow from an impermeable area and running it to a pervious area with some kind of surficial depression; sometimes they are much more recessed than the one in this photo and the water just does what it would do naturally, infiltrate into the ground. Typically there is a rock layer or something below that has some kind of reservoir volume so that you can accommodate the volume of water that comes off impermeable surfaces. What we find, especially in California and in urban areas, is that you start to have development densities that drive up the cost of land and also decrease the amount of land with which you have to work. Often people don't want to give 10, 12, or 15 percent of their site area over to a bio-retention system because it represents lost parking spaces or other useable space.

Figure 6. Bio-retention of parking lot runoff in San Diego

A way to get around that problem is to do subsurface infiltration. Figure 7 provides an example with before and after photos of an Ohio college dorm. Instead of having a pond for retention, a below grade pond was built essentially out of corrugated pipe with the land surface on top. There are lots of ways to do this. In this case there was a detention system, but those pipes could be perforated and it could be infiltration as well.

Figure 7. Subsurface infiltration: Construction (left) and after (right)

It should be pointed out that especially when we are talking about subsurface infiltration, pretreatment is critical; basically, infiltrating surfaces are going to be below some landscaped or paved area. You do not want to have to go back in there during the life of the project, 20 or 30 years, and rehabilitate that infiltrating surface. To the extent that you can keep solids out by using advanced pretreatment, it is a very good idea. Figure 8 is a cartoonish version of what that might look like: we have a catch basin taking runoff from the parking lot, running it through a separator, and running into long barrels, in this case perforated corrugated metal pipe. From the perspective of someone parking their car there, they would have no idea that this system exists, but it is performing the recharge function and doing it in a way that is really unobtrusive.

Figure 8. Subsurface infiltration where pretreatment of runoff would be required

A lot of different materials are available for infiltration and detention, including concrete, metal, and plastic (Fig. 9). Some systems are extremely large. The CON/SPAN units are precast, delivered, and usually set up with strip footings, at least in an infiltration application, and it is essentially an underground spreading basin. Crushed rock lies between the strip footings and water would be able to infiltrate. We have placed these at airports; they drive planes right over the top because it can be reinforced. Essentially we are taking an infiltration basin and putting it underground to recover some of that useable land. Corrugated metal pipe tends to be one of the cheaper ways to go about this, in many cases $.50 to $1.00 per gallon of storage volume. And these systems can look like just about anything and are very versatile. When we are doing stormwater work in most cases, we use aluminized pipe as opposed to galvanized pipe because the zinc content of galvanized pipe can sometimes cause problems downstream so it is avoided.

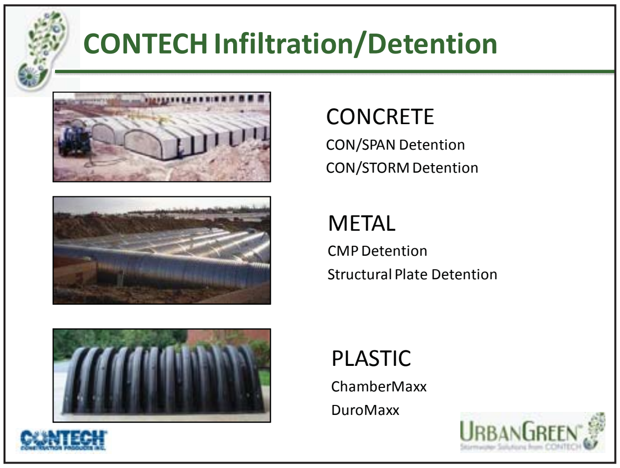


Figure 9. Example of concrete, metal, or plastic for infiltration

Lots of plastic systems are out there; for example, there are milk-crate type systems (their generic term), that are square boxes that you can stack. They have a 90 percent void space; there are lots of different containers for the water and you can think of them as gravel replacements. You basically fill the trench with gravel and sometimes put an under-drain on the bottom. All these systems are a way to avoid using a lot of gravel, thereby shrinking the size of your system pretty dramatically and improving the loading capabilities.

Depending on what your constraints are, if you have a very wide or shallow application, you might use plastic. If you are looking to save a lot of money and have room for an 8- or 12-foot diameter pipe to be buried under-site, then corrugated pipe is typically the most cost-effective option. There are lots of ways to install it, but the idea is to get the water below the surface and to infiltrate it into the ground.

An example I thought was interesting was a recent job I worked on in downtown Los Angeles (Fig. 10). It was located in an old industrial area with a bunch of buildings, some housing, but mostly old dilapidated commercial buildings that they tore down and are building a massive new development on the city block. No landscaping is required because it is in the downtown commercial zone; there aren't even setbacks, you can literally do a lot-line to lot-line development. As you can imagine, as they develop and add a lot of paving, either for the driveways and parking lot or for the building rooftops, there is a whole lot of stormwater runoff that is going to be generated. A big concrete system with drywells punched in the bottom was installed. The system will hold the runoff volume and over the space of a couple days, it will infiltrate the drywells, three of them underneath manholes that go down about 40 feet below the bottom of the system. Eventually there will be a fire lane over the top in the middle of the site so there is access to maintain or inspect it as needed. This is an extreme example of a very dense site, but that is how it can look.

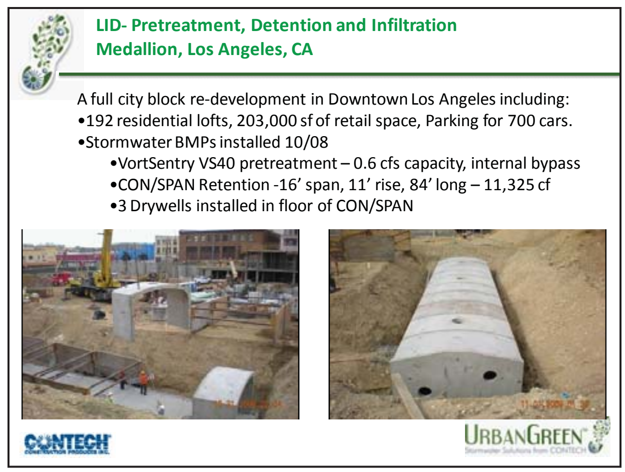


Figure 10. Los Angeles concrete infiltration and drywell system

Let's switch gears a bit and talk about rainwater harvesting, the other way to capture and hold onto water. Two philosophical design approaches exist when you are talk about stormwater or rainwater harvesting. Traditional water harvesting is the collection and reuse of stormwater, grey water, and other sources to reduce or eliminate the consumption of municipal potable water. Typically, the way we've been doing things for thousands and thousands of years is essentially an attempt to conserve water; you try to offset demand for water that you might have to bring in from some other source by increasing your catchment area. Rainwater harvesting for low impact development is the collection and reuse of stormwater for beneficial purposes to reduce or eliminate post-construction runoff.

Figure 11 contrasts the two approaches. If you are trying to conserve water to offset municipal water demand, you want to have a big catchment area to increase your supply. If you are doing it for stormwater purposes, you want to make your catchment as small as possible so that there is less runoff to try to eliminate. If you are trying to minimize and conserve the water usage, it is a conservation approach. With a stormwater focus, you must search for water reuse applications to get rid of that water somewhere onsite so that you can recover the cistern storage space for the next time it rains. Taking that further, it is good in a conservation paradigm if your tank is full because that means you have water available for your next irrigation. In a stormwater application, if you have a full cistern and its going to rain, you aren't going to be able to retain that water, so you want to empty the tank as soon as possible. There are some competing design ethics that are interesting in the way that they determine what the systems actually look like. As it turns out, usually if you are designing for conservation, you probably are going to be meeting your stormwater requirements as well, but it doesn't necessarily work in the other direction.

Rainwater Harvesting – Two Perspectives

	Conservation Focus	Stormwater Focus
Primary Goal	Reduced municipal demand	Eliminate runoff (pollution prevention)
Secondary Benefits	Reduce SW Runoff, Energy, CO_2	Conservation, Energy, CO_2
Catchment Area	Maximize, to Increase Supply	Minimize, to Reduce Supply
Water Usage	Minimize and Conserve	Find Reuse Applications
Seasonal Challenge	Dry Season – not enough rain	Wet Season – too much rain
Cistern Goal	Keep it full	Empty it quickly
Economic ROI	Negative – "external costs" not included in market price of water	Positive – best LID solution in many cases

Designing for conservation usually meets stormwater requirements but not vice versa.

CONTECH UrbanGreen

Figure 11. Stormwater approach vs conservation approach in rainwater management

Where is this used? It is used primarily for irrigation, toilet flushing, clothes washing, vehicle washing, process water cooling, and fire suppression. Plumbing codes and public health issues are concerns when you start to bring water inside a building. It turns out that when you do rainwater harvesting for stormwater runoff production purposes, it is very important to find those reuse applications for inside, because typically when it rains you need to get rid of water quickly to recover the volume in your cistern. However, you usually don't need the water right then for your landscaping, so you can use it to flush toilets, do laundry, or something similar.

We generally have two types of systems; although an oversimplification, you have passive and active systems. First, let's look at passive systems briefly. These are typically intercepting roof runoff just because of the head or grade differential; you need the gravity from the roof to be able to fill your cistern and the cistern should be located above where you need to use it. Figure 12 is an example. The conservation design of the tanks corresponds to the annual rain volume and can get very large. For a low-impact development design, we usually see tanks designed to hold the average storm, 1 to 1.5 inches, and which empties relatively quickly over the space of a couple of days. This kind of system does not do anything to offset potable demand, but it does solve the stormwater runoff issue. Typically, you have some connection to the roof, a screened opening, sometimes a screen in the downspout, an overflow pipe in case it gets full, a spigot connected to a hose or some other water distribution system, and a drain to clear the system out periodically (Fig 13).

Figure 12. Passive rainwater harvesting design [Credit Sherwood Design Engineers]

Figure 13. Components of a passive rainwater harvesting system

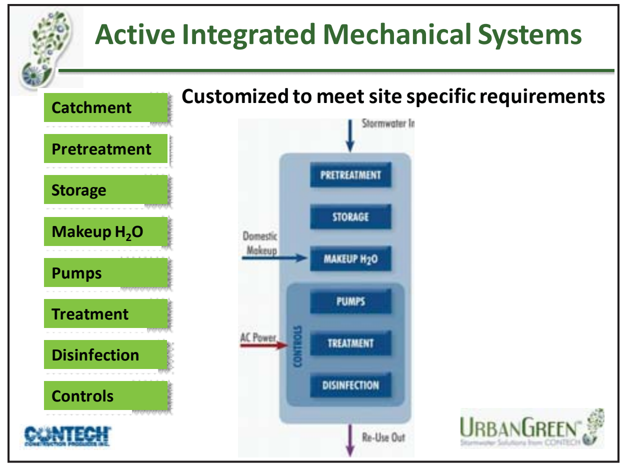


Figure 14. Active mechanical rainwater harvesting diagram

Active systems are a bit more complex; essentially water comes in and goes out and you need a way to model what happens over the course of a year or multiple years to determine the system's design. A notable difference with the passive system is that power is required for the active system because you have controls, like pumps, treatment, or disinfection oftentimes, and depending on the system's design, you may have municipal makeup water pumped directly into the system. Figure 14 shows the components of an active integrated mechanical system. The catchment is very important depending from where your water is coming. If it is from your rooftop, it's going to be relatively clean, probably just a couple millimeter screen will suffice to catch the leaves and other large debris. If you are draining from a parking lot or roadway, there will be a whole lot more stuff in it and you probably want to go down to a 20-micron screen just to get the pavement abrasion, the organics that may be accumulating, tire and brake pad disintegration, and so on. Obviously you want to avoid any industrial areas where you have potential for spills. Once you get that water off your impervious surface, pretreatment is important. Again, if you are at a rooftop, you want to use a screen; if it is coming from the surface, you want to use a filter or at least some kind of gravity separator. We want to keep the BOD level down; we don't want to have organics going into a cistern and sitting there for a long time making the water anoxic or septic, which can be an issue.

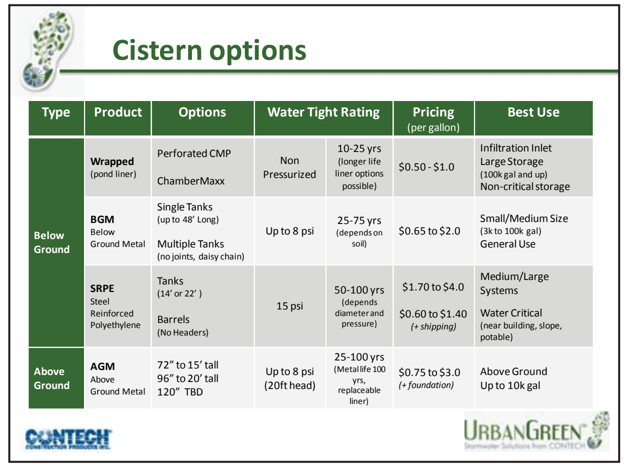
Figure 15 is a mechanical system that looks more complicated than that rain barrel we saw in Figure 12. Typical component options include treatment with screen, filters, manual or auto back flush; makeup water with day-tank with air-gap; back-flow preventer; disinfection of UV with chlorination, instant or recirculation; pressurization with suction pumps or submersible pumps; controls for operation, monitoring with tie to building management; power supply of 120/240/480 v in 1-phase or 3-phase, and enclosure indoor, outdoor, or underground. CONTECH has been supplying these types of skid mounted or palletized systems. We heard again and again from engineers, developers, and designers that these systems were just too complicated: to get the parts sourced and working together, and to get the control panel built and able to talk to the pumps and flow meters. We thought this was an opportunity for innovation and we started working with a couple companies who do this work. We now are providing systems that look somewhat like the system in Figure 16.

What you can't see in Figure 16 is the back where there is the feed-in from the cistern; it goes through the back of the panel and through a filter and drops into the tank, which is an empty day tank. The filter backwashes and this backwash travels from the filter through a pipe and discharges. It is not ultimately part of the water use, so some water is lost. We have a municipal makeup waterline in this system with a little air gap so the water comes in from the municipal source and tops off the tank in times when you don't have enough water available in your cistern to fill the tank. This system has a UV disinfection loop. We aren't disinfecting the whole cistern; we disinfect the water that gets used on a daily basis. It's best to disinfect water as close to the time it's needed and disinfecting a smaller volume is less expensive. The pump at the bottom of the figure takes water from the day tank and delivers it to the use application. In this case the water will be used for irrigation. A control panel on the left side keeps track of different valves, flow-meters, and so on, and makes sure the system is operating as intended. The water from this system goes outside to an enclosure (although it could go to an indoor basement); sometimes we use a vault, so there are lots of different ways to go.

Figure 15. Traditional active mechanical rainwater harvesting components

Figure 16. New active mechanical rainwater harvesting

Cisterns oftentimes are the biggest cost. Lots of types exist and some of the types we provide are described in Figure 17.



Cistern options

Type	Product	Options	Water Tight Rating		Pricing (per gallon)	Best Use
Below Ground	**Wrapped** (pond liner)	Perforated CMP ChamberMaxx	Non Pressurized	10-25 yrs (longer life liner options possible)	$0.50 - $1.0	Infiltration Inlet Large Storage (100k gal and up) Non-critical storage
	BGM Below Ground Metal	Single Tanks (up to 48' Long) Multiple Tanks (no joints, daisy chain)	Up to 8 psi	25-75 yrs (depends on soil)	$0.65 to $2.0	Small/Medium Size (3k to 100k gal) General Use
	SRPE Steel Reinforced Polyethylene	Tanks (14' or 22') Barrels (No Headers)	15 psi	50-100 yrs (depends diameter and pressure)	$1.70 to $4.0 $0.60 to $1.40 *(+ shipping)*	Medium/Large Systems Water Critical (near building, slope, potable)
Above Ground	**AGM** Above Ground Metal	72" to 15' tall 96" to 20' tall 120" TBD	Up to 8 psi (20ft head)	25-100 yrs (Metal life 100 yrs, replaceable liner)	$0.75 to $3.0 *(+ foundation)*	Above Ground Up to 10k gal

Figure 17. Cistern options

Figure 18 shows the standard components of the system. In Figure 19, you can see the pond liner, which is an impermeable geotechnical membrane that gets wrapped around the entire system. Figure 20 shows corrugated metal pipe that is perforated and will be backfilled with gravel and wrapped over the top, similar to the chamber system. We also install metal pipe tanks below grade, which is a technology we've adapted that is similar to a rhino liner for the back of a pickup truck bed, it is basically a rubberized sealant (Figs. 21 and 22).

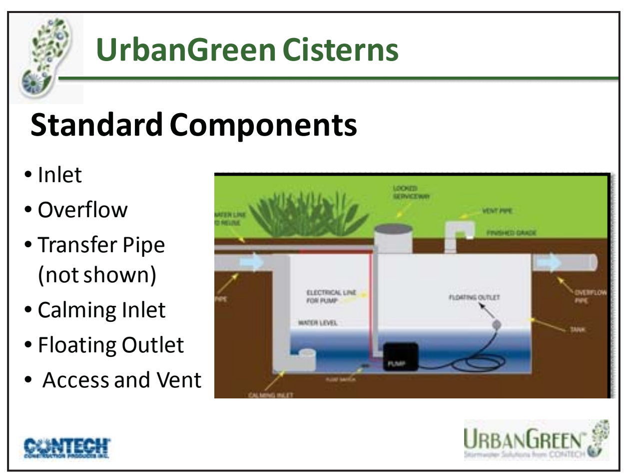


Figure 18. Standard cistern components

Figure 19. Impermeable pond liner in the background and perforated metal pipe that will be filled will gravel and wrapped over the top, similar to the chamber system

Figure 20. Wrapped corrugated metal pipe that has been filled with gravel

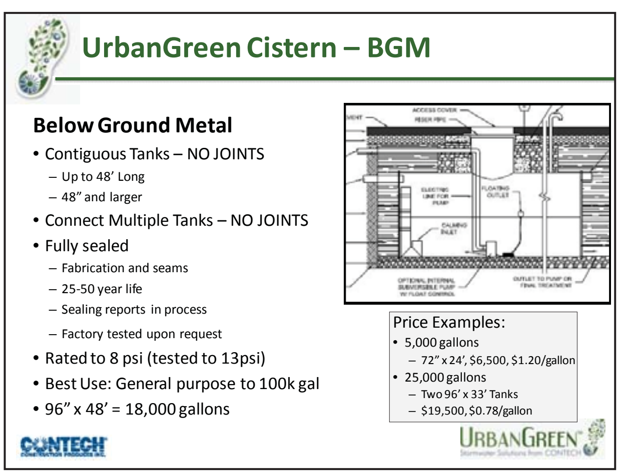


Figure 21. Diagram for below ground metal cistern with rubberized sealant

Figure 22. Rubberized sealant was adapted from industrial tank lining and is rated to 8psi

We did a project in Tucson recently, a big plastic pipe system (Fig. 23). Another project was done on a ranch where the farmer was withdrawing water year-round to irrigate his crops using too much water in the summertime (Fig. 24). The downstream users actually paid for the system for him. They were able to take water captured during the rainier parts of the year when they had higher flows in the stream and store it for use later in the dry season.

Figure 23. Tucson plastic pipe cistern system

Figure 24. California ranch cistern system

Figure 25 shows an above ground metal tank. Your tank size and catchment area involve very site-specific design parameters. Typically you need to know what the water supply will be, like rainfall, or perhaps air conditioner condensation, or whatever you are using for water supply. You also need to know what the demand is in terms of your irrigation, or number of toilets and rate of flushing, or similar. You can use actual rainfall data and daily rainfall totals over a period of years to model how your cistern fills and how it depletes. We have a model that does exactly that and can also calculate potential monetary savings by using rainwater instead of potable water, based on local water rates.

Figure 25. Above ground metal cistern

Parting thoughts: Rainwater harvest generally does not make sense from a purely economic perspective because water rates are usually very low. I don't know what they are here, but in most cases it is somewhere less than $5 per hundred cubic feet so you have to fill your cistern and overturn it many, many times, usually thousands of times, before it pays for itself in terms of municipal water savings. But there are other opportunities here, particularly with tax incentives where you can get 8 or 10 LEED points if you have a rainwater harvesting system, depending on its uses. Some areas allow development density bonuses if you are doing rainwater harvesting; some places allow you to move to the head of the line as far as plan reviews, plan checks, and building safety; sometimes fees are reduced for plan checks. Other incentives must be put in place if we are going to encourage rainwater harvesting to happen on a more widespread basis.

Figure 26 lists other things I haven't had a chance to talk about, like 4 percent of our energy nationally is used to treat or move water around, in California it is closer to 40 percent. So to the extent that we can do this on a local level, we are building in some redundancy to the system. We are building in some additional water security, reducing our carbon footprint, as well as meeting energy demands. And potentially, we create habitat and recreational opportunities. So there is a lot beyond rainwater. Thank you.

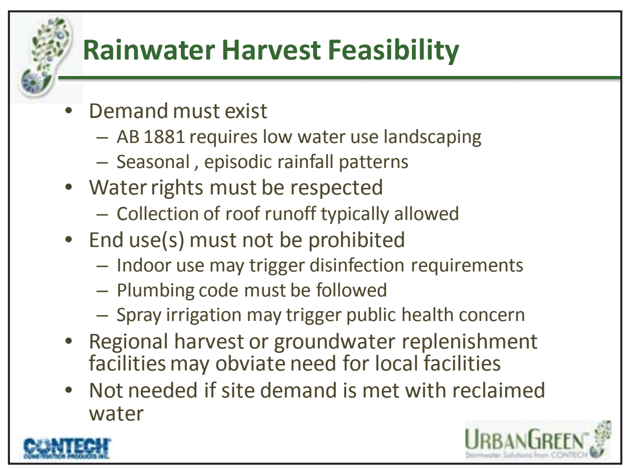


Figure 26. Rainwater harvest feasibility concerns

The Role of Decentralized Artificial Recharge Systems in Water Resources Management

Daniel B. Stephens, Daniel B. Stephens & Associates, Inc.

Dan is Principal Hydrologist and Chairman of the Board of Daniel B. Stephens & Associates, Inc., founded in 1984. It has become an employee-owned firm of over 100 employees providing water resources and environmental engineering consulting services with offices in New Mexico, Texas, and California. Dan received his PhD in hydrology from the University of Arizona; his MS in hydrology from Stanford University; and his BS in geological science (with honors) at Pennsylvania State University. He was on the faculty, and a former department chair, of the geoscience department at New Mexico Tech from 1979 to 1989, and he continues as an adjunct faculty there as well as at UNM. Dan currently serves on the Board of Directors of the National Ground Water Association.

The following is a transcript of an oral presentation given by Dan Stephens.

I would like to acknowledge a coauthor, Stephanie Moore who also helped co-organize this conference, but couldn't be here due to a vacation commitment, as well as coauthors Mark Miller, Todd Umstot, and Deb Salvato. In putting this talk together, the topic I was invited to speak about evolved over time and what I am going to present is actually somewhat similar to the presentation of the previous speaker, Vaikko Allen, although I had no prior knowledge of what he was going to discuss. The coincidence of our themes suggests that there really is something to this concept, which I call decentralized artificial recharge. I think this is an appropriate topic for this conference because of its futuristic view.

I want to spend a minute looking at how "hardscaping" in our urban environment has affected the hydrologic cycle. We have done a great deal to install curb and gutter systems and other impervious pavements. At our company's Albuquerque office site, we put in a back driveway and the water that comes off of this lot goes into a concrete-lined flume that discharges into the Rio Grande. Figure 1 is a sketch that is relevant to a Floridian aquifer, but it has the same importance practically everywhere urbanization has taken place to modify the hydrologic balance. Whereas in Florida you might have 40 percent of precipitation evapotranspiring, 10 percent runoff, and 50 percent going to infiltration, the percentages elsewhere change to 30 percent evapotranspiration, 55 percent runoff, and 15 percent infiltration. Urbanization has led to a significant reduction in deep percolation or recharge.

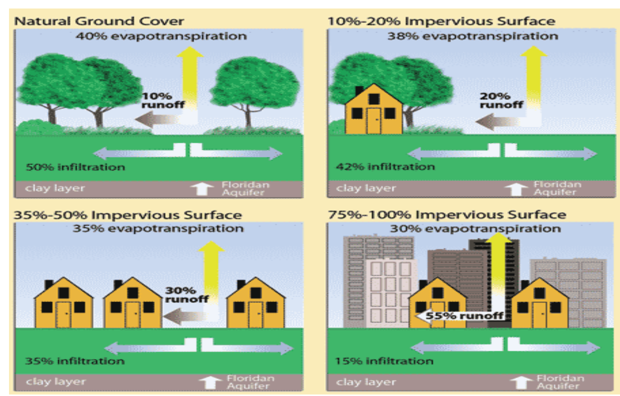


Figure 1. Urbanization decreases ET, reduces runoff

Another factor that is becoming more well established, at least through computer simulations, is the importance of climate change altering the hydrologic balance in certain parts of the world. For example, as you can see from Figure 2, global climate models predict much lower precipitation over the next century, and that is going to lead to much less recharge. In fact, recent research published in *Water Resources Research* showed that the incremental reduction in precipitation leads to a much larger reduction in recharge; it is not simply proportional.

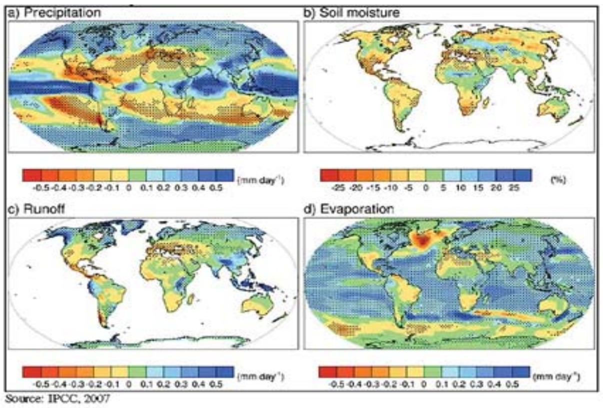


Figure 2. Global climate model predictions: less precipitation, less recharge

So what have people done over the years to augment recharge? Artificial recharge is a technique to get water under the ground artificially. For example, traditional methods use spreading basins like the one pictured in the top left photo of Figure 3. The photo was taken near Anaheim California. The basin fills with water, the water percolates over some period of time, and infiltration occurs. Also pictured in the figure is a typical infiltration gallery, and a vadose zone or dry well by Hydrosystems Inc. in the Scottsdale area. The bottom right photo shows an ASR well in the Las Vegas valley.

Figure 3. Artificial recharge supplements loss

For millennia, sources of water used for artificial recharge have including capturing runoff. In Biblical times, water was captured from streams and stored for agriculture. In the United States, the first artificial recharge project that I can find information on took place in Iowa in 1871. In 1895, artificial recharge projects began in California, followed by Long Island in 1935 with a program to take stormwater and other water from air conditioning systems and infiltrate that water into the Long Island aquifer. Today there are about 3,000 artificial recharge basins. Figure 4 is an inflatable dam diverting water from the Santa Ana River in California. Figure 5 shows spreading basins in India, very similar to what you might have seen in biblical times.

Figure 4. Inflatable dam diverting water from the Santa Ana River

Figure 5. Spreading basins in India

Centralized artificial recharge projects typically are conducted by agencies, cities, counties, and water agencies. Figure 6 is an example of in-channel recharge with levees on the Santa Ana River in Los Angeles that slows down the runoff. When a storm comes in, it wipes out these dirt-filled levees and they are then rebuilt.

Figure 6. Artificial recharge project with levees on the Santa Ana River

Recently, the main driver for capturing stormwater has been the Clean Water Act. The Act requires that the water discharged to receiving bodies should be improved; it is very simple and straightforward. To bring home the importance of this stormwater capture and recharge, we recently conducted a project in an industrial area with a lot of hardscape parking lots and some buildings. This is in an area of New Mexico that sees very little rainfall, is a sandy site, and under natural conditions, most if not all of the water evaporates, leaving almost no measureable runoff. Figure 7 illustrates the monitoring wells that were installed (black circles). After about 20 or so years, the monitor wells started to fill with water where previously no water had been found. We could see groundwater mounds developing in the vicinity of the retention ponds that were used to capture the runoff from hardscape. We conducted computer simulations to show how much water would be needed to simulate the buildup of the groundwater. Using the computer simulator ModFlow, we found that 40 percent of rain that fell in that little watershed became recharge. We used another type of model based on infiltration through the individual basins and surface water runoff modeling and found about 60 percent of the rainfall was necessary to produce those conditions. So how much water was that? If a subdivision were developed, there would be enough water to provide 25 percent of its needs given a 5-home per acre density; so it probably is significant.

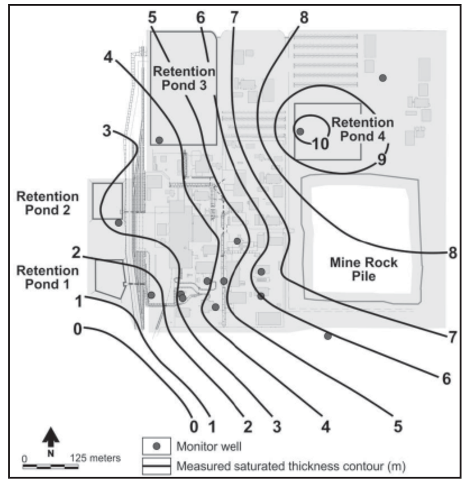


Figure 7. Groundwater mound beneath retention ponds (black dots are monitoring wells)

Figure 8 shows a graph of harvestable stormwater for the City of Tucson, taken from a recent planning document from the county. The graph shows that the amount of harvestable rainwater coming into the watershed is a function of the area where the water is being captured. In a developed urban area, the red line shows the predicted amount of capture; as you get to the lot scale or neighborhood scale, you are in the vicinity of about 50 percent capture of the water that falls or more. As the area gets smaller and smaller, you get more efficient at capturing rainfall. If you were trying to capture rainfall, you'd like to capture it close to the source before it has time to be intercepted or otherwise detained. This type of lot-scale rainwater harvesting is catching on as a green technology (Fig. 9).

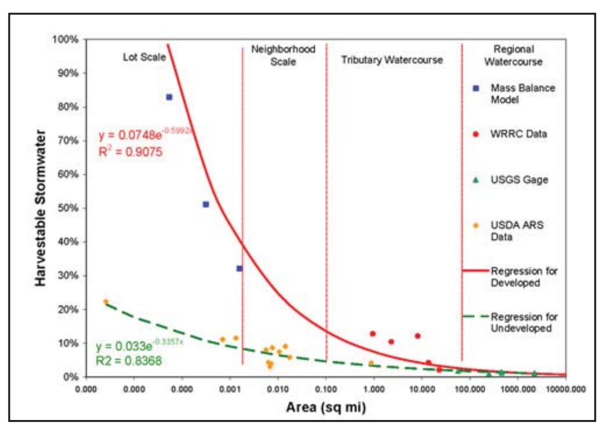


Figure 8. Potential stormwater recovery, City of Tucson

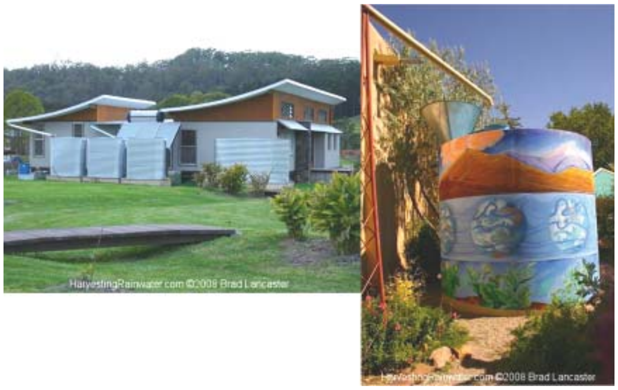


Figure 9. Lot scale rainwater harvesting

Low impact development (LID) is a technology that has evolved since the 1990s. The concept started in Maryland and has now taken off. LID is a means of compliance with the Clean Water Act on a local scale. Figure 10 shows a couple illustrations of how water from a hardscape street can be diverted into a vegetation lined channel, and where water is diverted into "rain gardens" used to beautify with plants. In the process of getting water onto lawns or gardens, the peak discharge from floods is reduced and the water that runs off is spread over a longer period of time so flood potential is minimized.

Figure 10. Water from a hardscape street diverted into a vegetation lined channel or “rain garden”

Green roofs are part of LID technology, and Figure 11 shows two examples. The first is a home being constructed in the Albuquerque area. The second shows the roof of the EPA building in downtown Denver; you can see the green roof is very well vegetated. This trend in LID and stormwater management helps improve habitat and recreation and affords some improvement in the water quality of the runoff, which is what was intended. Some of these designs are appropriate to recharge groundwater as shown in Figure 12 where an infiltration basin in a landscape lot leads water into a dry well.

Figure 11. Green (ET) roofs

Figure 12. Infiltration basin leads water into a dry well

Figure 13 shows permeable pavers, Figure 14 shows underground infiltration basins, and Figure 15 is a photo of an infiltration gallery. All these LID technologies are once again modifying the landscape and the hydrologic cycle and the local hydrologic balance as shown in Figure 16. It is an example of a plan to take a shopping mall in Maryland and put green roofs on top of it so that more of the water can be captured onsite and runoff prevented. This is in compliance with the Clean Water Act to minimize urban runoff. The green roofs and rain gardens, however, do not promote recharge. As a groundwater hydrologist, my interest is not so much in stormwater, but in recharge. Perhaps Mr. Allen, our prior speaker, and the LID people are focusing on stormwater control; I want to twist this around and see how it can be used primarily for groundwater recharge.

Figure 13. Permeable pavers promote recharge

Figure 14. Underground infiltration basins

Figure 15. Infiltration gallery

Figure 16. Emerging trends in water and land use again are modifying hydrologic balance

A recent investigation that I came across in the Los Angeles area is called the Water Augmentation Study. This investigation used modeling, field experiments, and instrumentation around LID sites and commercial and residential areas in the Los Angeles and San Gabriel River basins. Their simulations show that if you were to capture the first ¾ of an inch of runoff, that would amount to about 384,000 acre-feet per year of water in the Los Angeles and San Gabriel River areas, enough for 1.5 million people and with a water value of $311 million; that is not small change.

As you heard earlier today, a recent federal driver may lead to increased recharge opportunities. The 2009 U.S. EPA Guidance for Federal Facilities interprets the 2007 Energy Independence and Security Act for redeveloped and new facilities to maintain predevelopment hydrology. They do that by retaining up to the 95th percentile storm onsite and I think this will be a model for states and municipalities in the future.

Local mandates for recharge began in the early 1970s. The local governments in Maricopa County, Arizona, have been using stormwater retention basins and dry wells to keep recharge in the basin as high as practical. Very recently, the Santa Ana Water Quality Control Board issued orders for the NPDES permits in a three-county area for new residential, commercial, and industrial developments and redevelopments to implement LID with infiltration as the first priority. I think that is going to be a significant trend as we move forward.

In 2004, the state of New Jersey implemented stormwater management rules for new developments where you either have to maintain all the pre-construction recharge volume or you must infiltrate the increase in post-development runoff volume for the two-year storm. That is a mandate example that comes from a state initiative. From an international perspective, in some provinces in

India, rainwater harvesting is mandated and in some places the rainwater harvesting is used for artificial recharge such as shown in Figure 17. Figure 18 shows sketches from guidance documents that municipalities and states give to developers to instruct them as to how to use rooftop rainwater for recharge. The hotel pictured takes water down into a subsurface vadose zone well and an infiltration basin combination. Other designs are provided to show developers how to build so that recharge is enhanced in India.

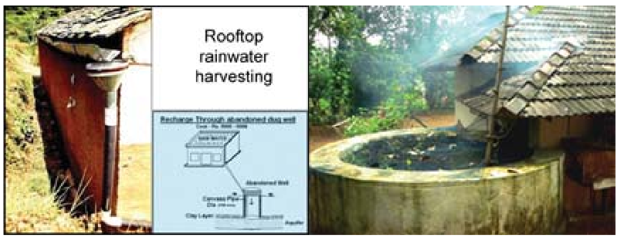


Figure 17. Artificial recharge with roof water is mandated in some provinces in India

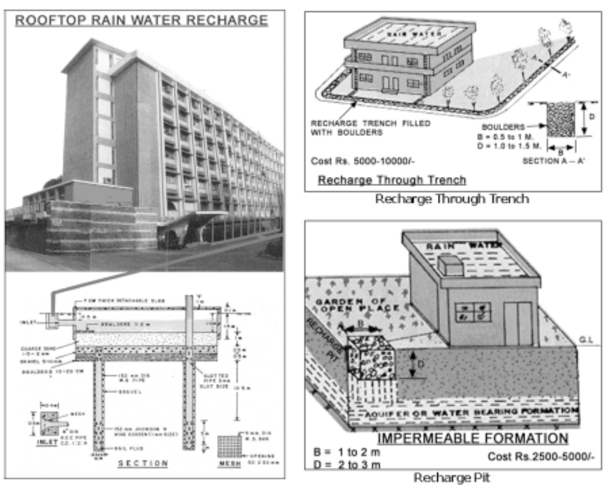


Figure 18. Guidance documents for developers on using rooftop rainwater for recharge

Try to extend this concept to an urban watershed, recognizing that we don't want to impair downstream surface-water users. We would like to be able to capture the runoff above the pre-development flow and the lost evapotranspiration (ET). I think this is a concept that is simple but probably not commonly recognized. The regulatory focus has been on stormwater runoff control, and every time we put down an urban hardscape, what really happens is that we are cutting off evapotranspiration. We take water that soaked into the soil and was retained, and recover that water so it can percolate on down. Thus, there will be some decrease in evapotranspiration every time we put more hardscape down and don't do anything else with that water. Evapotranspiration is typically the largest natural output of the water balance in an area.

Figure 19 is a graphic of how this concept works. Let's say we had 20 inches of rainfall, and about 4 inches of that runs off, and about 12 inches is taken up by the native plants. That leaves about 4 inches for recharge. Figure 20 shows a home set in an area with a lot of hardscape. So the runoff increases to 8 inches and, because I've used hardscape, the recharge decreases. Figure 21 shows a LID rain barrel installed and there is some overflow into a basin and some vegetation; as a result, the runoff has returned to 4 inches. I've increased my ET a little bit for onsite vegetation use, but my recharge has increased a couple inches, even though we kept the runoff about the same.

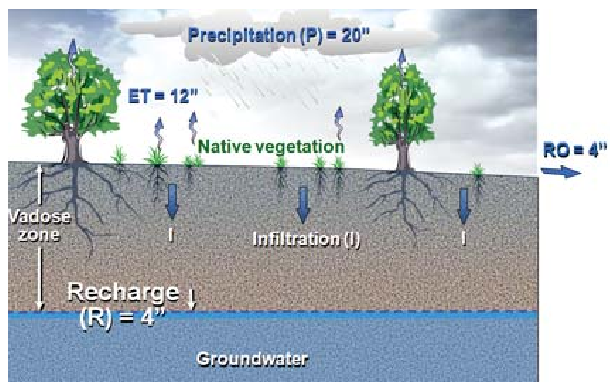


Figure 19. Capture evapotranspiration (ET) and restore runoff (RO) for improved sustainability: baseline condition

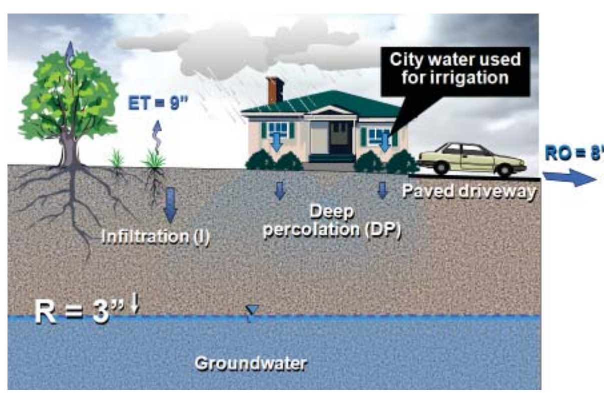


Figure 20. Home set in area

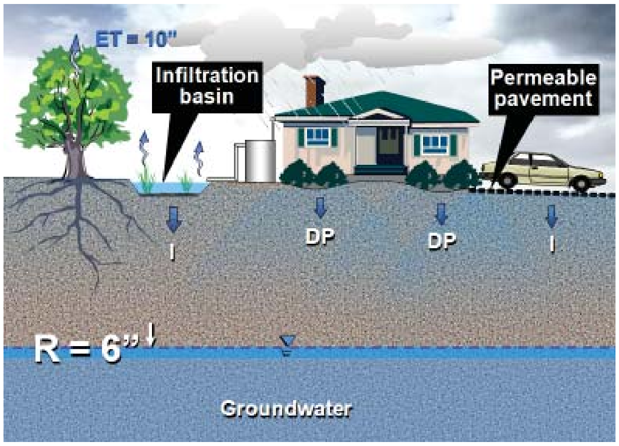


Figure 21. Home with LID rainbarrel installed

The question is how significant this is on a regional scale in a basin. Let's look at, for example Figure 22. Consider a 10-mi-wide aquifer and a river—it could be the Rio Grande 10 miles away—where the water table is represented by the red line. If the recharge rate were 2 percent of precipitation, we aren't taking any water out, so that would represent a natural condition. A recharge rate of 20 percent of precipitation is represented by the green line and a 50 percent is represented by the blue line. You see a difference of over 130 feet or so in increased water level that would result from raising the recharge rate from 2 percent to 50 percent. Similarly, if you had a well pumping a couple thousand gallons a minute in the center of the system, the effect of recharge on water levels is certainly significant (Fig. 23)

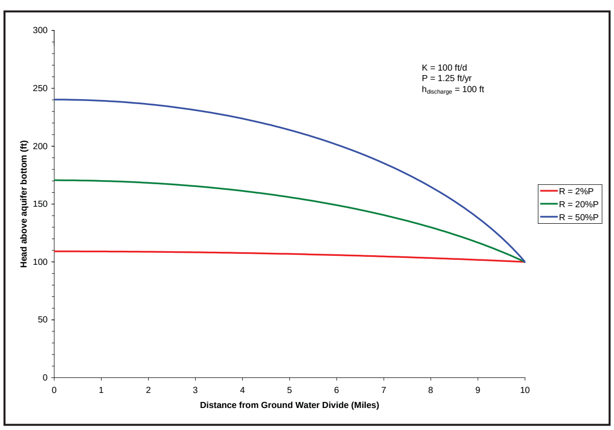


Figure 22. Benefits of decentralized artificial recharge

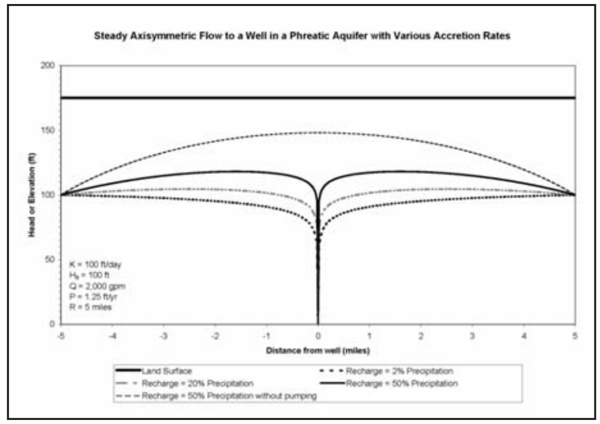


Figure 23. Steady axisymmetric flow to a well in a phreatic aquifer with various accretion rates

Figure 24 shows how roof water harvesting could be done on a local level. The system would include a storage tank and some type of underground infiltration structure that would use a soil treatment natural process to cleanse and filter the water so that the cleaner water goes down into an impaired aquifer. This would raise the water table and allow more and fresher water to be pumped from the well.

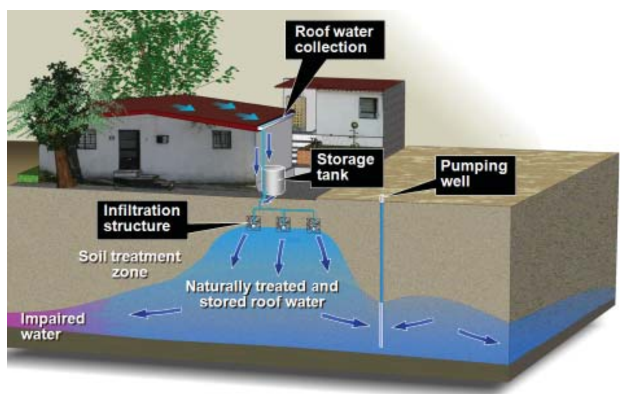


Figure 24. Roof water harvesting done on the local level

I did some calculations to determine the value of increased runoff. Assuming a 40-acre subdivision with five homes per acre, if we were able to capture 2 inches of precipitation as increased recharge, we get over 10,000 gallons for every 1/5-acre lot for a total of 2.17 million gallons per 40 acres, which is 6.7 acre-feet per year. If that water has a value of $5,000 per acre-foot, the resulting value is $33,500. That does not sound like a whole lot; the infra-structure to enhance the recharge for these homes may cost more than $33,500. We would need more incentives.

Let's look at scaling up to a larger area of 400 square miles, about the size of Los Angeles or half the size of Orange County. Assume precipitation of 15 inches, and 50 percent of precipitation becomes recharge through a decentralized system using LID methods. The potential new recharge would be 76,500 acre-feet per year. So is that a big deal? The Orange County Water District and the Orange County Sanitation District teamed to create the OCWD (Centralized) Groundwater Replenishment Project (Fig. 25), and I am on the advisory board of the Orange County Water District for this project. It is no coincidence that the Orange County Sanitation District and the Water District are located next to one another, because the Sanitation District's water goes into the Water District's water. Some of the water is used for seawater intrusion; some gets pumped into spreading basins where the water percolates down and into the wells; and after a significant amount of water treatment is done at a treatment plant, it flows into homes. This project uses advanced procedures to treat the water.

Remember the 76,500 acre-feet of water we calculated for a 400 square mile area? Orange County Water District built their treatment plant at a cost of $481 million, it operates at a $30 million annual rate, and it produces 72,000 acre-feet of water per year. That is about the same amount as what results from an increase in the recharge rate to 50 percent using LID. And these costs include taking treated wastewater, pumping it uphill into the Anaheim area, spreading it in the basins, moving it down, pumping it back out, treating it again, and then providing it to the customers.

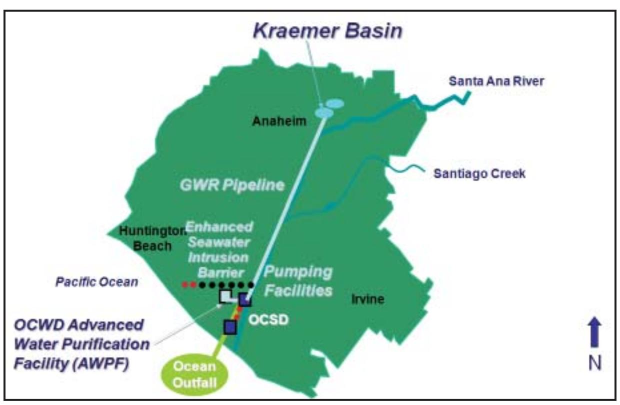


Figure 25. Orange County Water District (centralized) groundwater replenishment project

In Tucson, about 40 percent of municipal water is used for home irrigation and landscaping. That amount is probably typical for New Mexico and other areas in the Southwest. Why use treated and pumped (expensive) municipal water for lawn and garden? A combination of roof water harvesting with local artificial recharge could be used as a local conjunctive use approach. Rain barrels could be used during the summer for gardens and outdoor use. In the winter when we don't need to water gardens, we could recharge the excess winter precipitation. When we have intense thunderstorms in the summer and the rain barrels fill, we can put that water back into the aquifer and use the existing municipal well system for indoor/potable use. These decentralized lot and neighborhood artificial recharge systems make sense to me: they increase the recharge to the well fields; increase base flow to streams; support springs, wetlands, and riparian habitat; and diminish surface runoff volume to the background pre-development condition.

How would this apply in New Mexico if we did a combination roof water harvesting or LID? The Office of the State Engineer (OSE) supports the harvesting of rainwater for onsite domestic uses. OSE states, "The collection of water harvested in this manner should not reduce the amount of runoff that would have occurred from the site in its natural, pre-development state." I think that is a fine objective, but OSE does not give any guidance on how to calculate natural runoff or how to obtain any sort of approval. OSE also says that rainwater harvested cannot be used for any other use; it is not appropriate for anything other than onsite purposes. What about using that water for artificial recharge? No, according to OSE, because they have concerns. Those concerns most likely relate to downstream surface-water right holders. By holding back rainwater on your site, it may prevent the runoff from flowing into the Rio Grande or other tributaries, thereby impinging on some other surface water right. Also, it would significantly reduce the amount of water that goes into Elephant Butte Reservoir and leave less water available to meet our Rio Grande Compact obligations. But if we divert surface runoff and tried to capture it in our neighborhood, the same kinds of issues emerge. In addition, the State Engineer is likely to be concerned that we would want to claim some water right to any of the water we captured. The salvaged ET could be viewed as a claim to some right to that water. Another concern is that if we incentivize local scale artificial recharge, we may be setting a precedent for septic system users to request credit for their water returns to the aquifer.

A decentralized approach to groundwater sustainability and runoff control is consistent with sound water conservation practices. It supports Clean Water Act requirements, off-sets the need for additional water supplies, utilizes existing potable supply infrastructure, and avoids land purchases for large scale, centralized basins as seen in Los Angeles, California. The concept affords many water quality benefits by catching water at the local level with home roof or office building systems, or at the subdivision scale. If you capture the runoff before it flows far from the property, you avoid the industrial chemicals and petroleum hydrocarbons on the land surface. Keeping the water from mixing with other wastewater discharge in streams allows the use of natural soil-aquifer treatment processes in the soil that come with LID such as filtration through lawns and gardens, biodegradation, volatilization, and absorption of metals.

A number of studies have shown no significant impact to groundwater quality from stormwater infiltration. The USGS has studied 2,100 stormwater ponds in the Long Island area. The U.S. Department of Agriculture investigated 100 stormwater ponds in industrial residential and commercial areas in Fresno, California. The University of Arizona has looked at dry wells in the Phoenix area, and more recently, the Los Angeles River and San Gabriel River Watershed Council has conducted very detailed investigations on catching poor-quality water and looking at monitor well quality underneath six well-instrumented LID sites in the Los Angeles area. Even early EPA documents say that runoff from residential areas is the largest component of urban runoff in most cities and is usually the least polluted urban runoff flow and should be considered for infiltration.

Some concerns with enhancing recharge on a local scale include the situation where fast flowing gravels and karst sites provide little chemical attenuation; perched conditions on impervious soil horizons can create difficult conditions; shallow water tables offer little storage and afford lower treatment potential; and in some areas of Albuquerque, for instance, collapsible soils produce technical instability.

A challenge to local scale recharge implementation in New Mexico is the fact that a property owner or developer receives no benefit for adding to the groundwater recharge by salvaging ET or capturing the excess runoff through a new or retro-fitted construction. In essence, as I see it, in a fully appropriated basin, a party who adds water to the basin would have to purchase the water rights, thus paying for water rights as well as for all the infrastructure costs incurred to recharge the aquifer.

In conclusion, I think decentralized artificial recharge systems are in the future and may be decades out, but they can significantly add to the groundwater reserves without depleting the pre-development runoff. Nationally, local artificial recharge with roof water and runoff is likely to be increasingly considered in water management planning. In New Mexico, clarity and consistency are needed in regulations to encourage a decentralized artificial recharge approach to augment groundwater supplies.

Thank you.

How Do We Deal with Our Aging Structures?

Bruce Jordan, U.S. Army Corps of Engineers

Bruce received a BS in engineering technology from NMSU in 1994 and has worked for the U.S. Army Corps of Engineers as a civil engineer since 2003. Currently, he is assigned as the lead geotechnical engineer for the design and construction of the Albuquerque Levee Rehabilitation, Middle Rio Grande (Isleta to Belen), and the Rio Grande Levee (San Acacia to San Marcial).

The following is a transcription of the talk presented at the conference by Bruce Jordan.

Good morning. When I started with the U.S. Army Corps of Engineers (Corps), it was beaten into me that the Corps has two main authorities. The first authority is navigation, but that doesn't really affect us here in New Mexico. Our second authority is flood control and my talk is primarily concerning flood control. I understand that the Corps gets involved in restoration projects and involved in holding water for other people; we have special authorities, but primarily our job concerns flood control and navigation so that is what I'll address.

I am looking primarily in the Albuquerque District at Middle Rio Grande levees in terms of dealing with our aging infrastructure (Fig 1). It is important to pinpoint those that I am talking about: Corrales levee, which we built in 1997 and is owned by the Middle Rio Grande Conservancy District (MRGCD); the Albuquerque levees, which we built in the 1950s are also owned by MRGCD; Mountain View Isleta units and Belen Units constructed by MRGCD in the 1930s; San Acacia to Bosque del Apache Units, which were initially constructed by MRGCD in the 1930s but have since been upgraded or overbuilt by the Bureau of Reclamation (BOR) when they constructed their low-flow conveyance channel.

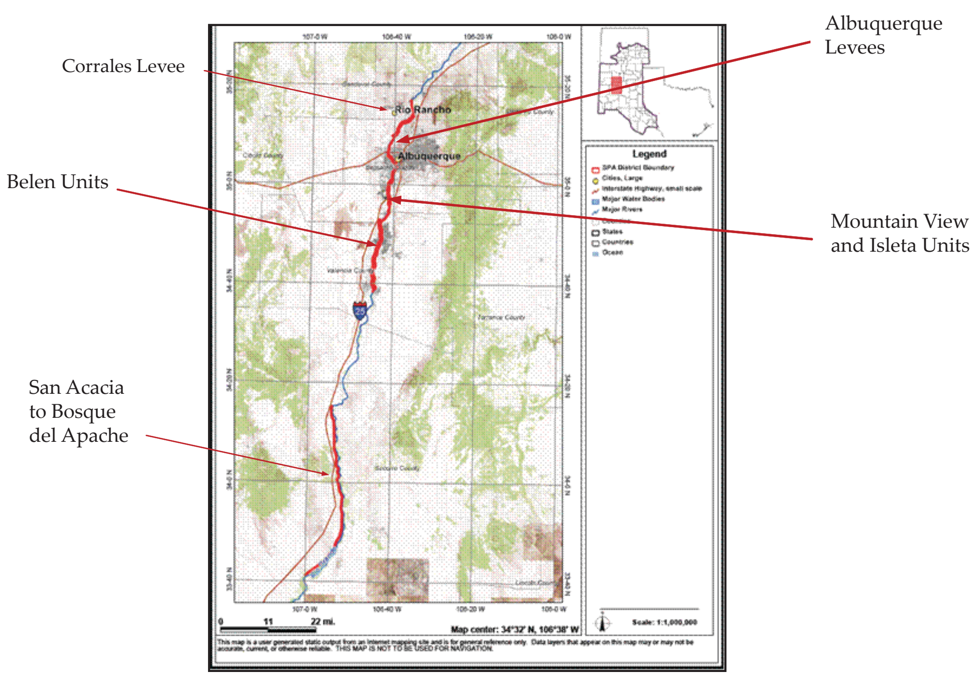


Figure 1. Middle Rio Grande levees

Let me mention a bit of history of floods in the Middle Rio Grande: the Corrales 1874 estimated a flood-flow of 100,000 cfs; in 1904, the Albuquerque Journal reported a four mile-wide river at Albuquerque; in 1929, in the San Acacia Unit, we lost the town of San Marcial in heavy August rains; in 1941, we had the Belen Bridge washout. In 1925, the MRGCD was formed. It was initiated in 1923 but had to wait for a court decision to determine that it was constitutional. From 1930 to 1935, MRGCD constructed approximately 190 miles of levee, spoil embankment, primarily as part of the drainage. The MRGCD calls this the Riverside Drain that helps drain some of the water table for irrigable lands in order to put them back into development. So projects were mostly spoil levee construction, which was common for that time. From 1953 to 1957, the Corps constructed Phases I, II, and III of the Albuquerque Levees as a flood control project, which is an engineered levee. From 1951 to 1959, the Bureau of Reclamation constructed the Low Flow channel to Elephant Butte, upgrading those levees in the Socorro area. In 1997, the Corps came back and constructed the Corrales levee.

Figure 2 is a construction drawing for the Albuquerque levees depicting the difference between a spoil levee and an engineered levee. You can see the spoil pile is non-engineered; it has thickness but does not have any definite slope control. The figure shows the spoil levee being moved and actually being used as the borrow materials for the engineered levee. The installation of the toe-drain system helped relieve pressure so it didn't escape.

In 2005, the Corps provided a report to Congress on the condition of the Albuquerque levees. As part of that report, I, along with the other engineers in the district, surveyed those levees to ascertain their true condition. As you can see in Figure 3, we have animal burrows in the Albuquerque levees. The photos in the figure are all engineered levees. We have sloughing of the Riverside drain; the subsurface discharge pipe in the top right photo has been exposed by about 20 feet, so we've lost that. The actual drainage system has been compromised by sedimentation. And then we have our famous and lovely trees, which have been an issue for the Corps for the last five years.

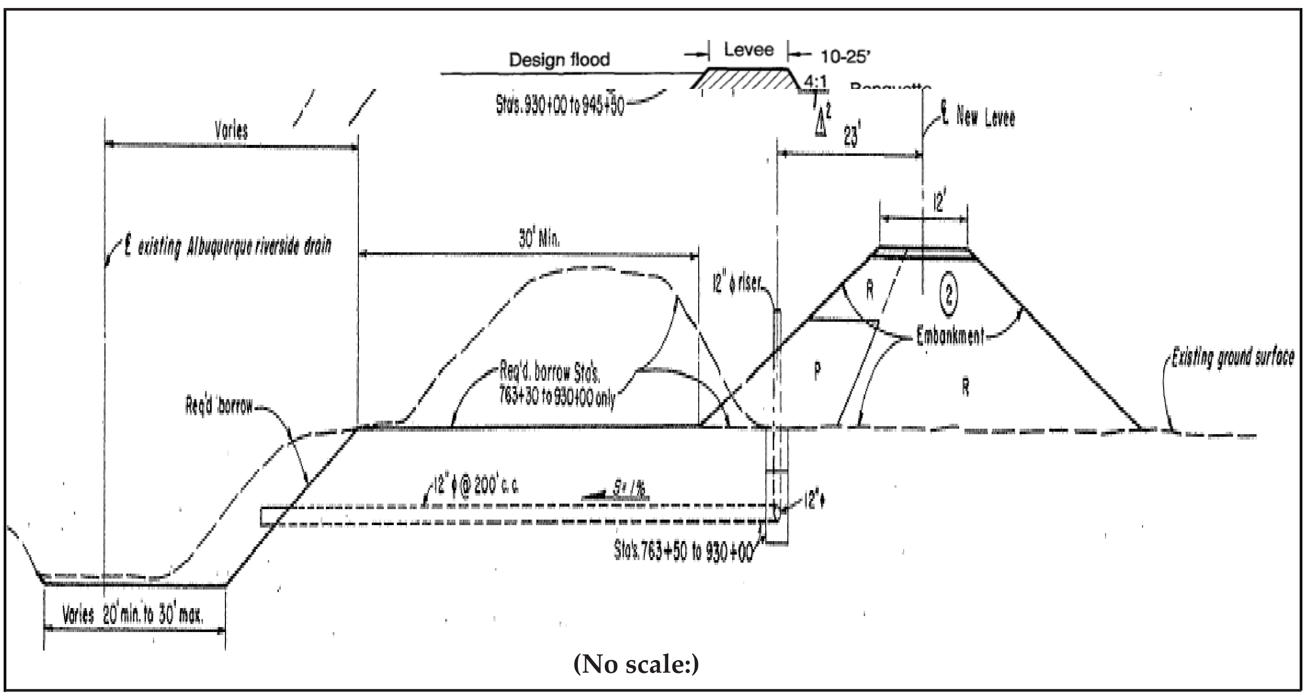


Figure 2. Typical levee section from the Albuquerque levees construction drawings

Figure 3. Current Albuquerque levee conditions

Figure 4 shows the un-engineered levee at Bosque Farms, and in 2005 we topped out on a discharge from Cochiti of about 6,500-7,000 cfs in this area. We tried to stay at 7,000 cfs for about a week, but the conditions made us back off the discharges. There was subsequent sloughing of the Riverside Drain. It was a fast occurring event so we weren't necessarily worried about losing the levee from a breech in the levee, but losing the levee from the water seepage coming under the levee (a foundation issue) and breaching the levee from it washing away from underneath was a concern.

Figure 4. MRG Levee (Bosque Farms) conditions

Figure 5 shows 2005 runoff in the Socorro area. The BOR had extensive problems with the way that the levee was constructed. The low-flow channel borrow material was dumped on top of the original spoil levee and they found voids within that lower section and have had to fight the resulting seepage. The actual bank of the low-flow channel seems pretty stable, but they have experienced catastrophic failure of the levee further south of Socorro from seepage coming through the levee.

Figure 5. Socorro Levee conditions

Changes in criteria for levees for the Corps have been made to help combat some of the condition problems that we have seen over the last 50 years from studying at Albuquerque levees. We have adopted a change in our filter design criteria, which was first presented by the Natural Resources Conservation Service (NRCS). It is contained in chapter 26 of their National Engineering Handbook (Part 633), and we at the Corps have adopted that as part of our levee and dam construction manual. Another criteria change deals with vegetation on the levees. The Corps has, since at least the 1980s, had guidance for keeping trees out of levees, although guidelines were not always widely executed (ETL 1110-2-571 "Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment, Dams, and Appurtenant Structures"). We have since clarified that and shown that we now need a 15-foot minimum root-free zone. We would like for the levee to be vegetated but only with grasses. We also do not want tall grasses because we need to be able to inspect for the presence of animal burrows. During times of flood, we need to be able to evaluate where the seepage is coming from, if seepage is present. The ETL has been finalized after a thorough three-year process of white-paper comments.

Current Albuquerque construction studies include the Albuquerque Levees Condition Report 2005, which recommends rehabilitation of the current levees. In my eyes, this means completely removing the existing levee, putting in a new drainage system, and then putting the levee back down. It will include hydrology upgrades so it might not be the same size as the current levee. The current levee is built for a 42,000 cfs event, but that is pre-Cochiti. Cochiti takes the peak off of that number quite a bit. Another study produced the Middle Rio Grande Flood Protection, General Reevalution Report for Mountain View, Isleta, and the Belen Units, and a third report is for the Rio Grande Floodway, Limited Reevaluation Report for San Acacia to Bosque del Apache. Preliminary estimates for construction are: a $120 million for Albuquerque, $100+ million for the Middle Rio Grande Flood Protection, and $115 million for the Rio Grande Floodway (San Acacia to Bosque del Apache).

What does this mean for our water? Figure 6 is from Mussetter Engineering Inc.'s hydraulic report for the Middle Rio Grande and Albuquerque levees. It shows the 500-year snowmelt event being routed through Albuquerque. You can see the Corrales Levee, the Albuquerque levees, Paso del Norte and Montano bridge, and that floodwaters stay within the two levee systems. It is hard to see at this scale but the red boxes are for 100-day durations. We are describing floodwater up against the levee for 100 days, which is quite a long time to depend on that levee. Figure 7 shows what happens when we take the Albuquerque levee section out of the model and we have flooding that travels past Edith, which is quite a distance from the Rio Grande. We would also have extensive flooding in the greater metropolitan area.

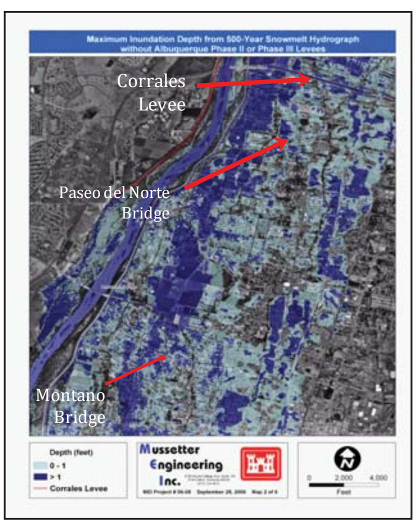


Figure 6. Mussetter Engineering Inc.'s hydraulic report for the Middle Rio Grande and Albuquerque levees

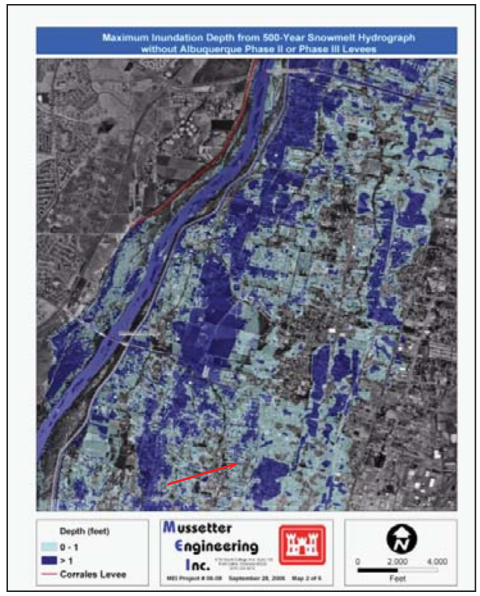


Figure 7. Maximum inundation depth from 500-year snowmelt hydrograph without Albuquerque Phase II or Phase III levees

Figure 8 is the hydrograph for Cochiti for that 500-year flood. You will notice the duration is approximately 110 days long, fairly stable at 7,500 cfs, and peaks at about 14,500 cfs. That peak would activate the Cochiti spillway. No one thinks that there will be a 500-year event. Look at Figure 9, on the top is the normal pool for Cochiti with a recreation pool elevation of 5340.3 ft. On the bottom is a photo of the 1987 record pool. This was a high water year but it wasn't a terrific flood, it wasn't a 100-year event and you can see that record pool is within 60.5 feet from the notch and activating the spillway. We created the pool; the reservoirs downstream of Cochiti were full, and we didn't want to flood the communities of Isleta, Mountain View, Bosque Farms, or Belen. We held the water and didn't release it out of Cochiti. If we had three years of that, I could see how it could activate the spillway at Cochiti without another large event. If we had to release the floodwater, we would be pushing 7,000 cfs down the river. The Corps couldn't do much about it because it needs to release the floodwater to get the capacity back in anticipation of the next spring runoff.

Thank you.

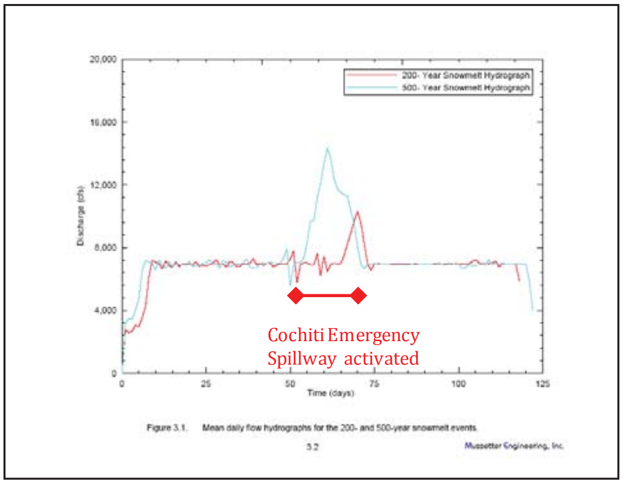


Figure 8. Hydrograph for Cochiti and the 500-year flood.

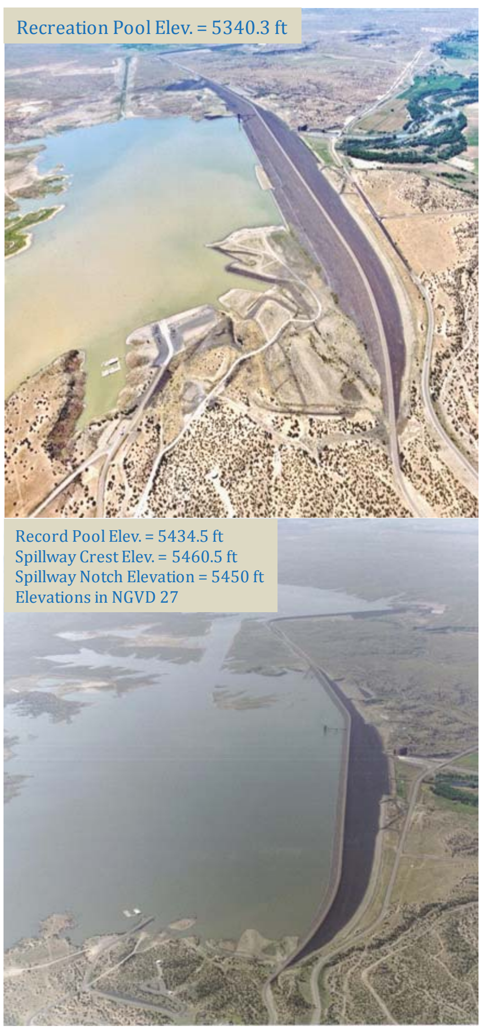


Figure 9. Normal pool and 1987 record pool for Cochiti Dam

Dealing with Aging Tribal Water Infrastructure

Derrick Lente, Middle Rio Grande Conservancy District, Pueblo of Sandia

Derrick is a son of two Pueblos in New Mexico, Sandia and Isleta. He holds two bachelor's degrees and a JD degree, all from the University of New Mexico. Derrick is the owner of Lente & Associates, a Native American consulting firm and is also an adjunct professor at UNM where he teaches federal Indian law and business law courses. Derrick grew up in an agricultural family and has over ten years of professional experience working on water issues in the Middle Rio Grande Valley of New Mexico. In 2009, Lente was elected to the Middle Rio Grande Conservancy District Board of Directors, unseating the incumbent whose family had held the seat for more than 30 years. He makes his home in Sandia Pueblo with his eight-year-old daughter, Jade, where they continue a ranching and farming lifestyle.

Good morning ladies and gentlemen. It is a pleasure to be here to talk about tribal infrastructure. As a disclaimer, I want to make sure that it is clear that I am not here on behalf of the Middle Rio Grande Conservancy District (MRGCD), although I am a board member, nor am I here as a spokesperson or representative for the Pueblo of Sandia; although I live there and am a tribal member.

I am here to give my perspective on practical matters as a farmer who has farmed for his entire life on both the Sandia and Isleta pueblos. I'll provide perspectives from my educational background and professional experiences as an attorney. The discussion this morning has been very 'scientific', and I am not a scientist. I am an attorney and have worked with water policy and laws with respect to pueblos. My perspective has a lot to do with the six Middle Rio Grande pueblos in the Middle Rio Grande valley of New Mexico.

When we talk about dealing with aging tribal water infrastructure, I think it is most important to go back to the history of who exactly we are discussing. If you don't know that history, it makes it hard to assume things about the culture. It is easy enough for the Corps to talk about its aging water infrastructure; but realistically, on pueblo lands, we are talking about a lot of different entities and a lot of different jurisdictions.

Those of us who have lived in the state for any length of time know that the pueblos have resided in this area for centuries. The pueblo name came from early Spanish languages meaning stone-masonry village dweller. The pueblos primarily made their homes in the four corners area of Utah, Colorado, Arizona, and New Mexico. In the beginning, they were very nomadic and followed the herds as hunters, but eventually they formed farming communities and raised corn, squash, beans, and other agricultural products. In the 1500s, when Coronado eventually wandered up the Rio Grande valley, he found farming pueblos with extensive ditch infrastructures on their lands. The pueblos had been farming these lands far beyond what we can imagine. The best way to begin a presentation about pueblos is by describing their infrastructure history.

Bruce Jordan, who is with the Bureau of Reclamation, and who just spoke, talked about the history of the MRGCD and a timeline. In the early 1920s, there was a movement to help control the water logged lands of the Middle Rio Grande valley so that it could support agriculture and development. In 1923, the MRGCD was changing the valley by digging ditches and building the El Vado Dam. By 1935, El Vado Dam was completed and other diversion structures established the Cochiti area. Angostura and Isleta had dug hundreds of miles of ditches, canals, and riverside levees. A lot of work was being done at that time, but we can't forget that the pueblos were already there.

On March 13, 1928, the U.S. Congress passed an act to protect the pueblo's water rights. These rights included protection of what are called "prior and paramount rights" for the pueblos. All the lands that were being farmed at the time the district was installed were included. The rights to those lands were going to be protected and would have a seniority right regarding their water. Today, it is calculated that pueblos now have a right to irrigate 8,847 acres of prior and paramount lands. Moreover, the pueblos, too, have a right to irrigate what are called newly reclaimed lands. Those are essentially lands that the district installed as ditches and structures that have the ability to become irrigated at some point in time. So in addition to those prior and paramount lands, pueblos have the reclaimed lands as well. Both of those together amount to over 20,000 irrigated acres on the six Middle Rio Grande pueblo land.

When we talk about how to help deal with aging tribal water infrastructures for the pueblos, it is a little bit different because the pueblos have many different organizations that have either a right-of-way, a property right, or some type of interaction on their lands. I would note that the MRGCD has miles of ditches on pueblo lands. Secondly, there are federal structures on pueblo lands as well that were built by the Department of the Interior, or installed by Bureau of Indian Affairs, the Bureau of Reclamation, or others. Nonetheless, pueblos are pueblos, it is their land-grant, it is their reservation. They have their aboriginal ditches that continue to be used to this day.

So what do we do to help better the system? Is there a solution? How do we get to a solution? What is the definition of a solution? Are we trying to, in fact, conserve water? In other words, should the pueblos conserve water so they can funnel it further down the system, or should they take full benefit of that water? A solution has yet to be identified.

Moreover, if there is a solution, who is responsible to help provide it? Potential solutions include dealing with all of the parties involved, collaborating on ideas, and networking so that a solution can be found if there is one. A solution for the pueblos water infrastructure could be: "I want to make sure that I can water all of my crops, period." But for somebody else, a solution could mean making sure that they get their water downstream. Thus, the other pueblos need to make sure to send the water downstream. In reality, the solution might be different to different people.

Obviously, collaboration among parties is easier said than done because especially in the Middle Rio Grande Valley, it is not an adjudicated area and we have six different forms of government. The federal government is present, the MRGCD is there; the interested parties are a mishmash of a bunch of different people. Proper management might mean conservation. If so, in system-wide terms, should that mean that we concrete-line ditches to help water get down the system faster with less seepage? Does it mean that entities like the MRGCD or the BIA, who have a trust responsibility to the pueblos, should mow more often so that there is less debris in the water and so it is cleaner? Should they dredge more often? Or, does the water management and improving the infrastructure on the pueblo lands mean on-the-ground improvements? Does that mean concrete-lined ditches on farmlands? Does that mean laser leveled fields? Does it mean larger turnouts at each farmer's field so that they can irrigate more effectively and more efficiently thereby pushing water downstream or down the ditch?

With that being said, I'll try to come to a solution. Obviously you can't do much unless you have funding. This is the crux of the problem because no one has money. If you want to make improvements on tribal water infrastructure, you need a money tree, you need a lot of money, period. Who will fund this? Who is going to pay for all of these improvements? Coming from somebody who farms on the pueblos, and somebody who has worked for a pueblo for many years, and from an attorney's perspective, it is easier said than done. At the same time, does the BIA have the responsibility to ensure that the pueblos have the right capacity and updated water infrastructure so they can make sure that they use the water for the best benefit? Or does it go back to the MRGCD, whose right-of-way that water runs through? Or, does it go back to the pueblos? Some are of the opinion that if these ditches are on pueblo land, the pueblos are benefiting from them and should have the responsibility to pay for any upgrades to their system. Or, does it come from other interested parties that simply want to see the pueblos use water and then push the water down stream? These are all just ideas and hypotheticals because no one really knows what the solution is.

Luckily, there are existing programs like one through the Natural Resources Conservation Service that many pueblo farmers take advantage of to help them pay for upgrades in their systems, and any little bit obviously does help. When we talk about pueblo water infrastructure and upgrades to truly aboriginal structures, one thing is important—

and I stress this not only because I am from a pueblo but I also teach federal Indian law at the University of New Mexico—that is that we always must remember that there is an acknowledgement of rights that the pueblos were first, that they do have prior and paramount water rights. They have the right to ensure that they obtain water with their surface water rights each year. Pueblo land and water are a part of our heritage, they are a part of who we are, and of our culture as farmers. When we talk about tribal water infrastructure, improvements, and upgrades, it is a fluid notion of what exactly that means, because, again, you have so many actors on the pueblo lands.

Water Rights Settlement Agreements in New Mexico: Institutional Change Underway

Elizabeth Richards, Sandia National Laboratories *

Elizabeth is a Principal Member of Technical Staff in the Earth Systems Analysis Department at Sandia National Laboratories. She has 25 years of experience addressing energy and water sustainability issues. Beth's most recent research is focused on the governance and management of water resources under conditions of increasing scarcity, with an emphasis on economics and institutional change. She is particularly interested in water over-allocation problems in the western U.S. and in the interdependencies between water and other systems. Beth's career includes research and development, evaluation, commercialization, and application of solar energy technologies as well as project management, program development, and strategic planning. She has extensive experience working with government, non-profit, and business organizations in developing countries and in the U.S. to build local institutional capacity for deploying solar and other renewable energy technologies to address energy security, environmental, and climate-change issues. Beth holds an interdisciplinary PhD in environment and resources and an MS in management science and engineering from Stanford University, along with BS and MS degrees in mechanical engineering from Iowa State University and the University of Michigan.

"The history of water resources development has been the creation of coalitions around big projects which increased the water pie—all the players got more. Now the challenge is to shape institutions that can respond to signals that the carrying capacity of the resource has been exceeded and that can pull groups together to reallocate a shrinking pie—a nearly impossible task for our current institutions."

-- Western Water Policy Review Advisory Commission (1998)[1]

Introduction

It is increasingly recognized that new approaches to the governance of water are needed to reconcile entrenched but outdated institutions and management processes with the new realities of scarcity, environmental change, and evolving attitudes toward the environment. This situation is exemplified in the American West, including New Mexico, where expanding populations and economies are colliding with dwindling water supplies and increased competition for water. There is increasing pressure to reallocate water from traditional uses such as irrigated agriculture to higher-economic-value uses in urban areas or to environmental purposes. The resulting conflicts between urban and rural populations, agriculture and other economic sectors, forces for environmental conservation and forces for development, wealthy and poor, and traditional cultures and suburban sprawl are not easily resolved.

As in much of the western United States, New Mexico's existing water institutions were motivated by the goals of settling and developing the west. However, for a number of reasons, these institutions are proving to be inadequate for addressing today's realities of increasing water scarcity and entrenched conflict. First, the water rights adjudication process is slow, expensive, complex, and has been completed in only a few basins. This situation, combined with hydrologic complexity and the difficulty and expense of metering and monitoring water withdrawals, has resulted in poor enforcement of rights and unsustainable water use in many basins. Second, pressure to reallocate water is increasing. Although New Mexico has a long-standing water market

[1] Wester Water Policy Review Advisory Commission, Water in the West: Challenge for the Next Century (Denise Fort ed., National Technical Information Service. 1998).

* Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

and many water transfers have occurred over the years, transaction costs, lead times, and increasing numbers of protests make the market highly inefficient in some circumstances. There are also unsettled questions regarding public welfare and the effects of transfers on third parties and areas of origin. Third, and perhaps most significant, much of New Mexico's economy is based on junior water rights, so using priority administration to curtail total water use in the absence of efficient water markets could be economically devastating. Changing the existing institutions is difficult though, because departing from the doctrine of prior appropriation or otherwise altering property rights to water would require a change to the state's constitution and possibly raise complex and potentially expensive federal takings issues among existing water rights holders.

This paper examines the use of voluntary negotiated agreements as an alternative to wholesale changes in existing entrenched institutions. Several large and complex water rights settlement agreements have been negotiated in New Mexico in recent years. This paper argues that these agreements are a response to problems that cannot easily be resolved via existing institutions, and that they represent significant change to New Mexico's water management institutions regarding both the determination of property rights to water and the administration of those rights. In the language of the quote above, the settlements "shape institutions" to address the fact that the "carrying capacity of the resource has been exceeded" and "pull groups together to reallocate a shrinking pie."

Defining Institutional Change

Before proceeding, it is useful to define what is meant here by the phrase "institutional change." North (1990) defines the word "institution" as the formal and informal rules that societies use to govern themselves. Schlager and Ostrom (1992) define rules as "generally agreed-upon and enforced prescriptions that require, forbid, or permit specific actions." For example, property rights regimes, which determine how rights to a good are defined and how they are monitored and enforced, are fundamental societal institutions.

Institutional change is thus defined here as significant changes in rules and associated norms, in this case those that relate to the allocation and management of water and water rights in New Mexico. Note that, as defined here, institutions are distinct from the organizations that administer the rules (e.g., the NM Office of the State Engineer).

Water Rights Settlement Agreements in New Mexico

In the last ten years, at least eleven significant water rights settlement agreements have been negotiated in New Mexico, and at least one other is under negotiation (Table 1). They vary by location, by the number of claimants involved, by the amount of water involved, and by the range of issues that they address. Some are focused on one particular issue, such as shortage-sharing, a specific aspect of a water right or group of water rights, or storage rights. Others are much more broad and complex, addressing a wide range of highly complicated, fiercely contested, and interrelated issues. Settlement participants and stakeholders include tribes and pueblos, centuries-old acequia communities and other non-Indian irrigators, ranchers, municipalities, power producers and other industrial interests, and domestic-well owners.

This paper is based on a comparative case study of four of the largest settlements from the list in Table 1 — the Lower Pecos, the San Juan-Navajo, the Taos, and the Aamodt. The map in Figure 1 shows the location of the basins associated with each of the four case-study settlement agreements. The Lower Pecos, in southeastern New Mexico, includes the Roswell Artesian and Carlsbad sub-basins, which are the primary focus of the settlement.[2] The San Juan basin, in the northwest portion of the state, encompasses a significant portion of the Navajo Nation, whose rights are of primary concern in that settlement. The Taos basin in northern New Mexico includes the Taos Pueblo, as well as the Town of Taos, fifty-five acequias, and other water users. The Nambé-Pojoaque-Tesuque basin ("NPT" on the map) is the location of the Aamodt adjudication and associated settlement involving the four Pueblos of Nambé, Pojoaque, San Ildefonso, and Tesuque. The map shows the considerable variation in the drainage areas of the basins. As became evident from the case studies though, the land area in a basin is much less of a factor in the complexity and difficulty of the settlements than the number of water rights claimants and the needs for water relative to the amount of water available.

[2] The Lower Pecos basin also includes the Hondo and Penasco sub-basins, but they are not directly involved in the settlement agreement.

Table 1. Recent Water Settlement Agreements in New Mexico

AGREEMENT	YEAR SIGNED*
Jicarilla Apache Tribe Water Rights Settlement	1992
Rio Jemez Shortage-Sharing Agreement	1996
San Juan Basin Shortage-Sharing Agreement	2003 & subsequent years
Lower Pecos Settlement Agreement	2003
Gila-San Francisco Basin: New Mexico Consumptive Use and Forbearance Agreement, a subset of the Gila River Indian Community Water Rights Settlement Agreement	2005
San Juan River Basin in New Mexico: Navajo Nation Water Rights Settlement	2005
Taos Pueblo Water Rights Settlement	2006
Aamodt Settlement Agreement (in Nambé-Pojoaque-Tesuque Basin, including Pueblos of Nambé, Pojoaque, San Ildefonso, Tesuque)	2006
Eagle Nest Reservoir Management Settlement Agreement	2006
New Mexico Pecan Growers Settlement Agreement (in Lower Rio Grande Basin)	2008
Elephant Butte Irrigation District and El Paso County Water Improvement District No. 1 Compromise and Settlement Agreement	2008
Rio Jemez	In negotiation

*(*Year settlement agreement signed by the key parties involved; some settlements not finalized until required legislation enacted and/or court orders issued, which in some cases may take years.)*

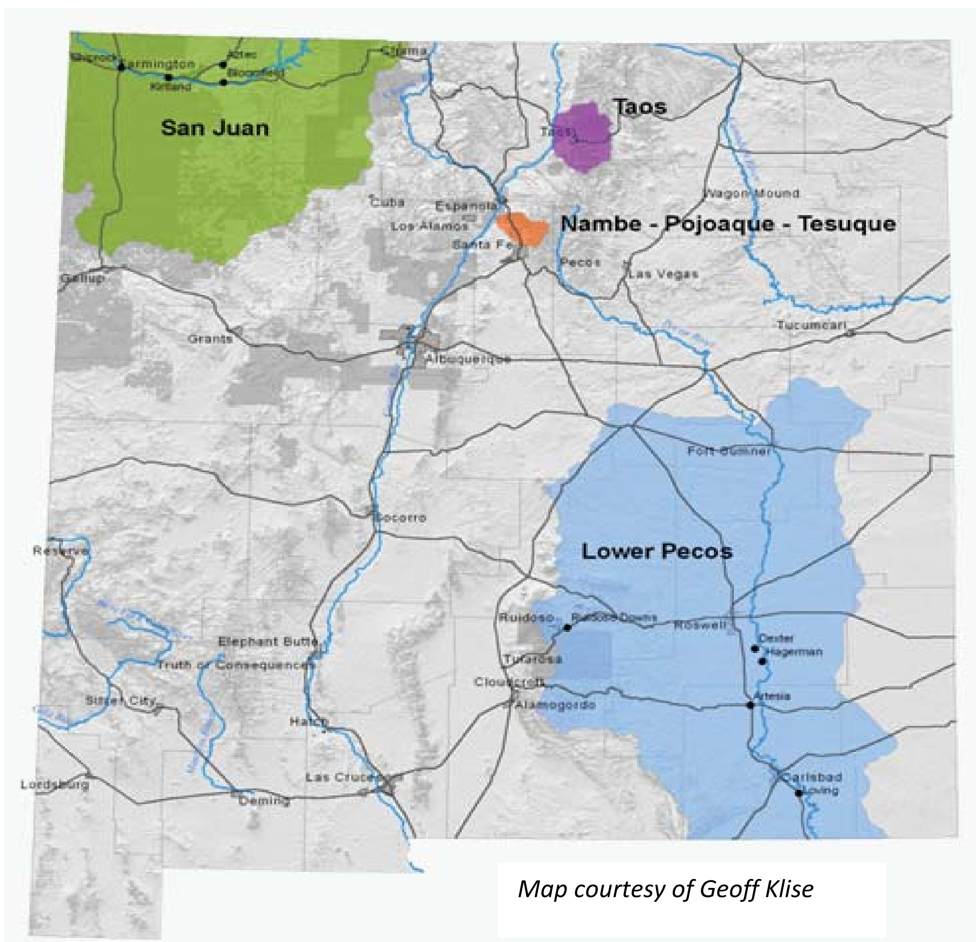


Figure 1. Case Study Basins: Lower Pecos, San Juan, Taos, and Nambé-Pojoaque-Tesuque

Lower Pecos Settlement Agreement

The New Mexico Office of the State Engineer (NM OSE) termed the Lower Pecos settlement a “landmark compromise of disputed water rights.” Signed in March of 2003, it settled a nearly fifty-year-old water rights adjudication dispute involving the Carlsbad Irrigation District, the Pecos Valley Artesian Conservancy District, the Fort Sumner Irrigation District, the federal government, and the state of New Mexico. In addition to defining certain property rights to water, the settlement includes a land and water-rights acquisition and retirement program, provisions for short-term leasing of water, a well field to pump groundwater from the Roswell Aquifer into the Pecos River, and resolution of a long-standing priority call (NM OSE 2003). It also allows for the substitution of shortage-sharing for priority administration in certain circumstances (NM OSE 2006). These features are intended to bring the Pecos River into short-term and long-term hydrologic balance,[3] meet the terms of the Pecos River Compact with Texas, and avoid federal takeover of water management in the basin. As of December 2010, the Lower Pecos settlement had largely been implemented.

San Juan-Navajo Water Rights Settlement Agreement

The San Juan-Navajo settlement agreement (NM OSE, et al. 2005) is intended to resolve the water claims of the Navajo Nation in the San Juan River Basin in northwestern New Mexico. Signed in April 2005 after more than twenty years of litigation to adjudicate the water rights of the Navajo Nation, it provides resources for water development projects for the Nation in exchange for a “release of claims to water that could potentially displace existing non-Navajo water users in the basin and seriously damage the local economy (NM OSE 1999).” The Navajo Nation is the senior rights holder and has made claims to essentially all of the water in the basin.[4] The settlement provides certain protections for other existing uses of water and is intended to allow for future growth in the basin within the amount of water from the Upper Colorado Basin apportioned to New Mexico by the Colorado River Compact. Thus, although only Navajo claims are determined through this settlement, the agreement resolves large uncertainties about the other water rights in the basin. As of December 2010, Congressional and presidential approval of the settlement had been obtained.

Taos Settlement Agreement

The Taos Settlement (NM OSE, et al. 2006b), announced in March 2006, was the result of seventeen years of negotiations representing most of the water users in the Taos basin. It settles the rights of the Taos Pueblo and expedites the adjudication of the other non-Indian water rights in the basin. It allows existing uses of water in the basin to continue and provides protection for the Buffalo Pasture, a wetland with great significance to the Taos Pueblo. It also provides funding for a water development fund for the Pueblo and a number of smaller water infrastructure projects for non-Indian entities. It includes some importation of San Juan-Chama Project water. As of December 2010, the settlement was nearing completion of the Congressional and presidential approval process.

Aamodt Settlement Agreement

The Aamodt adjudication is widely reported to be the longest-running case in the federal court system (*New Mexico ex rel. State Engineer v. Aamodt*, No. 66cv6639 (D.N.M.)). Filed in 1966 and extensively litigated for more than forty years at an estimated cost of $200M,[5] it seeks to define the water rights of the Nambe, Pojoaque, Tesuque, and San Ildefonso Pueblos and other water users in a geographically-small basin, the Nambé-Pojoaque-

[3] The term “hydrologic balance” as it is used here means that water withdrawals and consumption do not exceed the renewable supplies.

[4] The Navajo Nation’s claims exceeded New Mexico’s entire allotment under the Upper Colorado River Compact. If the Nation prevailed in court, all water for the Farmington and the San Juan Basin region would be under control of the Navajo Nation. NM OSE, 1998-1999 Annual Report (New Mexico Office of the State Engineer & Interstate Stream Commission. 1999). See also Appendix D of San Juan Basin Regional Water Plan (NM Interstate Stream Commission ed. 2003).

[5] This cost number was mentioned by several panelists at the 2005 New Mexico Water Dialogue Annual Meeting. (Brown 2005)

Tesuque (NPT) basin. This basin is located in north-central New Mexico just north of Santa Fe. The Aamodt settlement (NM OSE et al. 2006a) was signed in 2006 after five years of court-ordered settlement negotiations. The agreement is intended to resolve the water rights claims of the four Pueblos while protecting the water rights for other existing uses. It includes transfers of water rights into the basin to help balance supply with demand, and it provides for a regional water supply pipeline intended to reduce the use of domestic wells and deliver imported water to the Pueblos. Similar to the Taos agreement, as of December 2010, the Aamodt settlement was nearing completion of the congressional and presidential approval process.

Comparative Analysis

A comparative case study of the four settlements – the Lower Pecos, the San Juan-Navajo, the Taos, and the Aamodt – revealed that although there are significant underlying differences, the agreements have surprising and significant commonalities. All four of the agreements are highly complex and address long-standing entrenched conflicts. They stem from water rights adjudication processes that have been ongoing for decades. The adjudications and associated settlement agreements involve thousands of diverse litigants and stakeholders with a wide variety of interests. Despite the fact that the four agreements were negotiated largely by local people in different basins with substantially different local characteristics and widely varying amounts of water, the overarching outcomes of the settlements are surprisingly similar.

To provide some perspective, Table 2 lists some introductory statistics associated with each of the four case studies. Each of the case studies involves water rights adjudication litigation that was filed decades ago, is highly complex, and remains incomplete. All four involve settlement agreements that were signed within a few years of each other, although the length of time to negotiate each settlement varied widely. The basins vary greatly in size, population, and quantity of water involved. There are Native American lands in each of the basins, but only three of the settlements involve tribes. Correspondingly, although all four settlements require significant government funding, funding from federal sources is provided only for the three settlements involving tribes.

Table 2. Basic Statistics

	Lower Pecos	San Juan-Navajo	Taos	Aamodt
Year Adjudication Filed	1956	1975	1969	1966
Number of Water Rights Claimants	~2000+	~18,000	~7,000	~3,000+
Year Settlement Signed	2003	2005	2006	2006
Years to Negotiate Settlement	2	9	17	5
Population of Basin (in 2000)	139,000	97,000	16,000	11,000
Area of Basin (square miles)	16,777	9,762	524	200
Available Water in Basin (AF/yr)*	125,000	1,100,000	68,000	7,000
Water Rights Settled (AF/yr)*	56,000	326,000	~65,000	~7,000
Number of Tribes in Basin	1	3	1	4
Number of Tribes Involved in Settlement	0	1	1	4
Federal Funding **	0	$820M	$120M	$170M
State Funding**	$100M+	$25M	$14M	$50M
Local Government Funding**	0	$30M	0	$62M
Total Government Funding**	$100M+	$875M	$134M	$282M

** Available Water and Water Rights amounts are based on consumption, not diversion, and are rough estimates meant to allow comparison of the cases.*
*** Funding amounts are estimates as of 2008, may be out of date.*

The settlement agreements are extremely complex documents, with a myriad of provisions and details addressing the specific circumstances in each basin and the particular interests of the stakeholders involved. Correspondingly, there is variation in the specific provisions contained in each settlement. However, despite the quite large differences in structure, language, and details, the settlements address very similar core issues. All four settlements, in one way or another are about:

- determining property rights to water and the limits to these property rights;
- achieving hydrologic balance (meaning water withdrawals do not exceed the renewable supply);
- resolving over-allocation problems (meaning that the rights to water do not on average exceed the quantity of water available, or "paper water" is consistent with the supply of "wet water");
- avoiding priority administration as a means for achieving hydrologic balance and/or resolving over-allocation problems; and
- facilitating the leasing of water.

In addition, as mechanisms both to achieve settlement and to resolve chronic problems, all four settlements rely on physical water projects and external government funding.

Although certain agencies, such as the NM OSE, were involved in all of the settlements, the four agreements were negotiated largely by local people in different basins with substantially different local characteristics and widely varying amounts of water. The Lower Pecos is dominated by large irrigation districts and interstate compact compliance issues. Water in the San Juan is dominated by federal projects and a large Navajo Nation presence. The Taos basin has both a Pueblo and a large number of acequias competing with each other and a growing population. The NPT basin has four Pueblos and is located between the growing city of Santa Fe and Los Alamos National Laboratory, a situation with striking contrasts as well as development pressures. The language, organization, complexity, and details of each settlement are quite different, but much of the core content is strikingly similar. All four settlements contain provisions that are well beyond the scope of traditional litigated adjudications. In addition to clarifying property rights to water, all of the agreements provide for the construction of water projects and measures to balance demand with renewable supply. They also include provisions to facilitate the leasing of water, and they place heavy emphasis on avoiding priority administration. Thus, the settlements not only go beyond traditional litigations by "enlarging the pie" to create incentives to settle; they change how water will be managed.

Although the details and circumstances vary, the fundamental motivations underlying each of the settlements are essentially the same. Perhaps as expected in any settlement related to a lawsuit, all expressly seek to eliminate uncertainty in outcomes (and avoid the possibility of a negative outcome) inherent in litigation and to save the time and expense associated with continuing to litigate. But, all four of the settlements also seek to resolve uncertainty in the supply of water, bring the associated basins into hydrologic balance, and address the problem that there are more water rights than there is water, all in a manner that does not cause severe disruption to the economy or the society.

What is particularly interesting is that the settlements go to great lengths to avoid priority administration, the foundation of water law and management in New Mexico and the western U.S. To quote one eminent observer of the Pecos situation, "Priority enforcement had switched from a centerpiece of New Mexico state and federal Pecos River Compact law to a threat whose consequences should be avoided at any cost."[6]

Why were these settlements necessary? Why were negotiated agreements pursued rather than other options to address entrenched over-allocation problems? Why in some key circumstances was the Doctrine of Prior Appropriation set aside in favor of other approaches to managing water? The following sections explain that the existing water management institutions are not well-suited for addressing the problems that exist in the case study basins, that wholesale institutional change would be very difficult if not impossible, and that these voluntary agreements were a way to overcome these challenges.

[6] Quote by Emlen Hall in Johnson 2003, p. 60.

Water is Over-Allocated

When more water is allowed to be used than the system can support over time, a state of over-allocation exists. Also called over-appropriation, over-allocation is sometimes described as "paper water" exceeding "wet water."

In the western U.S., over-allocation is related closely to how rigorously the Doctrine of Prior Appropriation is implemented, including the degree to which water rights under that system are monitored and enforced. It is also in many cases closely connected to the use of non-renewable groundwater. In New Mexico, water has become over-allocated as a result of a variety of factors. Legal exceptions to the beneficial-use (or "use it or lose it") requirement allow the considerable amounts of water associated with unused senior Indian rights (and to some extent unused municipal rights) to be used by others. Reliance on unsustainable groundwater pumping has allowed municipal populations to grow and become dependent on diminishing water supplies without a clear source of water once supplies run low. Lack of enforcement (due in part to the lack of adjudication) has enabled water use in excess of water rights. Climate variability has allowed water usage patterns to be established during wet periods, patterns that cannot be supported during normal or dry periods. Climate change is projected to further reduce water supplies in New Mexico (Hurd and Coonrod 2007). Incomplete information about the resource, such as the delayed effects of groundwater pumping on streams or the establishment of water rights during wet years (such as was done among the states that share the Colorado River) has also contributed to over-allocation. As a consequence of these and other factors, there are now substantially more rights to water than there is water.[7]

The consequences of over-allocation can be severe. In the long run, consuming water at a rate that exceeds the renewable supply means that it will run out at some point. This is of particular concern for communities and economies dependent on nonrenewable groundwater supplies, but it also applies to surface water (typically viewed as a renewable resource) when it is hydrologically connected to declining groundwater resources. A more immediate consequence of over-allocation is failure to comply with the requirements of interstate compacts and the associated need to make large adjustments in allocation quickly when the compacts are enforced; a similar situation will exist with respect to Indian water claims if and when they are quantified and enforced. Over-allocation also causes serious environmental problems. For example, depletion of groundwater can result in desertification and decline in interconnected surface water flows. Endangered Species Act issues may arise if streams are diverted to the point that critical habitats decline.

In general, over-allocation increases uncertainty and conflict, and may result in potentially expensive litigation with unpredictable, potentially negative, outcomes.[8] In an increasing number of basins, the current rate of water consumption cannot be sustained, and allowing over-allocation to persist is no longer an option.

Correcting Over-Allocation with Existing Institutions is Not Feasible

In the past, over-allocation in New Mexico has been avoided or corrected by developing new water supplies and increasing storage capacity, but these options are, for the most part, no longer available. Measures such as water conservation and efficiency improvements can alleviate or postpone the consequences, but alone are not able to resolve severe over-allocation problems. In the absence of other options, the obvious approach to correcting an over-allocation problem would be to implement the existing law, using priority administration to curtail junior rights holders and allow the market to reallocate water as appropriate. (Note that reallocation alone, via markets or otherwise, is not a complete solution because what is required in the absence of new supplies is some form of "de-allocation" of water, which reallocation does not accomplish.)

[7] Having more rights to water than there is water would not necessarily be a problem in a prior appropriation system if priority was enforced to keep total water use within sustainable limits.

[8] One key example is the U.S. Supreme Court ruling that required New Mexico to pay Texas $14M and immediately begin delivering more water to the state line or face loss of management control of the Pecos basin. *Texas v. New Mexico*, 485 U.S. 953, (Supreme Court of the United States March 28, 1988). Another is a ruling by a lower court judge in response to a lawsuit by senior rights holders in Mimbres Basin declaring that the domestic well law is unconstitutional. *Horace Bounds, Jr. and Jo Bounds, and the San Lorenzo Community Ditch Association vs. The State of New Mexico, ex. rel, John D'Antonio, New Mexico State Engineer*, No. CV-2006-166, State of NM, County of Grant, Sixth Judicial District, (July 10, 2008).

However, actually implementing the Doctrine of Prior Appropriation to address pressing over-allocation or water-shortage problems has proven to be virtually impossible in key basins for several reasons. First, administering priority is difficult and possibly illegal[9] in the many basins where water rights adjudication has not been completed. If it is required that adjudication be completed in a basin before the state engineer can implement priority administration, then it is unlikely that priority could be administered in a meaningful time frame in most basins because of the time and costs associated with the water rights adjudication process. Second, the highest economic-value uses of water are generally associated with entities holding junior rights, so administering priority to curtail water use would cause immediate and severe welfare losses in local and regional economies.[10] In some basins, the priority system and the hydrology interact in such a way that a priority call would be futile; shutting down water withdrawals in most of the basin would be necessary in order to increase deliveries to the most senior users.[11] Third, water markets would not be able to mitigate adequately the welfare losses associated with curtailing high-economic-value uses. Although such welfare losses could be avoided in theory, this is not the case in practice: transaction costs and (especially) the time required to implement transfers make the market transfers too cumbersome to be relied on to prevent large losses, especially in the short run.

Both the time involved and the transaction costs could conceivably be reduced, but changes in the process are limited by laws that protect third parties from impairment. Thus, in circumstances where over-allocation must be corrected, alternatives to traditional litigated adjudications, priority administration, and existing market mechanisms are required. Many alternatives can be imagined; examples include streamlining the water rights adjudication process to make it less costly and time-consuming, using alternative water-sharing schemes instead of priority administration to alleviate economic welfare losses associated with the curtailment of water supplies, and/or developing expedited water leasing or transfer mechanisms that would make the water market more agile in responding to near-term shortages. However, these alternatives are difficult to implement at the state level, either via legislation or through directives from the OSE, because they would require fundamental restructuring of the legal basis for managing water in the state, including amending the state's constitution.

In sum, priority administration is not well-suited to resolving entrenched over-allocation problems. The water rights adjudication process is cumbersome, slow, and expensive. Adjudication has not been completed in most basins (or even started in many basins), and thus property rights to water generally remain unclear. Even where water rights have been determined, enforcement including metering, monitoring, and follow-up, is difficult and expensive, and resources are limited. The complexity of hydrologic systems adds to the difficulty, as it is often unclear whether one entity's use of water is impairing another's right. Most important, large-scale curtailment of high-value junior rights would incur huge welfare losses, and existing water market (reallocation) mechanisms are inadequate for mitigating losses despite the long-standing market for water rights in New Mexico.

Incentives to Negotiate

The over-allocation problems in the case study basins were severe enough to require resolution, but implementing the existing rules ("institutions") to resolve the problems was not politically, economically, or logistically feasible. Changing the relevant water management institutions is very difficult, as wholesale departure from the Doctrine of Prior Appropriation would require a change to the state's constitution. Even if such a change was politically feasible, it would raise complex and potentially expensive federal takings issues among existing water rights holders. However, voluntary (negotiated) measures are allowable, including mutually agreed upon departures from the

[9] In the past, the state engineer has maintained that priority could not be administered unless a basin was adjudicated. More recently, the OSE has proposed administering priority in basins that have not been adjudicated, using existing records as a basis.

[10] For a more complete economic analysis of the welfare effects of priority administration in New Mexico see Chapter 5 of E. H. Richards 2008. Administering priority may also be politically difficult when large populations are dependent on junior rights for household use.

[11] A futile call situation was present in the Lower Pecos case study. Shutting down the upstream junior groundwater users would have no effect on downstream senior surface deliveries, including compact deliveries, for decades.

Doctrine of Prior Appropriation, without requiring wholesale change to existing laws.

In addition to allowing for rule changes, negotiated agreements offer other advantages. A wider range of alternatives can be considered as compared to traditional litigated adjudications, including solutions that are tailored to local circumstances and/or based on historically successful practices. A collaborative process can be employed rather than the inherently adversarial court-based process. Negotiated settlements also make it possible to reduce transaction costs, time, and uncertainty involved in the determination of water rights.

The water rights claimants who were parties to the four settlements were diverse entities. The attributes of each entity's water rights also varied, for example, senior vs. junior, upstream vs. downstream, surface water vs. groundwater, and so on. Correspondingly, the entities had diverse preferences for specific provisions in the settlements. For example, senior rights holders suffering impairment might prefer priority administration (to the extent it did not damage the overall economy), while junior rights holders at risk of being denied water in the event priority was enforced might prefer alternatives to priority administration. Some parties no doubt benefited, at least in the short term, from the status quo.

Although their specific preferences varied, most or all of the claimants were concerned about uncertainty associated with their water supply. For example, the size of tribal rights was unknown and, due to lack of resources for infrastructure, it was largely unclear if and when tribes would be able to make use of their water rights. These uncertainties with respect to senior tribal rights affected all rights holders in the associated basin, not just the tribes. Some acequias were concerned that individual water rights transfers out of their communal ditch systems would render their systems inoperable. In addition, increasing hydrologic imbalance made the future water supply less certain, and incomplete adjudications left water rights unclear.

Although reducing uncertainty was a primary motivation for both junior and senior rights holders to agree to the settlements, it was not the only motivation. While the agreements reduce uncertainty about overall water supplies in a basin, some provisions in the settlements may increase risk for specific parties in certain circumstances. Achieving agreement required consideration of the different and competing interests of all of the parties to the settlements. Any provisions that negatively affected some rights holders had to be offset with other provisions that compensated for the negative effect in order to create the necessary incentives to settle.

Settlements as Institutional Change

The four case study represent diverse agreements with common themes. Similar to the outcome of a litigated adjudication, all four case-study settlements clarify property rights to water and reduce uncertainty. But the settlements also go well beyond determination of water rights to avoid large-scale priority administration, facilitate water leasing, improve enforcement, include federal and/or state funding for projects and other measures, and resolve over-allocation problems to restore hydrologic balance.

The water rights settlement agreements represent institutional change in at least two ways. One is that they significantly alter the procedure by which property rights to water are determined. The traditional litigation procedure still exists, and may continue to be followed in some basins, but the settlements establish a new option that fundamentally changes the process of defining rights. In particular, instead of exclusively using the top-down formal and adversarial litigation process controlled by the state government and the courts, participants may instead engage in direct communications, negotiate, and/or collaborate with the OSE and each other in the determination of water rights. Unlike the purely litigated process, compromise and bargaining is possible, and interactions are not constrained by prescribed court processes. More alternatives are possible, including the use of principles besides historical water usage to establish rights, consideration of interdependencies, and the use of water transfers or government funding (assuming it can be appropriated) to "enlarge the pie." Participation by stakeholders other than those who claim water rights may be possible. Unlike litigation that can (and has) dragged on for decades, settlements may involve a deadline that greatly speeds the process. Settlements may be used to augment the litigation and/or to replace pieces of the litigated process substantially, such as the inter se phase where rights holders may challenge the rights of others.

The second way that the settlement agreements represent institutional change is that they change some of the formal and informal rules for how water is managed. One of the most striking changes is that all four settlements have alternatives to priority administration, the heretofore fundamental procedure for managing water allocations in New Mexico. These alternatives include government-funded buyouts of water rights and transfers, shortage sharing or other "alternative administration" procedures, and forbearance agreements with respect to priority calls. The settlements also change the rules regarding the leasing of water, creating mechanisms to expedite the leasing of water under some circumstances and facilitating legislation to allow leasing of large amounts of Indian water that previously was not permitted. And, the settlements adjust various other management processes to enhance enforcement of water rights.

The fact that five major water rights settlements have been signed in New Mexico (the four case-study agreements, plus the 1992 Jicarilla Apache agreement), a sixth major one is currently being negotiated (in the Jemez Basin), and a variety of smaller ones have been completed, provide evidence that negotiated water rights settlements are not anomalies. The total water rights resolved in the five settlements to date represent a substantial portion of the water consumed each year in the state: ~486,000 AF/year of consumptive water rights out of the 2.0 MAF/year of water consumed in New Mexico. Settlement of Indian water claims also has been and is being pursued in other states, and it is conceivable that settlements will be pursued for other basins in New Mexico with unresolved Indian water claims. In addition, the fact that one of the agreements (Lower Pecos) is not related to the settlement of Indian claims demonstrates that negotiated water rights agreements are not limited to adjudications involving Indian claims.

Conclusions

The settlements are a response to inadequate but entrenched institutions (rules). They represent institutional change with respect to the governance of water in New Mexico in that they change the rules for both how water is allocated (or how water rights are determined) and how water is managed (or how water rights are administered). Because they are voluntary agreements, the settlements were able to change key institutions through collective action without requiring changes to the underlying fundamental water law and remain compatible with the state constitution. Voluntary collective action was possible because the provisions in the settlement provided net benefits not only to the group as a whole but also to the individual signatories. The number of settlements and amount of water involved indicates that fundamental institutional change in New Mexico's water management is underway. It is conceivable that the settlements represent an interim step to broader, more overarching, institutional change in the management of water.

Going forward, a number of additional questions can be raised: When are settlements desirable, from a local, basin, state, and/or national perspective? What do the various stakeholders gain or give up relative to litigated adjudications or business as usual? How are settlements initiated and negotiated, and is an external threat necessary to get the process started? Given the large number of claimants involved in a typical water rights adjudication, how can transparency and participation be maximized while keeping the negotiation process feasible? How can settlements be implemented successfully? And finally, how should settlements be funded? What are the cost-benefit tradeoffs relative to traditional litigated adjudications and the status quo? Are large sums from outside the basin in question necessary to achieve agreement, and if so, what are the incentives for outside entities such as the federal or state government to provide such funding?

References

Brown, J.R. 2005. Statewide Meeting Focuses on Negotiated Settlements, New Mexico Water Dialogue Newsletter Summer 2005.

Horace Bounds, Jr. and Jo Bounds, and the San Lorenzo Community Ditch Association vs. The State of New Mexico, ex. rel, John D'Antonio, New Mexico State Engineer, No. CV-2006-166, State of NM, County of Grant, Sixth Judicial District, (July 10, 2008)

Hurd, B.H. and J. Coonrod 2007. Climate Change and Its Implications for New Mexico's Water Resources and Economic Opportunities. New Mexico Water Resources Research Institute's 52nd Annual New Mexico Water Conference Proceedings, *Beyond the Year of Water: Living within Our Water Limitations*, Report No. 343. Las Cruces, NM.

Johnson, P.S., et al. 2003. Water Resources of the Lower Pecos Region, New Mexico: Science, Policy, and a Look to the Future (New Mexico Bureau of Geology and Mineral Resources, a division of New Mexico Institute of Mining and Technology 2003).

New Mexico Interstate Stream Commission 2003. San Juan Basin Regional Water Plan. http://ose.state.nm.us/isc_regional_plans2.html

New Mexico Office of the State Engineer, Website - Water Rights Adjudication, NM Office of the State Engineer 1999. At http://www.ose.state.nm.us/legal_ose_adjudication.html

New Mexico Office of the State Engineer Interstate Stream Commission 1999. 1998-1999 Annual Report. New Mexico Office of the State Engineer & Interstate Stream Commission. New Mexico Office of the State Engineer Interstate Stream Commission. 2003. 2002-2003 Annual Report. pp. 51-52. http://ose.state.nm.us/PDF/Publications/AnnualReports/02-03-annual-report.pdf

New Mexico Office of the State Engineer, et al. 2003. Settlement Agreement, March 25, 2003 (Lower Pecos River Basin) (2003). http://www.ose.nm.us/isc_pecos_carlsbad_project.html

New Mexico Office of the State Engineer, et al. 2005. Settlement Agreement, April 19, 2005 (San Juan River Basin in New Mexico Navajo Nation Water Rights Settlement). http://www.ose.state.nm.us/water-info/NavajoSettlement/NavajoSettlement.pdf

New Mexico Office of the State Engineer 2006. Proposed Rules and Regulations Providing for Active Administration of the Waters of the Lower Pecos River Basin Water Master District and Implementation of the Pecos River Settlement Agreement. http://www.ose.state.nm.us/PDF/ActiveWater/Lower Pecos/PecosProcessSchedule2006-01.pdf

New Mexico Office of the State Engineer, et al. 2006a. *New Mexico ex rel. State Engineer v. Aamod*t, No. 66cv6639 (D.N.M.) Settlement Agreement, January 19, 2006. http://ose.state.nm.us/PDF/Settlements/Aamodt/settlement_agreement_aamodt.pdf

New Mexico Office of the State Engineer, et al. 2006b. Abeyta Water Rights adjudication: ... (Taos Settlement). http://www.ose.state.nm.us/PDF/Settlements/Taos/AbeytaSettlementAgreement-2006-03-31.pdf

North, D.C. 1990. Institutions, Institutional Change and Economic Performance (Political Economy of Institutions and Decisions) (Cambridge University Press. 1990).

Richards, E.H. 2008. Over-Allocation and the Doctrine of Prior Appropriation: Water Rights Settlement Agreements in New Mexico. Stanford University.

Schlager, E. and E. Ostrom 1992. Property-Rights Regimes and Natural Resources: A Conceptual Analysis, 68 *Land Economics.*

Texas v. New Mexico, 485 U.S. 953, (Supreme Court of the United States March 28, 1988).

Western Water Policy Review Advisory Commission 1998. *Water in the West: Challenge for the Next Century* (Denise Fort ed., National Technical Information Service).

PARTICIPANT LIST
2010 Annual New Mexico Water Conference

Eugene Abeita
Middle Rio Grande Conservancy District
1931 Second St SW
Albuquerque, NM 87102
505-247-0234
evelyn@MRGCD.US

Diana Alba
Las Cruces Sun News
256 West Las Cruces Ave
Las Cruces, NM 88004
575-541-5443
dalba@lcsun-news.com

Vaikko Allen
CONTECH, Inc.
Santa Monica, CA
allenv@contech-cpi.com

Jana Amacher
New Mexico Finance Authority
207 Shelby St
Santa Fe, NM 87501
505-992-9662
jamacher@nmfa.net

Scott Anderholm
US Geological Survey
5338 Montgomery Blvd NE, Ste 400
Albuquerque, NM 87109
anderhol@usgs.gov

Jared Andersen
KRWG
PO Box 30001
Las Cruces, NM 88003
575-646-2818
jander@nmsu.edu

Thomas Annear
Water Management Coordinator
Wyoming Game and Fish Department
5400 Bishop Blvd.
Cheyenne, WY 82006
307-777-4555
Tom.Annear@wgf.state.wy.us

Ed Archuleta
El Paso Water Utilities
PO Box 511
El Paso, TX 79961
915-594-5501
earchuleta@epwu.org

Scott M. Armstrong
Bohannan Huston, Inc.
7500 Jefferson St NE
Albuquerque, NM 87109
505-798-7832
sarmstrong@bhinc.com

Murl Baker
HC 69, Box 48
Sapello, NM 87745
505-429-0670
murlbaker@yahoo.com

Aron Balok
PVACD
PO Box 1346
Roswell, NM 88202
575-622-7000
ab@pvacd.com

Christopher Banet
Water Resources/MC461
BIA Southwest Region
1001 Indian School Rd NW
Albuquerque, NM 87104
505-563-3403
Christopher.Banet@bia.gov

Beth Bardwell
Audubon New Mexico
Las Cruces, NM 88005
575-522-5065
bbardwell@audubon.org

Samantha R. Barncastle
Law Office of Steven L. Hernandez
PO Box 13108
Las Cruces, NM 88013
575-526-2101
slh@lclaw-nm.com

Max P. Bleiweiss
EPPWS/MSC 3BE
New Mexico State University
PO Box 30003
Las Cruces, NM 88003
575-646-1367
mbleiwei@taipan.nmsu.edu

Claudia Borchert
Sangre de Cristo Water Division
801 W. San Mateo
Santa Fe, NM 87505
505-955-4203
ciborchert@ci.santa-fe.nm.us

Guy Bralley
Sandoval County
PO Box 40
Bernalillo, NM 87004
505-771-7953
gbralley@sandovalcountynm.gov

Hilary Brinegar
MSC APR
NM Department of Agriculture
PO Box 30005
Las Cruces, NM 88003-8005
575-646-2642
hbrinega@nmsu.edu

Neal Brown
Marina Del Sur, Rock Canyon Marina
and Damsite Resort
Elephant Butte Lake, NM 87935
575-470-8466
neal@lagorico.com

John Burkstaller
Daniel B. Stephens & Associates, Inc.
6020 Academy Rd. NE, Ste 100
Albuquerque, NM 87109
505-822-9400
jburkstaller@dbstephens.com

Oscar Vasquez Butler
Dona Ana County Commissioner
845 N. Motel Blvd
Las Cruces, NM 88007
575-644-0718
michelleb@donaanacounty.org

Fernando Cadena
City of Las Cruces, Utilities
680 N. Motel Blvd
Las Cruces, NM 88007
575-528-3636
jjohnson@las-cruces.org

Christopher M. Canavan
Watershed Protection Section
NM Environment Department
1170 N. Solano Dr, Ste M
Las Cruces, NM 88001
575-647-7926
chris.canavan@state.nm.us

Rick Carpenter
City of Santa Fe Water Division
801 West San Mateo Rd
Santa Fe, NM 87505
505-955-4206
rrcarpenter@santafenm.gov

Richard C. Collins
Executive Office
USACE - SPA
4101 Jefferson Plaza NE
Albuquerque, NM 87109
505-342-3433
richard.c.collins.maj@usace.army.mil

Filiberto Cortez
Bureau of Reclamation
10737 Gateway West, Ste 350
El Paso, TX 79935
915-534-6301
fcortez@usbr.gov

Lisa Croft
Albuquerque Area Office
Bureau of Reclamation
555 Broadway NE, Ste 100
Albuquerque, NM 87102
505-462-3542
lcroft@usbr.gov

Tony Davis
PO Box 729
Alto, NM 88312
575-336-4501
lidavis@peoplepc.com

Jens Deichmann
Parametrix
8801 Jefferson NE
Albuquerque, NM 87113
505-681-2536
jdeichmann@parametrix.com

Leo Delgado
MSC 700
New Mexico State University
Las Cruces, NM 88003
575-646-7827
leodelga@nmsu.edu

Leeann DeMouche
Ag Econ & Ag Bus, MSC 3AE
New Mexico State University
PO Box 30003
Las Cruces, NM 88003
575-646-3973
ldemouch@nmsu.edu

Suzanne Devergie
TSD-ALB-246
Bureau of Reclamation
555 Broadway NE, Ste 100
Albuquerque, NM 87102
505-462-3618
sdevergie@usbr.gov

Dale M. Doremus
Surface Water Quality Bureau
NM Environment Department
PO Box 5469
Santa Fe, NM 87502
dale.doremus@state.nm.us

Elizabeth Driggers
Senator Tom Udall's Office
505 S. Main St., Ste 118
Las Cruces, NM 88001
575-523-6561

Ashraf N. El Sadek
Plant and Environmental Sciences, MSC 3Q
New Mexico State University
PO Box 30003
Las Cruces, NM 88003
575-571-7216
elsadek@nmsu.edu

Gary Esslinger
Elephant Butte Irrigation District
530 S. Melendres
Las Cruces, NM 88005
575-526-6671
gesslinger@ebid-nm.org

Robert Faubion
Elephant Butte Irrigation District
530 S. Melendres
Las Cruces, NM 88005
575-526-6671
gesslinger@ebid-nm.org

Alexander (Sam) G. Fernald
Animal and Range Sciences, MSC 3I
New Mexico State University
PO Box 30003
Las Cruces, NM 88003
575-646-1041
fernald@nmsu.edu

Rodger F. Ferreira
US Geological Survey
5338 Montgomery Ave.
Albuquerque, NM 87109
505-830-7902
ferreira@usgs.gov

Steve Finch
John Shomaker & Associates
2611 Broadbent Parkway NE
Albuquerque, NM 87107
505-345-3407
sfinch@shomaker.com

John Fleck
Albuquerque Journal
7777 Jefferson Street NE
Albuquerque, NM 87109
jfleck@abqjournal.com

Gretel Follingstad
Interstate Stream Commission
PO Box 25102
Santa Fe, NM 87504-5102
505-827-4136
gretel.follingstad@state.nm.us

Roger Ford
Natural Resources Conservation Service
US Department of Agriculture
6200 Jefferson NE
Albuquerque, NM 87109
505-761-4430
roger.ford@nm.usda.gov

Donald J. Gallegos
US Army Corps of Engineers
4101 Jefferson Plaza NW
Albuquerque, NM 87109
505-342-3382
donald.j.gallegos@usace.army.mil

Karen E. Gallegos
WWIDD
NM Environment Department
525 Camino de los Marquez
Santa Fe, NM 87505
505-476-8611
karene.gallegos@state.nm.us

Dennis Garcia
Reservoir Control Branch
USACE - SPA
4101 Jefferson Plaza NE
Albuquerque, NM 87109
505-342-3380
dennis.e.garcia@usace.army.mil

Jorge Garcia
City of Las Cruces, Utilities
680 N. Motel Blvd.
Las Cruces, NM 88007
575-528-3636
jjohnson@las-cruces.org

Kenneth L. Garcia
Utilities Director
City of Las Vegas
905 12th Street
Las Vegas, NM 87701
505-426-3310
kgarcia@ci.las-vegas.nm.us

Timothy T. Gibson
Freeport-McMoRan Copper & Gold
333 N. Central Avenue
Phoenix, AZ 85004
602-366-8084
Tim_Gibson@fmi.com

Susanna Glaze
NM Water Resources Research Institute
MSC 3167
PO Box 30001
Las Cruces, NM 88003
575-646-4337
sglaze@wrri.nmsu.edu

Guillermo Granados
21st Century Science & Technology
PO Box 16285
Washington, DC 20041
703-777-6943

David G. Griffin
49 CES/CEAN
Holloman Air Force Base
550 Tabosa Ave.
Holloman AFB, NM 88330-8458
575-572-6654
David.Griffin@holloman.af.mil

Mark Gunn
US Geological Survey
5338 Montgomery Blvd NE
Albuquerque, NM 87109
505-830-7903
mgunn@usgs.gov

Steve Harris
Far Flung Adventures and
Rio Grande Restoration
575-751-1269
steve.harris39@gmail.com

John W. Hawley
Hawley Geomatters
PO Box 3470
Albuquerque, NM 87196
505-255-4847
hgeomatters@qwest.net

Martin Haynes
SCM Partners, LLC
PO Box 9043
Albuquerque, NM 87119
505-898-6622
martin@scmpartners.com

Elaine Hebard
1513 Escalante SW
Albuquerque, NM 87104

Michelle Henrie
MHenrie | Land | Water | Law
126 East DeVargas
Santa Fe, NM 87102
505-842-1800
michelle@mhenrie.com

Steve L. Hernandez
Law Office of Steven L. Hernandez
PO Box 13108
Las Cruces, NM 88013
575-526-2101
shl@lclaw-nm.com

Bill Hume
Formerly of the Governor's Office
505-476-2206
william.hume@state.nm.us

Brian H. Hurd
Ag Econ & Ag Bus, MSC 3169
New Mexico State University
PO Box 30003
Las Cruces, NM 88005
575-646-2674
bhurd@nmsu.edu

Janet Jarratt
Middle Rio Grande Conservancy District
1931 Second St SW
Albuquerque, NM 87102
505-247-0234
jj@jjwater.info

Alvin Jones
PVACD
PO Box 1346
Roswell, NM 88202
575-622-7000
ajones@nmproattorneys.com

Dudley C. Jones
Carlsbad Irrigation District
5117 Grandi Road
Carlsbad, NM 88220
575-236-6390
dudley.jones@cidistrict.com

Bruce Jordan
U.S. Army Corps of Engineers
Albuquerque, NM
Bruce.A.Jordan@usace.army.mil

David L. Jordan
INTERA
6000 Uptown Blvd, NE
Albuquerque, NM 87110
505-246-1600
djordan@intera.com

John Kay
Daniel B. Stephens & Associates, Inc.
6020 Academy Rd. NE, Ste 100
Albuquerque, NM 87109
505-822-9400
jkay@dbstephens.com

John P. Kelly
713 Camino Espanol NW
Albuquerque, NM 87107
505-362-1270
j.p.kellype@gmail.com

Susan Kelly
Utton Center, MSC11 6070
University of New Mexico
1 University of New Mexico
Albuquerque, NM 87131
505-277-0514
skelly@law.unm.edu

Todd M. Kelly
US Geological Survey
5338 Montgomery Blvd NE, Ste 400
Albuquerque, NM 87109
505-830-7916
tmkelly@usgs.gov

Randy L. Kirkpatrick
San Juan Water Commission
7450 E Main Street
Farmington, NM 87402
505-564-8969
sjwcoffice@sjwc.org

Elizabeth J. Kistin
International Development Studies
Oxford University
1524 Bryn Mawr NE
Albuquerque, NM 87106
505-238-9461
ekistin@gmail.com

Graham Knowles
NM Environment Department
5500 San Antonio Dr NE
Albuquerque, NM 87109
505-222-9537
Graham.Knowles@state.nm.us

Marcy Leavitt
NM Environment Department
PO Box 5469
Santa Fe, NM 87502
505-827-0187
marcy.leavitt@state.nm.us

Derrick Lente
Middle Rio Grande Conservancy District
Pueblo of Sandia, NM 87004
505-507-3063
derricklente@spherion.com

Andrew Lieuwen
ABCWUA
PO Box 1293
Albuquerque, NM 87103
505-768-2570
alieuwen@abcwua.org

William Little
City of Las Cruces
680 N. Motel Blvd
Las Cruces, NM 88007
575-528-3636
jjohnson@las-cruces.org

Owen Lockwood
Lockwood Engineering & Surveying
4021 Oleta Drive
Las Cruces, NM 88001
575-523-1369
Lockwood@nmsu.edu

Martin Lopez
Lower Rio Grande Public Water Works Authority
325 Holguin Road
Vado, NM 88072
575-571-3628
martin.lopez@lrgauthority.og

Donald T. Lopez
URS
7816 Rio Grande Blvd NW
Los Ranchos De Albuquerque, NM 87107
505-715-3068
donaldtlopez@msn.com

Thomas Maddock, III
Dept of Hydrology and Water Resources
University of Arizona
1133 E. James E. Rogers Way
Tucson, AZ 85721
520-621-7120
tm3@email.arizona.edu

Joseph Maestas
Bureau of Reclamation
555 Broadway NE
Albuquerque, NM 87102
505-462-3615
jmmaestas@usbr.gov

Mike A. Matush
Surface Water Quality Bureau
NM Environment Department
PO Box 5469
Santa Fe, NM 87502
505-827-0187
dolores.herrera@state.nm.us

Doug McAda
US Geological Survey
5338 Montgomery Blvd NE, Ste 400
Albuquerque, NM 87109
505-830-7943
dpmcada@usgs.gov

Karen S. McAda
Montrose Consulting
410 Green Acres Lane
Bosque Farms, NM 87068
505-480-4380
ksmcada@comcast.net

Dwight Menefee
PVACD
PO Box 1346
Roswell, NM 88202
575-622-7000
dmenefee@pvtn.net

Ari Michelsen
Texas A&M AgriLife Research
1380 A&M Circle
El Paso, TX 79927
915-859-9111
a-michelsen@tamu.edu

William J. Miller
2019 Galistero St. #M4
Santa Fe, NM 87505
505-983-7694
williamjmiller@earthlink.net

Mikidadu Mohammed
MSC 700
New Mexico State University
PO Box 30001
Las Cruces, NM 88003
425-749-6500
mikidadu@nmsu.edu

Paul A. Montoia
Public Works - Water Resources
City of Farmington
800 Municipal Drive
Farmington, NM 87401
505-599-1393
pmontoia@fmtn.org

Les W.J. Montoya
County Manager
San Miguel County
500 West National Ave, Ste 200
Las Vegas, NM 87701
505-425-9333
smcmanager@smcounty.net

Hiram S. Muse
9 Tumbleweed Trail
La Luz, NM 88337
575-430-3409
hmuse@q.com

Nathan C. Myers
US Geological Survey
5338 Montgomery NE
Albuquerque, NM 87109
505-830-7942
nmyers@usgs.gov

Bill Netherlin
PVACD
PO Box 1346
Roswell, NM 88202
575-622-7000
bn@pvacd.com

Edward L. Nickerson
US Geological Survey
3655 Research Dr., NMSU
Las Cruces, NM 88003
575-646-7618
nickerso@usgs.gov

A.J. Olsen
PVACD
PO Box 1346
Roswell, NM 88202
575-622-7000
ajolsen@h2olawyers.com

Fernando Ortiz
Regulatory & Environmental Services
City of Las Cruces
680 N. Motel Blvd
Las Cruces, NM 88007
575-528-3533
fortiz@las-cruces.org

Ian Overton
21st Century Science & Technology
PO Box 16285
Washington, DC 20041
703-777-6943

Jed Parker
ALB-200
Bureau of Reclamation
555 Broadway NE, Ste 100
Albuquerque, NM 87102
505-462-3609
jparker@usbr.gov

Olga Pedroza
City of Las Cruces
680 N. Motel Blvd.
Las Cruces, NM 88007
575-528-3636
jjohnson@las-cruces.org

Roger Peery
John Shomaker & Associates
2611 Broadbent Parkway NE
Albuquerque, NM 87107
505-345-3407
rpeery@shomaker.com

Lee E. Peters
Peters Law Firm LLC
PO Box 2796
Las Cruces, NM 88004
575-649-9653
lep@lclaw-nm.com

Edward A. Polasko
National Weather Service - Albuquerque
2341 Clark Carr Loop SE
Albuquerque, NM 87106
505-244-9147
ed.polasko@noaa.gov

Mary J. Reece
PXAO-7000
Bureau of Reclamation
6150 W. Thunderbird Rd.
Glendale, AZ 85306-4001
623-773-6279
mreece@usbr.gov

John Reid
City of Las Cruces, Utilities
680 N Motel Blvd
Las Cruces, NM 88007
575-528-3635
jreid@las-cruces.org

Elizabeth (Beth) Richards
MS 1350
Sandia National Laboratories
PO Box 5800
Albuquerque, NM 87185
505-844-6351
ehricha@sandia.gov

Gary L. Richardson
METRIC Corporation
PO Box 1591
Los Lunas, NM 87031
505-866-1602
Gary1metric@aol.com

Rob P. Richardson
Bohannan Huston, Inc.
425 S Telshor Blvd C103
Las Cruces, NM 88011
575-832-8670
rrichardson@bhinc.com

Greg Ridgley
Office of the State Engineer
PO Box 25102
Santa Fe, NM 87504-5102
505-827-6174
Greg.ridgley@state.nm.us

Clifford E. Sanchez
Natural Resources Conservation Service
US Department of Agriculture
6200 Jefferson NE
Albuquerque, NM 87109
505-761-4404
clifford.sanchez@nm.usda.gov

Dominic M. Scaringe
AWWA Member
1232 Sonnet CT.
Las Cruces, NM 88007
607-207-7378
dmscaringe@aol.com

Gerald K. Schultz
Black Range RC&D
PO Box 637
Tyrone, NM 88065
575-538-0792
gkltz@yahoo.com

Herman R. Settemeyer
MC-160
Texas Commission on Environmental Quality
PO Box 13087
Austin, TX 78711-3087
512-239-4707
hsetteme@tceq.state.tx.us

Subhas K. Shah
Middle Rio Grande Conservancy District
1931 Second Street SW
Albuquerque, NM 87102
505-247-0234
shah@mrgcd.us

Thomas L. Shelley
Reclamation
Freeport-McMoRan Copper & Gold
701 Lance Dr.
Silver City, NM 88061
575-313-3098
Thomas_Shelley@fmi.com

Thomas R. Shelley
701 North E Street
Silver City, NM 88061-4042
575-538-9502
trshelley@q.com

John W. Shomaker
John Shomaker & Associates
2611 Broadbent Pkwy NE
Albuquerque, NM 87107
505-345-3407
jshomaker@shomaker.com

Xochitl Torres Small
Senator Tom Udall's Office
505 S. Main St., Ste 118
Las Cruces, NM 88001
575-526-5475
Xochitl_Torres@tomudall.senate.gov

Dick Smith
PVACD
PO Box 1346
Roswell, NM 88202
575-622-7000
ccfcdick@gmail.com

James T. Smith
Office of the State Engineer Office, Retired
9904 Academy Knolls Drive NE
Albuquerque, NM 87111-1733
505-292-2946
takajts@aol.com

Gill Sorg
City of Las Cruces, Utilities
680 N. Motel Blvd.
Las Cruces, NM 88007
575-528-3636
jjohnson@las-cruces.org

Dan B. Stephens
Daniel B. Stephens & Associates, Inc.
6020 Academy Rd NE, Ste 200
Albuquerque, NM 87109
505-822-9400
dan.stephens@dbstephens.com

David C. Thompson
MSC 3BF
New Mexico State University
PO Box 30003
Las Cruces, NM 88003
575-646-3125
dathomps@nmsu.edu

Bruce Thomson
Water Resources MSC05-3110
University of New Mexico
1 University of New Mexico
Albuquerque, NM 87131
505-277-4729
bthomson@unm.edu

Julian W. Thrasher
Pecos River Compact Commission
PO Box 340
Monahans, TX 79756
432-940-1753
j.thrasher@sbcglobal.net

Mac Todd
American Water Intelligence
PO Box 684787
Austin, TX 78768-4787
512-961-5693

Dan Townsend
624 Tuner Ave
Las Cruces, NM 88005
575-523-1207
ecolo100@hotmail.com

John W. Utton
Sheehan & Sheehan
PO Box 271
Albuquerque, NM 87501
505-247-0411
jwu@SheehanSheehan.com

Judge Jerald Valentine
Third Judicial District Court
201 W. Picacho Ave.
Las Cruces, NM 88005
575-523-8200
lcrdjav@nmcourts.com

William James Walterscheid
Carlsbad Farmer
3129 Hepler Rd.
Carlsbad, NM 88220
575-236-6080
jsw@cavemen.net

Frank Ward
Ag Econ & Ag Bus, MSC 3169
New Mexico State University
PO Box 30003
Las Cruces, NM 88003
575-646-1220
fward@nmsu.edu

Ellen Wedum
Cloudcroft, NM
dotellen@gmail.com

Bob Wessely
Water Assembly
170 County Road A3
Las Vegas, NM 87701
505-908-9400
Wessely@SciSo.com

James G. White
White Ent, Inc.
649 Cielo Vista Ct
Las Cruces, NM 88005
575-526-9638
jwhite@zianet.com

Adrienne Widmer
Regulatory & Environmental Services
City of Las Cruces
680 N. Motel Blvd
Las Cruces, NM 88007
575-528-3548
awidmer@las-cruces.org

Charles Wohlenberg
PO Box 27010
Albuquerque, NM 87125