WRRI Report No. 336
March 2005

Proceedings

49th Annual New Mexico Water Conference

Water Desalination and Reuse Strategies for New Mexico

September 21-22, 2004
Ruidoso Convention Center

The Proceedings are available in full text and color at:
wrri.nmsu.edu/publish/watcon/proc49/proc49.html

New Mexico Water Resources Research Institute
New Mexico State University
Las Cruces, New Mexico

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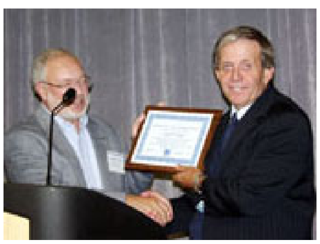
DIRECTOR'S STATEMENT






Ruidoso hosted our 49th Annual New Mexico Water Conference in mid-September, a beautiful time of the year to be in the mountains. Our nearly 200 participants particularly enjoyed our evening banquet out on the patio.

This year's theme, *Water Desalination and Reuse Strategies for New Mexico*, was kicked off by Senator Pete Domenici, a driving force behind New Mexico's desalination efforts, especially the new Tularosa Basin National Desalination Research Facility. Although Senator Domenici was unable to attend due to Congress being in session, he sent a videotape with his remarks. The Senator said his goal is to give groups in New Mexico an opportunity to implement new technologies to address the state's water needs. He foresees "…that much of the development, testing, and manufacture of the next generation's water technology will occur in New Mexico if we are vigilant…"

The conference covered technical issues related to emerging desalination and reuse programs as well as policy related issues involved in using this resource. Of special interest this year was the panel discussion moderated by Bill Hume, Governor Richardson's Director of Policy and Strategic Planning. Mark Fesmire from the New Mexico Oil Conservation Division, Matt Lavery of PNM, Paul Saavedra from the Office of the State Engineer, and Frank Yates, Jr. of Yates Petroleum Corp. discussed the use of produced water; water which emerges from the far depths of oil and gas wells, which historically has presented a disposal problem for the oil and gas industry. The panel discussion is contained in these proceedings.

As always, the success of the conference is due in large part to the input received from the Water Conference Advisory Committee. We look forward to planning next year's milestone conference – our 50th – to be held on the New Mexico State University campus, where the first 20 or so annual water conferences were held. See you there!

M. Karl Wood
Director

Funds for the proceedings publication were provided by registration fees, the U.S. Department of the Interior, and state appropriations to the New Mexico Water Resources Research Institute.




Photos by Stephen's Photo Service



WATER CONFERENCE ADVISORY COMMITTEE AND REPRESENTATIVES

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Wayne Cunningham, *Arch Hurley Conservancy District*
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WATER DESALINATION AND REUSE STRATEGIES FOR NEW MEXICO

49th Annual New Mexico Water Conference

PROGRAM

Tuesday Morning, September 21, 2004

7:30 a.m.	Registration
8:30	Opening Remarks Karl Wood, Director, WRRI Leon Eggleston, Mayor of Ruidoso Senator Pete Domenici (DVD)
8:45	New Mexico's Brackish Water Program as It Relates to the State Water Plan John D'Antonio, Office of the State Engineer
9:30	National Perspective on Saline Aquifers Kevin Dennehy, U.S. Geological Survey, Office of Ground Water
10:00	Break
10:30	Regional Issues and Hydrologic Characteristics John Shomaker, John Shomaker & Associates
11:00	Hydrology of Saline Ground Water in New Mexico Rick Huff, U.S. Geological Survey
11:30	Tularosa Basin National Desalination Research Facility Mike Hightower, Sandia National Laboratories and Bill Karsell, Bureau of Reclamation
12:00	**Luncheon** High school essay competition awards

Tuesday Afternoon, September 21, 2004

1:30 p.m.	Albuquerque Water Reuse Initiatives John Stomp, City of Albuquerque
2:00	Strategies for Produced Water Handling in New Mexico Robert Lee, Petroleum Recovery Research Center, New Mexico Tech
2:30	Produced Water Treatment Program: A Cooperative Effort Rick Arnold, New Mexico State University Agricultural Science Center/Farmington
3:00	Break

3:30	Panel: Water Rights Issues of Produced Water moderated by Bill Hume, Office of the Governor Mark Fesmire, New Mexico Oil Conservation Division Matt Lavery, PNM Paul Saavedra, Office of the State Engineer Frank Yates, Jr., Yates Petroleum Corp.
4:30	Open Forum for Questions and Comments
6:00	Dinner Banquet Patio, Hawthorn Suites Golf and Convention Resort (located next to Ruidoso Convention Center)

Wednesday Morning, September 22, 2004

8:00 a.m.	Water Quality Issues Concentrate Management Regulations Karen Menetrey, New Mexico Environment Department The Science of Concentrate Management Anthony J. Tarquin, University of Texas El Paso Graywater Use in New Mexico Gary Beatty, New Mexico Environment Department
9:00	El Paso's Well-head Desalting Program John E. Balliew, El Paso Water Utilities
9:20	White Cliffs Mutual Domestic Water Users Association Reverse Osmosis Water Treatment System Eddie Livingston, Livingston Associates, P.C.
9:40	El Paso's Desalination Efforts Bill Hutchison, El Paso Water Utilities
10:00	Break
10:30	California Desalination Projects Jerry Johns, California Department of Water Resources
10:50	Yuma Desalting Plant Mike Norris, Bureau of Reclamation
11:10	National Desalination Efforts Frank Leitz, Bureau of Reclamation
11:30	Roadmap for National and International Desalination Research Tom Hinkebein, Sandia National Laboratories
12:00	Closing Remarks Karl Wood, WRRI

Senator Pete Domenici *was born in Albuquerque, graduated from The University of New Mexico in 1954, from Denver University Law School in 1958, and was admitted to the New Mexico bar the same year. He was elected as a Republican to the United States Senate in 1972 and reelected in 1978, 1984, 1990, 1996, and again in 2002 for the term ending January 3, 2009. Domenici has served longer in the U.S. Senate than any other New Mexican in history. He has chaired the Committee on the Budget (1995-January 3, 2001; January 20, 2001-June 6, 2001) and the Committee on Energy and Natural Resources (2003-). Senator Domenici has been the prime supporter of the Tularosa Basin National Desalination Research Facility in Alamogordo, now under construction.*

OPENING REMARKS

Senator Pete Domenici
Washington Office
328 Hart Office Building
Washington, DC 20510

Hello, I'm Senator Pete Domenici and it is my pleasure to speak with you today. Let me first extend my gratitude to the Water Research Institute for hosting the 49th annual water conference.

More and more people are moving to this beautiful state that we call home and we need to find a way to sustain our water needs to accommodate a growing population and most importantly, create new and better jobs. I am particularly pleased that the theme of this conference is water desalinization and reuse strategies for New Mexico. The use of water purification technology will be one of the key tools in our efforts to provide usable water for all New Mexicans.

I would like to have been with you today, in particular I would like to have gone with you to take the tour of the Tularosa Desalination Facility in Alamogordo. I have a keen interest in bringing less expensive, less energy intensive, and less wasteful water purification technology into common use in New Mexico and hopefully across the nation.

The Tularosa Desalination Facility, once complete, will allow us to do cost performance testing for new technology in order to reduce the financial risk of using a new technology for our communities. Improved technology will also help our access to much lower quality water, which is currently stored in the Tularosa Basin and basins like it.

Commissioner John Keys of the Bureau of Reclamation and I are working to have the facility ready to begin testing the new marine expeditionary force desalinization unit in the early spring. The facility should be completed by the end of 2005.

While the key theme of this conference is desalinization and water reuse, I need to provide you with a glimpse of the wider federal efforts we are undertaking to help our state and other water-stressed areas. We have a global water supply problem. In 1998, 28 countries experienced water stress or scarcity. That number is expected to rise to 800 million people in 56 countries by 2025. Water shortages will be faced by nearly every major city in the world over the next 20 years. New Mexico and the southwestern United States already know what I am talking about. Transfers and advanced water treatment are necessary. Our small communities are even more dramatically impacted.

Our solutions will require a broad set of tools including water markets, understanding our resources more completely, efficient use of existing supplies, and expanding water supplies. A key issue in establishing water markets is to build a cohesive understanding of water rights. In many regions of the West, Indian rights have not been adjudicated and this uncertainty affects a long-term investment needed to expand our water supplies. At this point, we are working on four such settlements that affect New Mexico alone. These negotiated settlements, if completed within a manageable budget, offer the best opportunity to support existing uses and to bring surety to the basins in conflict. Congress does not negotiate the settlements but I have directed a great deal of my staff time to study these settlements. All of them are difficult and all are expensive. But I am confident that we will persevere to completion. An equally important job related to water markets is assessing existing resources. We are working to support the Office of the State Engineer by providing support for the measurement of water resources within the state of New Mexico. Additionally, Senator Bingaman and I are developing a new program to assess the groundwater resources along the U.S.-Mexican border with initial focus on the basins in southern New Mexico.

Efficiency means more than just turning off the tap when you do not need water. It means rebuilding infrastructure in a way that utilizes every drop of diverted water to its maximum extent. However, the money to build or revitalize our infrastructure is lacking. To partially address this issue, I am pushing for a loan guarantee program for the Bureau of Reclamation. The money is intended to revitalize existing infrastructure with an eye to increasing all forms of efficiency.

Conservation is also essential, as you know. I am a strong proponent of two initiatives: to clean up our forest watersheds and to improve the health of our riparian bosque areas. Last year we were successful in passing healthy forest legislation. This year we hope to pass a salt cedar management demonstration program. New water supplies are essential. We must tap resources that have previously been unusable, like the large saline aquifers. We need to reuse water as we have been saying. The key issues to expanding water supplies are cost effective water treatment and appropriate disposal of waste by-products.

I am a believer in technology. I got together a bi-partisan group in the Senate along with a similar group in the House to introduce a bill to develop a new national program in water technology. Our desire is to revitalize U.S. water augmentation technology and the development effort that will accompany it. To do this, we are going to try to invest as much as $225 million a year in an array of technologies. Best of all, the national laboratories and universities of New Mexico, in partnership with their colleagues throughout the Southwest, will lead this effort.

A couple of weeks ago, I toured the city of Rio Rancho where they have a water reuse pilot plant and was very encouraged by what I saw. El Paso is also moving forward aggressively with desalinization. Alamogordo and Albuquerque are also making steps in this direction.

My goal is to give groups an opportunity to implement new technologies to address their water needs. It is my expectation that much of the development, testing, and manufacture of the next generation's water technology will occur in New Mexico if we are vigilant and work hard to make sure what we have is known. Those of you here are aware of the crisis we are facing and are dedicated to finding solutions and options that will address the water shortage. I am pleased to see so many water experts and policy makers gathered to discuss these problems and to look forward to their solutions. I look forward to them with you. We will do our part, you do yours.

Thank you very much and it is good to be with you.

John R. D'Antonio, Jr. *was appointed as the New Mexico State Engineer by Governor Bill Richardson in January 2003. He also serves as Secretary of the Interstate Stream Commission. John is a registered Professional Engineer in New Mexico and Colorado and has experience in hydraulic design, acequia rehabilitation, water resource management, and water policy development. John was Cabinet Secretary of the New Mexico Environment Department in 2002. Before that, he was the Director of the Water Resource Allocation Program for the Office of the State Engineer from 2001 to 2002, and served as the District 1 Supervisor in Albuquerque from 1998 to 2001. John also worked for 15 years with the U.S. Army Corps of Engineers as a hydraulic design engineer, as the Chief of the Hydrology, Hydraulics, Sedimentation, and Floodplain Management Program, and was the project manager for the Acequia Rehabilitation Program. A native New Mexican, John received a bachelor's degree in civil engineering from the University of New Mexico in 1979 and pursued graduate course work in water resources engineering, hydraulic structures, and water resource administration. John is chairman of the Water Trust Board for the State of New Mexico. He is also the New Mexico Commissioner to the Rio Grande Compact and is the New Mexico Commissioner to the Costilla River Compact.*

NEW MEXICO'S BRACKISH WATER PROGRAM AS IT RELATES TO THE STATE WATER PLAN

John R. D'Antonio, Jr.
New Mexico State Engineer
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Good morning everybody. It's nice seeing all of you here today. I addressed this conference last year about this time and talked about the State Water Plan and its implementation. At that time, we were trying to complete the State Water Plan for that calendar year. I recognize many of you from different forums - some of you work for me and some of you have worked for me. Many are professional peers in water related areas. A lot of expertise exists in this room. I really like this conference as I've said before. It is one of my favorite conferences where people with an expertise in water get together to talk about important water issues.

Brackish water and the reuse of water are highly important issues. It is nice to follow a talk like the one Senator Pete Domenici just gave. Everything he talked about is something we are intimately involved with in the State of New Mexico. We need that federal partnership in order for things to work. We are a relatively poor state in terms of financial assistance and it very much helps to be on the same page with our federal counterparts, especially with someone as strong as Senator Domenici. Hopefully he will be around for quite a few more years to help us by helping leverage our New Mexico dollars.

One of the things I want to address is funding issues. Governor Bill Richardson is very active in the water area and very supportive of water infrastructure projects. We are trying to develop programs in the State of New Mexico that will dovetail into a federal matching component that in turn will help every one of us in developing our water infrastructure needs. We have a Governor's Finance Council and an investment infrastructure team that the Governor has put together. We are trying to get projects together, so we can look at regionalization, spending dollars wisely, and leveraging those dollars. We will talk about this later.

As you know, New Mexico has been in a drought for four or five years. I think we are going into the fifth year of drought no matter how you look at it. We must administer our resources and anticipate that the drought will continue for some time. As far as I can tell, the drought is here to stay for potentially a long time. I am not a doom and gloom person, but the reality of it is that there are climatic factors in both the Pacific and Atlantic oceans that dictate whether we are in for a drier than normal period. With our reservoir levels so low, we can expect hard times in front of us. We must pull together to solve our water shortage issues.

New Mexico had a pretty decent snowpack last year but we need several years of above average snowpack to even come close to replenishing our limited supplies of surface waters in our reservoirs. What translates into actual runoff is far less than normal. This year seemed like a pretty good year. We had some timely monsoons, some good rainfall events here and there, but it was good only relative to how bad the last few years have been. Looking at statistics for Albuquerque, where I live, August was the eighth driest month in Albuquerque on record. I thought we were doing better than that this year and the perception was that we are doing better.

The reality is that reservoir levels are extremely low. For example, Elephant Butte Reservoir was projected to be at 14 percent of capacity by Memorial Day, about 12 percent of capacity on the 4th of July, and I hear various numbers that by Labor Day it would be down to 4 or 5 percent. It will approach those numbers depending on how much water is used at the end of the irrigation season. We could be anywhere from 2 to 4 percent of capacity, which for a 2-million acre-foot reservoir is only between 40,000 to 80,000 acre-feet of water, if that much. Elephant Butte has become the "poster child" for the western U.S.

We are not the only ones suffering through this drought. I attended a Western State Engineers meeting last week with 15 western state engineers and it was evident that the drought is everywhere. The Colorado River has far reaching affects on shortages, power supply, and water supply issues including an impact on our state because of the San Juan/Chama Project and the shortage area issues we have and the water brought down from the San Juan area to the Middle Rio Grande.

I also want to talk about Active Water Resource Management (AWRM). Because of the drought, it touches on the need for additional supplies of water through technology advancement, water reuse, desalination, and other technologies that we are trying to introduce and perfect in New Mexico. This has all come about as a result of the drought and there is no time better than now to continue exploring these areas. Active Water Resource Management, initiated by my office, is the Office of the State Engineer and the Interstate Stream Commission's attempt to address the drought proactively. This management scheme refers "…to a broad range of activities including permitting transfers, monitoring and metering diversions, and limiting diversion of water to the amount authorized by existing water rights." This initiative will guide what my office staff will look at during the next four or five years in order to get a handle on our water resources and to create the stepping stone to priority administration.

At this time, the tools necessary to enforce priority administration are not available to the Office of the State Engineer. We cannot actually go in and make a priority call and shut off the junior users because we do not have tools and measuring devices in place necessary to make the call. But we are developing the necessary tools and developing them rapidly. We have an initiative underway that will allow us to hire water masters. We have developed a general set of rules and regulations and have received a lot of feedback on them. The regulations are meant to be a general set of framework regulations with more basin-specific regulations to fall under the general set. The regulations have yet to be promulgated but will be soon. The general regulations are nearly complete and will be so within the next couple of weeks. We have already addressed the comments and we are trying to get the group of commenters together soon so we can present the framework rules and regulations. From them, we will begin developing the basic rules and regulations, which means we will have a defensible plan in place to administer our water resources. That will require hiring water masters, complying with the rules and regulations of specific basins, and installing measuring and metering devices. We can then actually go in and enforce priorities. This is an extremely important initiative. You heard Senator Domenici talk about the need for measuring and metering around the State of New Mexico. The Senator spoke at the Continuing Legal Education conference about a month ago in Santa Fe. I was kind of hiding in the back. He asked if the State Engineer was present. I raised my hand and he said, "You know, what you are doing is the right thing, the measuring and metering has to be done. There will be a lot of struggles along the way, but we are behind you 100 percent." We are expecting to receive some funding from the Senator's office to help set up the measuring and metering devices. If we can continue to move forward with assistance from the federal government and we get these tools in place, we can start actively managing our water resources.

We obviously have a problem in the state with our water supply and this is where a desalination program plays a role. We have a long-range water supply concern within the State of New Mexico, and we will always have that concern. Drought cycles will continue to leave us with little precipitation. This is not unique to New Mexico, but common throughout the southwestern United States. If you look at the one-hundredth meridian, which kind of splits the nation, and look at the eastern verses the western parts of the United States and how the states are affected by drought, you'll note how dry the West has become. Yet western populations continue to grow steadily. We very much need new technology to enhance our water supplies throughout the West.

We currently are meeting demand with a limited fresh water supply. My feeling is that there is not really a shortage of water, but a shortage of inexpensive water. We are continuing to go through our water supply at a fairly alarming rate. We need to slow down that rate and look toward using fresh water diluted with some poorer quality water. If we can do that, we can reduce costs in the short-term and hopefully the technologies will continue to develop allowing us to produce less expensive water as time goes on.

Obviously we have to protect existing water rights. One of my main concerns when I look at desalination is where are we going to get the water. Economics plays a role in setting up a desalination facility; if you are looking at a large, regional system to supply water – for it to be cost effective – you are going to have to take out a large amount of water to justify the expense of the plants, the pipelines, and all the other associated expenses. Obviously, you must charge the end-users to help pay for the facility. It becomes very critical where you locate these facilities because the amount of water you extract from the ground will have an impact and will cause impairment to those senior water rights located around the facility.

One of my chief responsibilities as the State Engineer is to protect senior water rights and to make sure that points of diversion do not cause impairment. If they do cause impairment, some type of compensation must be made to the person who holds the water right so that the project can go forward.

New Mexico's compact obligations are huge, and the state must make our compact deliveries. Whenever we can enhance our water supplies, it gives us flexibility concerning our delivery obligations and improves the state's position overall. It is imperative that we make our compact deliveries. We do not want to lose control of our water in the State of New Mexico for not meeting our obligations.

We must find ways to prolong the life of fresh water resources in New Mexico. How do we do this? Conservation is a huge component. We need to continue our conservation efforts and stress the conservation message to our citizens. But we also need to look at the systems that exist today and a lot of leaky, inefficient systems are around. The least expensive way to enhance our water supply is through conservation. Municipalities must look at leakages in their systems and inefficient metering devices that cause overuse of water. Desalination efforts are great, reuse is great, but we must not overlook the conservation component.

Having talked about the importance of conservation, brackish water may be the only significant new source of water available for future use. Senator Domenici mentioned watershed improvement and enhancement. We know we have some unhealthy watersheds and know healthier watersheds will generate additional water supply, but a large amount of funding is required to improve our watersheds. It is not an easy fix. However, if we are truly serious about new water supplies, brackish water development is one of the keys.

How do we develop brackish water in New Mexico? How do we find those resources? We estimate that there are billions of acre-feet of brackish water in our state. But where does it make the most sense to locate treatment plants and use water near those plants? Are there wellhead solutions so we can have smaller applications to treat brackish water?

We first need to quantify our supplies. A Brackish Water Development Task Force was created in May 2004 comprised of about nine different public and private entities including the U.S. Geological Survey, the Bureau of Reclamation, Sandia National Laboratories, our state universities, and the WRRI. The task force will create awareness and promote the use of brackish water.

The Brackish Water Task Force is intended to provide a vehicle to secure funding. In the short-term, the effort will:

- Ensure communication among the state’s experts;
- Provide a forum for review and evaluation of proposed projects and aquifer prioritization;
- Develop a saline aquifer web page to be accessible to the public;
- Prepare a summary report of saline aquifer resources; and
- Develop a hydrogeologic characterization and feasibility study of priority locations.

The task force came up with priority locations for brackish water assessments based on areas where quantity has been defined and also where there is a need for that water due to a lack of fresh water supplies. You may not be familiar with all the locations on this list. I don’t even think the Tularosa Basin is on this list, where the new desalination research facility will be built. The task force, in their limited time together, came up with a priority list including: Galisteo Basin, Mesilla Basin, San Juan Basin, Hueco Basin, Estancia Basin, Southern High Plains, and Lea County. This is a primary list where we can begin looking at developing brackish water in New Mexico.

One thing that comes into play when we look at these different basins is, “Where can we put regional projects together so that we can look toward sharing the cost and passing that cost on to a private investor?”

We need public/private enterprise money in New Mexico to fund our $5-billion-dollar need for infrastructure. The only way to secure funding is to start charging adequately for our water resources so that private enterprises can get a return on their investment. We currently are not charging enough for our water. Systems are old, infrastructure is decaying, and as I have said before, we have spent more on cable TV in a lot of areas than we have on water. The era of cheap water is gone. We must face that fact, water is going to be more expensive. Technology is there and we need to foster pilot projects that will lead to regionalization of projects that make sense.

One short-term goal in the brackish water project plan is to assure communication among the field experts. We often feel like we are herding cats in all these different areas. Anne Watkins is here today, she usually has the responsibility of herding the cats as she coordinates these different task force groups. Since we are spread so thin, it is difficult to get groups together, but this is an important issue and it is now a matter of making it a priority.

A conference like this provides a great forum for raising awareness of the problems and opportunities related to brackish water resources. We are able to learn about the great work Sandia National Labs and the Bureau of Reclamation are involved with, like the pilot projects in Alamogordo. This forum helps to focus the need for the projects in which we must invest our money. The Governor and the Governor’s Finance Council have supported the project financially. I think he will continue to support these types of projects. As you heard from Senator Domenici, we need the grassroots level to continue to put the pressure on both state and federal governments to continue the prospect of developing the finances for these projects.

We need to develop a saline aquifer web page accessible to the public, prepare summary reports of the resources, and develop a hydrogeologic characterization and feasibility study of priority locations. Again, these are short-term goals. We need to reconvene that task force and attempt to find some additional monies.

Long-range water management would best consider brackish water resources that are not well connected to stream systems thus minimizing the issue of making our compact delivery requirements. We are fully aware that in some cases, our brackish water is hydraulically connected to a stream system and that for every gallon of water taken out of the stream system, it will eventually affect that stream system. We must look at how we are going to pay back the river and keep the river whole.

There are some opportunities in areas such as the Estancia Basin and the Tularosa Basin where the water is not connected to streams that have compact delivery requirements. There are fewer management issues in those areas because groundwater withdrawals are not impairing a river because there is no hydraulic connection.

A final thought: when we began putting this presentation together, I wondered how I was going to talk for forty-five minutes on brackish water. I don’t know that we have actually done that much in the State of New Mexico on the resource, but I think it gets down to, "Where do we go from where we are now?"

I think we are making progress in the things that we are doing. Brackish water must be part of our plan for the future. We must maintain long-term supplies as our population grows. We must be flexible in our administration. When I look at projects and applications, I try to give the benefit of the doubt to most applications. But how do we deal with the situation where we have the desire and need to develop potential areas but know that we will be causing impairment to the existing water supply? I have to pay attention to that. I think the State of New Mexico is large enough and our brackish water supply extensive enough that we can find those locations that are best suited for taking diversions out of the ground and we can start developing that water supply.

In developing and following through with our State Water Plan, we need to work together and continue to support Sandia Lab's efforts as it has been so successful in developing the Tularosa Basin alternative as a potential brackish water source.

Now I would like to take questions.

Question: John, I am with Sandia Labs and my question relates to water rights and the use of brackish water. Given that water rights are essentially given out to senior-holders, when we start talking about brackish water, will we have the same process in your vision or do you see a different way of allocating brackish water rights if we start using methods to purify it?

Answer: No. Most of the saline supplies, as you know, are in aquifers that are connected to streams. When you file an application for saline water, you will learn that in most cases water resources are fully appropriated. We really have to look at areas where there is available water. Alamogordo is a perfect example. There is an application before me that our hearing officers have looked at and have made recommendations. There is a point of diversion: and if they want to take out 10,000 acre-feet of water from a point of diversion, you must look at whether over time, a cone of depression will develop and how it will affect existing users. If you will be drying up existing uses of water, you have to go in and evaluate who will be harmed and in what way. If there will be harm to existing users, conditions will be placed on that permit. One condition could be to either reduce the amount of water allowed or allow that applicant to work with the impaired parties to make them whole in one way or another. You must work with the senior water holder and look at the situation as one source of water. The process is really not any different from any other application. We call the request a new appropriation, but water is usually connected unless you have a very good picture of an isolated aquifer or a situation where the water is not interconnected and have verifiable information. You could conceivably find some saline water somewhere that is not connected and would not cause impairment. That is an issue we are looking at in our efforts to map the state's aquifers. We need a whole lot more information because we will continue to explore this opportunity to develop saline resources while continuing to protect our existing water rights. A whole lot of water may be underground but we cannot harm current senior users.

Question: I'm Sat Noriega and am a New Mexico facilitator for the Southwest Water Company out of Los Angeles. I think I have some good news. I have been talking to water rights holders over the past year, and to financial people, our own people, and to our own engineers and technicians. As you know, we have opened a desalination plant in El Paso that is going full blast right now. While traveling through New York, Chicago, and Los Angeles, the conversations I've had with many people, including those in the Southwest, indicate that private money is available for this effort. New Mexico has an abundance of collateral; billions of acre-feet of water but the problem is, as you know and the finance council of the government knows, it is just a matter of crossing the "T's" and dotting the "I's" and being backed up by collateral, which is not insurmountable. Our own company will finance any of the desalination projects with as much as is needed. As you mentioned, the rates have to become adequate. My company tries to finance a project in which we will pay ourselves back mostly from added usages. The added usage is very predictable and automatically goes up. The taxable base will increase because of new industry coming into the area. It is just a matter of good management. The second point is that I have talked with most of the water rights holders from Oro Grande all the way to Three Rivers and about 70 percent of them have said that they have water that is already adjudicated, it is in full use, and it is not harming anybody and will not do so if it continues. I have looked at their numbers and their numbers add up to much more than what Alamogordo is asking for, even with a 20 percent penalty. The potential is there … it is nice to know that there is a fall back position in the private industry.

Answer: Thank you for those comments.

Question: My name is Sterling Spencer and I'm a private operator in Lincoln County. I want to thank you for coming to the conference and making a presentation. I have a comment I want to publicly make to you. I want to thank you for the comments you just made in protecting us, the culture, and the public economy of New Mexico through the senior water rights issues. I think we all know as a society we are moving toward where those massive needs will be [confronted] but we have to recognize, as you stated, that we either have to compensate or protect. I really appreciate your comments that you have made here today.
Answer: Thank you.

Question: I am Bruce Prior with Tucson Water. When you were discussing long-term water resource enhancement, I noticed that you did not mention the reuse of effluent. Do you feel it is something not to be addressed now because of the public's perception or do you feel that the technology being developed in desalination will transfer over to water reuse of effluent?
Answer: No. Reuse is obviously needed and is essential, but the topic I was given was brackish water and I have stuck to that issue. But reuse is very important and I know in Arizona it gets a lot more use than here in New Mexico. I have spent some time with Jim Holway from Arizona's Department of Water Resources and last week we talked about some of the things they are doing. They have 200+ golf courses around Phoenix and are able to inject in the shallow aquifer and bring water back out. Maybe this is not the reuse you are talking about. The aquifer storage and recovery could be very great but we do not know enough about the aquifers in our state yet. We do not have enough data to say, "Is this an appropriate way to start using that technology?" In 2003, a graywater law was passed that allowed for using graywater in homes. A lot of people in Santa Fe are using graywater systems and thereby utilizing reuse technologies. The City of Las Vegas is trying to start a reuse program for their golf course. The same is starting to happen around our state, especially with so many people whose water rights are dependent upon the return flow credits they get. Some of them, their municipalities especially, have a certain amount of water rights and they get a credit for the amount of return flow that goes through their water treatment facility. If they start to reuse that water, their return flow decreases and they have to go back and acquire additional water rights. Some communities have to deal with other issues. Rio Rancho is using a significant amount of reuse technologies. We encourage communities to use reuse. We will need to calculate the final numbers affecting water rights but reuse is definitely in our plans and is something we promote.

Question: Hello, I'm Joe Ortiz and am representing the Realtors Association of New Mexico. Thank you for your presentation. … [Given that] the Office of the State Engineer is the gatekeeper, what facilitates the financial mechanisms that the previous gentleman talked about? Can the Office of the State Engineer be a guiding light and help find those basins? What kind of timeline are we looking at based on [recent] studies for some initial testing facilities?
Answer: I believe the State can be that entity, and we are trying to do so as demonstrated by establishing the task force I mentioned earlier. One year we tried to get, if my memory serves me correctly, $600,000 for New Mexico Tech to start mapping aquifers, but we did not get funded. We continue to need funding at this early stage in the effort. We struggle with this all the time. We have some cooperative programs with the USGS that are headed by Tom Morrison, our Hydrology Bureau Chief. We must look at our workload and where we can spend our limited financial resources wisely. We simply do not have enough of our state adequately mapped and this is one of the areas we are looking into. We talked about the Governor's Finance Council, private investment, and the Governor's infrastructure team. One of the things we are trying to do is to get technical information upfront and employ some of the engineering entities to help us look at what makes sense regarding regionalization. This means not only water development infrastructure needs but also development of desalination projects. We have some pretty good ideas but it is a matter of obtaining that initial funding to start the teams. It does not make much sense for individual applications to go in different areas without a real knowledge of the process because that results in a lot of wasted time in the process. Regardless of what we do in my office, there will be an application filed, there will be a protest, and there will be a hearing. Many attorneys and hydrologists will be involved and before you know it, you are two years down the road and you cannot get off that dime and get things developed. It would make more sense if we go in early and get the information that we need and make

the smart choices since we have limited funding. Let's put a project here, here, and here, and focus on these projects because they are our best choices. This is what we are trying to do: make some smart investments, entice private partnerships, and look at where we can get projects off the ground. The price of gasoline isn't coming down but the price per thousand gallons of desalinated water is coming down to the point where it is becoming more feasible.

Question: I'm Colleen Logan from Weston Solutions, Inc. You mentioned conservation as the cheapest alternative among the arrays facing your office and the state. I wondered if you would talk about current efforts in your office regarding conservation and any future plans that you may have.
Answer: Thank you for that question. We do have a Water Use Conservation Bureau within our office. Again, we are hampered in that office by limited funding. In the past, we did a lot of water conservation programming and had cost-share programs with the Bureau of Reclamation but that funding has dried up. However, the conservation component is something I look at when I evaluate applications and I always look at impairment issues. Statutorily, I am required to review applications as to whether or not they are contrary to conservation or detrimental to the public welfare. So conservation is a huge component. I recently approved a permit for the City of Albuquerque to start using their San Juan/Chama surface water for drinking water. That means they must build a treatment plant, pipe water into storage facilities, and start using this water in lieu of groundwater, thus saving groundwater for times of drought. I put some fairly stringent requirements on the city as conditions of the permit, like a per capita water use maximum in Albuquerque. They have made great strides in conservation but I feel they can come down from their current usage level. I will continue to place requirements for conservation especially for municipalities. One area I think we are weak in, as is the entire U.S., is, "How do we create incentives for the agricultural community to conserve?" If you talk to individual farmers and irrigation districts, you will learn that many farmers are putting in laser-leveled fields and drip irrigation systems. These efforts are helping to conserve water but there really are not incentives for a widespread approach to conservation by the agricultural sector. Every time there is a bill introduced in the legislature, the tax credits are stripped out. The tax credits are not necessarily attractive to the farming community because the farmers are not showing a whole lot of income anyway so a tax credit will not help pay for their conservation systems and improvements. We do not have adequate incentives for agriculture to conserve water and the state law is such that if you save water by diverting less water, your water rights stay the same. You are not increasing that water right because your water rights are defined on consumptive use of a crop and although you may be diverting less water, that water stays in the system. By conserving 50 acre-ft of water, you cannot simply use that amount of saved water elsewhere. We have to be careful about additional depletions of that extra use of water. We are trying to educate farmers about this process. We educate about water conservation within the schools, we distribute brochures, and we have water saving techniques on our website. I think we have a great educational component for our young kids in schools, but we probably do not have enough money to continue the educational programs although it is one of the things we are looking at. Earlier I mentioned efforts by municipalities to detect leaks and water losses and old metering systems. If we can replace those systems gradually, we can be much more efficient in our water use component.

Question: I am Pat McCourt from the City of Alamogordo. John, I want to thank you for coming here and talking about desalination. We think it is an important component in our state's future, as far as allowing us to address our future growth. We are a growing state, and we think it is a method to [allow increases to our population] without having us at each others' throats. It is a way to actually expand our water supply. Lastly, this isn't a question, but we hope you have a fast and safe journey back to your desk, so you can work on other matters.
Answer: And for your benefit, we will try to have a decision out by the end of October.

Thank you everybody. I definitely appreciate your time and your attention.

Kevin F. Dennehy *is the Program Coordinator for the U.S. Geological Survey's Ground-Water Resources Program in Reston, Virginia. The Ground-Water Resources Program focuses on national and regional interests in ground water by conducting multidisciplinary studies of ground-water availability, by developing new techniques to monitor and analyze ground-water systems, enhance the national ground-water monitoring network, and make new ground-water data more easily accessible. For the last 25 years Kevin has been employed by the U.S. Geological Survey and worked in New Mexico, South Carolina, Massachusetts, and most recently, Colorado. Prior to his present assignment at Headquarters, he was Project Manager of the National Water-Quality Assessment (NAWQA) Program's High Plains Regional Ground-Water-Quality Study. Kevin received undergraduate and graduate degrees from the University of New Hampshire and the University of South Carolina, respectively. He is the author and coauthor of more than 50 publications on a variety of water resource topics.*

NATIONAL PERSPECTIVE ON SALINE AQUIFERS

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Good morning and thank you for the invitation to speak at this year's conference. Today I'm going to give an overview of the U.S. Geological Survey's (USGS) activities related to saline-water resources in the United States.

My presentation today will consist of five parts. We'll start with a discussion to put into context fresh and saline waters across the world and then within the U.S. Next, I'll talk about the distribution of saline ground water, the chemical characteristics of saline-water resources, tools the USGS has developed for evaluation of the effects of saline ground-water extraction on subsurface waters, and I would like to end by talking about current USGS activities and future opportunities to investigate this valuable and important resource.

Figure 1 addresses the first topic for discussion: where is the Earth's water located and in what form does it exist?

The distribution of the Earth's water is illustrated by these three columns. The first column shows the breakdown between fresh and saline water on Earth. Only 3 percent of the Earth's water is fresh. Next, if you take that portion of fresh water and break it into its components, you'll see that 68 percent of the fresh water is captured in the world's ice caps and glaciers leaving this component of fresh water unavailable for our use. The next largest portion of fresh water, 31 percent, is ground water.

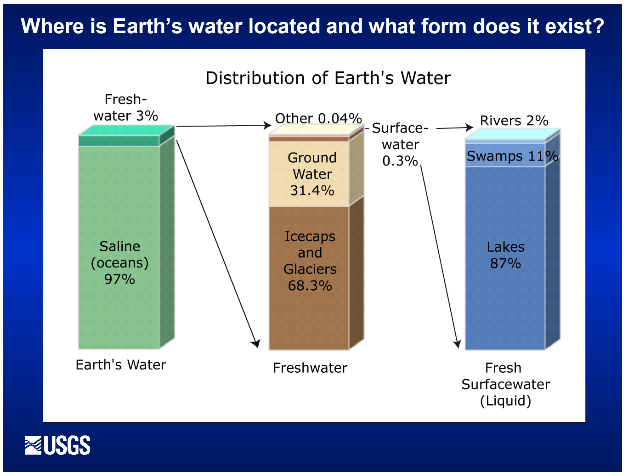

Figure 1.

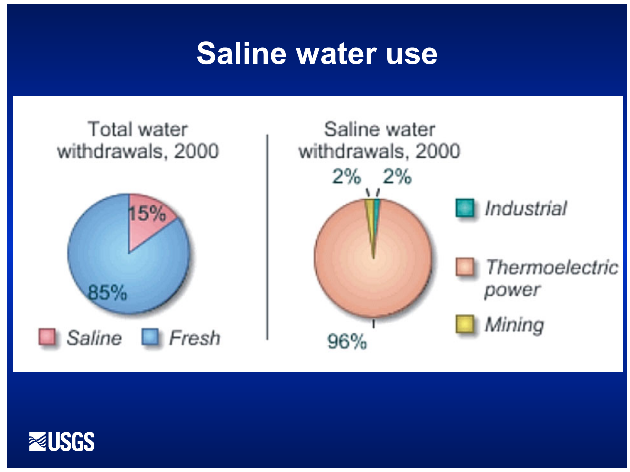

Figure 2.

The world's surface water accounts for only 0.3 percent of the available fresh water. The last column provides the breakdown of the surface water component of Earth's water. The fresh surface water component is composed of lakes, swamps, and rivers, with rivers accounting for only 2 percent of the available fresh surface water supply.

We rely heavily across the world on surface-water resources and it clearly constitutes a very small portion of the available fresh-water supplies. I think this highlights just how precious and limited surface water in rivers and streams is on a worldwide basis.

Another way to look at the Earth's fresh-water resources is by asking, "how much of the Earth's water is usable by humans?" Of all the Earth's water, only 0.3 percent is usable by humans. The largest usable component of that 0.3 percent is the ground-water share of the usable water supply. Although some of that ground water is deep and not very accessible, in comparison to rivers, it still greatly surpasses the quantity of fresh-water supplies on Earth but remains a very small part of the Earth's total water supply.

However, rivers are what this country and the world have traditionally relied on for most of our fresh-water supplies. This conference is evidence to the fact that we are starting to look at ground-water resources to meet the present water needs.

Let's change our perspective from the Earth, big picture, to the scale of the United States. Surface water accounted for 79 percent of the total water withdrawals in the U.S. during 2000. The remaining 21 percent of total water withdrawals was from ground water, with only 1 percent of the total ground-water withdrawals being saline.

Figure 2 illustrates that saline water was primarily used for thermoelectric power generation in 2000.

Figure 3 shows a map of the U.S. on which the relative quantities of saline-water withdrawals are shown by state. California and Florida account for 40 percent of the total saline-water withdrawals in the U.S. New Mexico reported zero saline-water withdrawals in 2000. That may or may not be totally true, but does reflect what was reported.

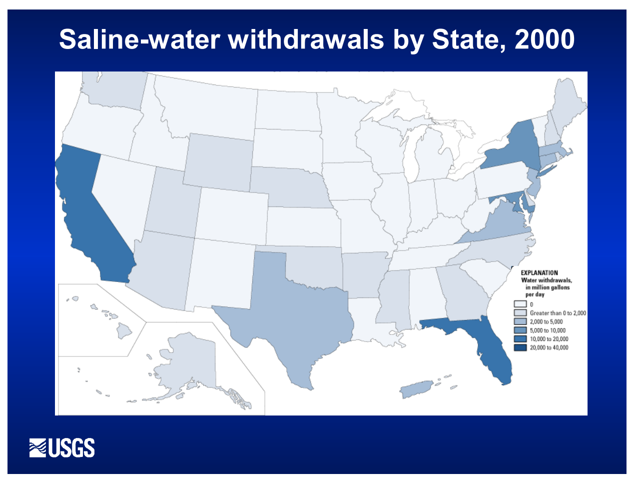

Figure 3.

Let's now look at some trends in total fresh- and saline-water withdrawals. Figure 4 uses blue bars to represent fresh water and red bars for saline-water withdrawals. From 1950 to 1980, there was a steady increase in total fresh-water withdrawals in the U.S. and that is also reflected in the saline-water withdrawals. After 1980, you will note a decline in fresh-water withdrawals that is likely a result of stabilization of technologies related to irrigation and thermoelectric power usage. Fresh-water withdrawals have remained level with a slight increase in 2000. However, if you look at the saline-water withdrawals, you will see a gentle decline.

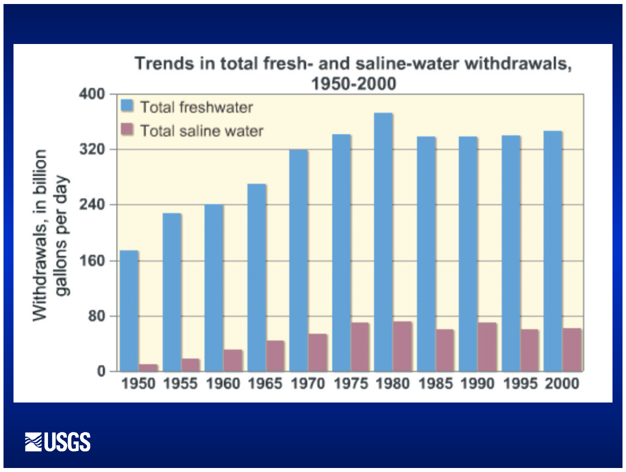

Figure 4.

The facts and numbers I am presenting are from a USGS publication recently released entitled, *Estimated Use of Water in the United States in 2000* (Circular 1268). The publication is available to you in hardcopy from USGS Information Services and on the web at: http://pubs.water.usgs.gov/cir1268.

Other factors affect water demand and are potentially important to the development of saline resources. Demographic changes in the U.S. during the last 10-year period are shown in Figure 5. It shows the percent change in the resident population in the 50 states. Darker colored states indicate a larger percent change in population. You can see that the greatest changes are in the West and Southeast. The U.S. population is migrating and with that migration comes additional demand for water.

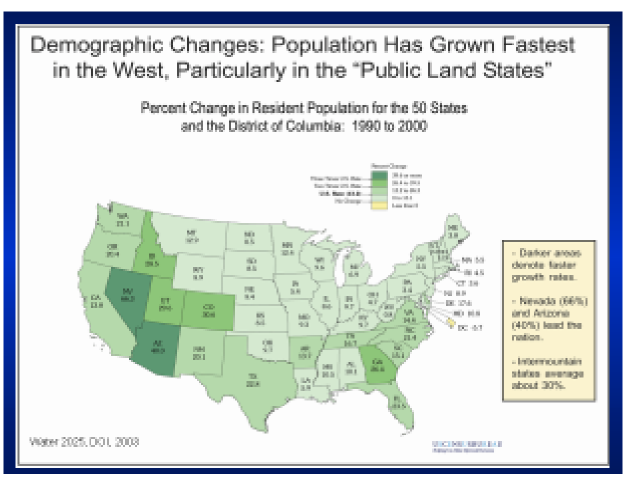

Figure 5.

Figure 6 is a plot showing trends in ground-water withdrawals over a 50-year period along with population trends. What can be seen is that population does not waiver very much as it continues an upward climb. However, recent ground-water withdrawals appear to be on a slight upswing after about a 15-year period of nearly level withdrawals. My contention is that the most recent withdrawals are using ground water to meet the growing population demand.

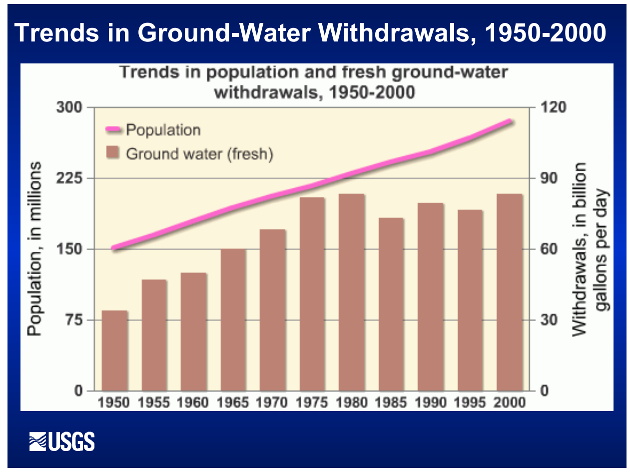

Figure 6.

Surface water resources, specifically in the West, are typically fully appropriated, and in the East, it is much the same story. This also points to the fact that rural water use is predominantly taken from ground-water sources and when cities grow, bands of land develop around cities where people often do not have access to public drinking-water supplies and therefore must develop their own domestic supplies from ground water.

Another important factor to consider when looking at the sustainability of water supplies concerns understanding stresses on those supplies. Figure 7 shows streamflow conditions in the U.S. during the summer of 2002. The dots indicate the location of USGS streamflow stations and illustrates how streamflow varies from normal conditions. I am sure you remember that two years ago, many of the streams in the West and the Southeast were experiencing severe drought. Drought compounds an already difficult situation with more demand than supply from surface water, so additional ground-water supplies need to be developed to meet current demand. If traditional ground-water resources are not available, alternative sources of water will need to be identified, including saline-water resources.

The bottom line is that our fresh-water resources are precious and limited. Total water use remains stable, however, the percentage of ground-water withdrawals may be increasing. Ninety-six percent of the saline-water withdrawals were used for thermoelectric power generation. In 2002, ground

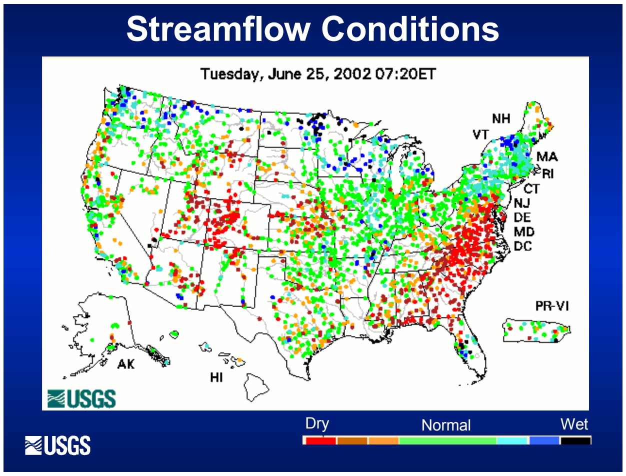

Figure 7.

water was used by more than 35 percent of the U.S. population as a source for public-water supply. Over 15 percent of the U.S. population relied on self-supplied ground water.

As previously stated, rural areas are highly dependent on ground water for their drinking-water supplies. Population growth is occurring faster in the arid West than other parts of the country. Climate change can exacerbate inadequate water supplies. For example, the severe drought of 2002 resulted in Rio Grande flows in New Mexico falling to 13 percent of normal, an indication that the Rio Grande was being substantially stressed.

The reality of limited fresh-water supplies and the increasing demands from a growing population points to the necessity to find alternative supplies. The USGS is well poised to address this problem. To aid in the next part of my presentation let's take a few minutes to look at some definitions. What is saline water? We classify saline water as water having greater than 1000 mg/L or ppm of total dissolved solids or salts. To give you a point of reference, ocean water is about 35,000 mg/L total dissolved solids. The U.S. EPA has established a nonenforceable drinking water standard of 500 mg/L. But in many rural communities people are consuming water with higher concentrations than the U.S. EPA drinking-water standard. When water gets up to about 3000 mg/L, it is probably at the point of being too salty to drink.

Now I would like to give an overview of the work the USGS has done in locating certain saline ground-water resources. First, I'd like to talk about several national studies. The first study was by Krieger and others that was published in 1957. That was a preliminary survey of saline waters in the U.S. It was not as comprehensive as the next study by Feth and others in 1965, which produced a generalized map with a depth to and quality of saline ground water in the U.S. This map is currently being used to show where saline waters are located in the U.S.

The USGS has more recently been involved in similar inventory type studies like the Professional Paper Series 813, a generalized analysis of ground-water resources within 21 Water Resource Regions of the U.S. This series provided general water chemistry information on total dissolved solids and a few selected ions. This study was a generalized broad-scale analysis of selected US water resources.

The first effort to look at U.S. ground-water resources in a detailed manner was the Regional Aquifer-System Analysis (RASA) Program in the 1980s and 1990s. It is obvious that before we look at alternative supplies, we need to characterize our existing fresh-water supplies. The RASA Program characterized the hydrogeologic framework, hydrology, and some general geochemistry for 25 different principal aquifers in the U.S.

The work was important but only looked at fresh-water resources. The most recent national study produced the publication, *Ground-Water Atlas of U.S.* in 2000. This publication was a compilation of existing information, therefore no new information was collected as part of the study.

Figure 8 is the Feth and others map of saline-water resources for the U.S. published in 1965. As I pointed out earlier, this is the map we still use today. However, the map is only a two-dimensional representation of the saline-water resources and therefore does not define the resource vertically with depth.

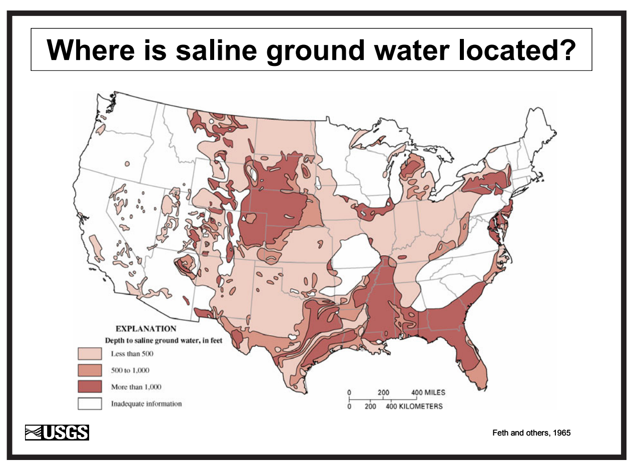

Figure 8.

In addition to USGS national efforts, we have also conducted investigations at the state level through our local District offices. Rick Huff will give a presentation later this morning detailing activities the USGS and others have conducted on a state basis, primarily in New Mexico.

I also want to acknowledge that state agencies are conducting studies of saline-water resources. They are conducting investigations alongside USGS and on their own.

The next topic I want to discuss is, what do we know about the chemical characteristics of the saline ground-water resources in the U.S.? Most of the national investigations focused on fresh-water resources. The USGS has done relatively little research on the geochemistry of saline-water resources. The USGS has been involved in studying the disposal of various industrial wastes as well as brines in deep saline aquifers. But there has been no consistent effort across the nation to study these type of activities.

Another question the USGS has addressed is, how do we examine the effects of saline ground-water withdrawals on the remaining fresh-water resource? I think this is where the USGS has made a substantial contribution. The USGS has developed numerical models to quantify the movement of inland saline-water resources to aid in the understanding of the impacts of using these resources in different hydrologic environments. Two examples are the SEAWAT and SUTRA models. SEAWAT is a combined flow (MODFLOW) and transport (MT3DMS) model. It simulates transient or stress related activities in the ground-water system. The model can also simulate variable-density ground-water flow in three dimensions. It is a very powerful tool. Another attractive aspect is that SEAWAT continues to be updated and compatible with new releases of MODFLOW and MT3DMS. This tool can be used to assess what would happen to ground-water reservoirs once withdrawals are made from either fresh or saline ground waters.

The other numerical model I mentioned that was developed by USGS is SUTRA. This model will simulate transient density-dependent saturated or unsaturated ground-water flow. It will simulate transport of solute or energy in ground water in two and three dimensions. The USGS will continue to support the development of these models.

For the last part of my talk, I want to go into some detail about the current status and future direction of USGS investigations on saline-water resources. In 2001, the USGS was given a Congressional directive to prepare a report describing the scope and magnitude of the effort needed to provide periodic assessments of the status and trends in the availability and use of fresh-water resources.

The USGS completed the analysis and delivered the report to Congress in 2002 (*Concepts for National Assessment of Water Availability and Use* - Circular 1223). The report is accessible on the web at URL: http://water.usgs.gov/pubs/circ/circ1223/.

After submitting the report, the USGS was asked by Congress to develop an implementation plan for such a national assessment. The implementation plan was developed to answer this question: "What is the availability of water resources in the nation and how does this availability relate to demand, source, and geographic location?" This question was asked by Congressman Ralph Regula of Ohio.

The products of the assessment include: data, GIS coverages, and a series of succinct reports that describe hydrologic conditions and trends in water availability on a regional and national scale. The topics that will be reported on include: 1) surface water, 2) historic trends in ground-water levels and updates of ground-water storage change, 3) identification and estimation of undeveloped potential water resources (the subject of this conference), and 4) documentation of surface- and ground-water withdrawals.

Finally, where are we now? We are awaiting passage of the federal budget for fiscal year 2005. The House of Representatives report for the 2005 USGS budget includes increases in funding over the Administration request for initiation of a Water Availability and Use pilot program. If that effort is funded as described in the House report, we would begin the pilot plan in the Great Lakes. In the future, under full implementation, the program would evolve and conduct similar investigations in the remaining aquifer systems across the country. A component of the initiative is to also synthesize existing information. That is when a new effort on saline-water resources will likely take place. If the complete pilot plan is funded, the USGS will likely start the synthesis in the West, and perhaps in New Mexico. The full Senate still must vote on the present recommendations in the report and then the House and Senate must meet in conference to iron out their differences.

I'd like to end by saying the USGS recognizes the need to study saline-water resources. It is evident from my presentation how important those resources will be, especially in certain parts of the country. My hope is that the Water Availability and Use Initiative is fully funded so we can proceed with the pilot study. I appreciate your attention, thank you.

***John W. Shomaker** is President of John Shomaker & Associates, an Albuquerque consulting firm specializing in water-planning, ground-water supply, water-quality, and water-rights matters. Clients include many of New Mexico's towns and cities, investor-owned water utilities, mining and industrial enterprises, and state government. He holds B.S. and M.S. degrees in geology from the University of New Mexico (1963 and 1965), an M.A. in the liberal arts from St. John's College in Santa Fe (1984), and M.Sc. and Ph.D. degrees in hydrogeology from the University of Birmingham, England (1985 and 1995). From 1965 to 1969 he was with the U.S. Geological Survey, Water Resources Division, and from 1969 to 1973 with the New Mexico Bureau of Mines and Mineral Resources. He has provided expert testimony in many New Mexico State Engineer water-rights hearings, in New Mexico Water Quality Control Commission and Environment Department hearings, in State District Court, and in interstate water litigation before a U.S. Supreme Court special master. He is author, coauthor, or editor of some 40 water-related publications and more than 100 consulting reports available in the public record.*

WHAT IS AND WHAT ISN'T A "BRACKISH GROUND-WATER RESOURCE?"

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The theme of this article is that brackish and saline ground water is subject to the same rules, both scientific and administrative, that govern the flow and use of ground water in general. New attention being devoted to New Mexico's brackish-water resources does not imply that they are newly discovered, that they are unrelated to more conventional water resources, or that they can be developed without attention to the constraints that apply to other ground-water supplies. As usual, it is not so much the gross volume of water that might be present, but the costs and effects of withdrawing it, project by project, that determine its usefulness as a resource. Nothing in this paper is new; it is here as a reminder that what we know about fresh-water resources applies to brackish and saline water as well.

Inventories of total ground water in place in the aquifers may appear important, but are really only of academic interest. In the San Juan Basin in the northwestern part of the state, it has been estimated that there are 300 million acre-feet of fresh water and another 50 million acre-feet of brackish water in the aquifers, all within reasonable drilling depth, which would be enough to supply New Mexico at the present rate of depletion for a century or so. Of only slightly more relevance is the same author's estimate of "recoverable" water, less than one-half percent of the total, but even here the huge numbers of wells, the great lengths of pipeline, and the pumping costs that are implied, put most of this "recoverable" water beyond practical reach. Whether a particular amount of ground water can be withdrawn at a cost someone will pay, and with acceptable effects on other resources, is what matters.

People always want to know whether a supply is "sustainable." There is a spectrum of conditions under which ground water is produced, from "mining," simply running down a stock of water stored in the ground, at one end of the spectrum, to intercepting water that would otherwise be streamflow at the other. Ground-water pumping generally involves a component of each, with the "mining" fraction diminishing over time, and the effect on streamflow increasing. Brackish water in an aquifer system is generally at greater depth than better-quality water, or is in an aquifer that is not stream-connected, and is therefore much more likely to be produced by mining. Water that is still more saline is generally even deeper and less in communication with surface streams, and would be produced almost entirely by mining.

Ground-water mining is clearly not sustainable for the long term: the stock is steadily depleted, and eventually runs out. Then what? If users have come to depend on the water but no Plan B is ready to be put in place, discomfort results. Ground-water mining commonly leads to some other negative symptoms: increasing cost over time (attributable to the increasing pumping lift required), declining water-quality as deeper parts of the aquifer contribute proportionally more of the amount pumped, and irregular subsidence of the land surface. Decline in water levels is, of course, greatest in and closest to a pumped well, so that the resource may be depleted only locally, in the sense that individual wells will no longer produce at economic rates. A well field can be exhausted in that sense, even though only a tiny fraction of the water in the aquifer may have been withdrawn. It can happen even if the rate of pumping is much less than the rate of recharge to the aquifer as a whole. This is the predictable future of the City of Gallup's wells, in some of which the drawdown of water levels has already been more than 900 ft.

The supplies of brackish water in bedrock beneath the High Plains Aquifer in eastern New Mexico are available for mining. In Lea County, for example, there are significant volumes of water ranging in quality from fresh to brine, at depths ranging from less than 1,000 ft to about 7,000 ft, but they would be developed on the same terms as the High Plains Aquifer itself has been: continuing decline of water levels, leading to eventual local exhaustion.

For a supply to be sustainable over the very long-term usually requires that it be taken at the expense of streamflow, because that is renewable (albeit with great variation, in a climate like ours) from rain and snow. This generalization applies to ground water pumping as well as to diversion of water from a stream. The rate of depletion of streamflow due to pumping from wells is governed by the properties of the aquifer (its permeability, and whether water in it is confined by overlying impermeable material, or unconfined), the distance from the stream, the pumping rate, and time. In New Mexico, most streams are fully appropriated, and any effect on streamflow due to pumping of brackish water would have to be offset by retirement of equivalent surface-water rights that are already in place.

In some cases, production even of brackish water would affect streamflow significantly. The Capitan Reef aquifer east of Carlsbad supports high well-yields, but one modeling analysis suggests that pumping from as far as 25 to 30 miles from the Pecos River would lead to depletion of river flow equivalent to about 29 percent of the rate of pumping by the end of 40 years. The brackish water could be pumped only if Pecos River water rights to offset that depletion were retired.

Even if a well is far from the river, and the bottom of the well is far above the level of the river, pumping from it will intercept water that would eventually be discharged to the river and be accounted as streamflow. Similarly, even if a well taps only a very deep, brackish-water zone in the aquifer, upward leakage from the aquifer, which contributes to the river's flow, will be diminished. In the latter situation, which would apply in the Rio Grande Valley just as does the former, almost all of the water would be produced by mining for a long time, but the effect on streamflow would always be rising. An insidious problem is that, even if pumping is stopped, the effect on streamflow does not stop at once but declines only gradually.

There is one other possibility–salvage of water that would otherwise be evaporated, under natural conditions, or transpired by vegetation that we don't care about. This is the case of ground-water basins that are not drained by a stream, in which recharge enters and passes through the ground-water system, then is discharged in the middle of the basin to a playa lake where it evaporates, or is "pumped" and transpired by salt cedar or other plants. The Estancia Basin is an example: some part of the water being pumped for irrigation and other uses is being mined (water levels are continuing to go down), and some is water that would otherwise be discharged to the playa lakes and simply evaporate.

In some basins, the brackish water is simply part of a body of ground water that includes some good-quality water already in use. Drawdown due to production of the brackish, or even saline, water may affect water levels in the fresh-water area. In these situations, water-rights administration may not distinguish between brackish water and fresh–except to invoke special guidelines to protect the remaining fresh water. This is the situation in part of the eastern Tularosa Basin.

Using brackish or saline water automatically presents an environmental problem to be solved: what is to be done with the highly saline concentrate left over from the desalination process? Is there a suitable deep aquifer zone into which it can be injected? Or would evaporation ponds be appropriate?

Legal control of the state's brackish and saline water resources is not as well defined as it is for fresh-water resources. Section 72-12-25 of the New Mexico statutes appears at first glance to take much of the poor-quality ground water out of the State Engineer's jurisdiction, but that issue is still debated.

Brackish and saline waters do represent an important resource for New Mexico, but analysis of the effects on other aspects of water resources, and on other parts of the environment, of any proposed project is at least as important as it would be for a new conventional fresh-water development. A useful brackish-water resource is one that meets all of the tests.

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AN OVERVIEW OF THE HYDROGEOLOGY OF SALINE GROUND WATER IN NEW MEXICO

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INTRODUCTION

Increasing demand on limited potable ground water supplies in New Mexico has stimulated interest in saline water resources. Saline water is defined for the purpose of this paper as containing a dissolved solids concentration equal to or greater than 1,000 milligrams per liter (mg/L). Saline water resources can augment potable water supplies following treatment to reduce concentrations of dissolved solids. This treatment, known as desalination, is expected to play and increasingly important role in meeting water demand in the desert southwest and the nation. "By 2020, desalination and water purification technologies will contribute significantly to ensuring a safe, sustainable, affordable, and adequate water supply for our Nation" (U.S. Bureau of Reclamation and Sandia National Laboratories, 2003).

Purpose and Scope

Successful development of saline water resources in New Mexico will require information on the geohydrology of aquifers containing these resources. Existing information is scattered throughout the scientific literature and, in some instances, is currently available only on the internet. The purpose of this paper is to present a reconnaissance-scale overview of the saline ground water resources of New Mexico and to compile and synthesize available information on the geographic location; geohydrologic setting; extent and movement of saline ground water; and the hydraulic properties of, yields to wells from, and saline water in storage in selected ground water reservoirs in New Mexico. The discussed reservoirs include the Albuquerque Basin, San Juan Basin, Roswell Basin, Capitan aquifer, Estancia Basin, and the Tularosa-Salt Basin (Fig. 1). Kelly and others (1970) and Kelly (1974) determined these reservoirs to be potentially important sources of saline ground water in New Mexico.

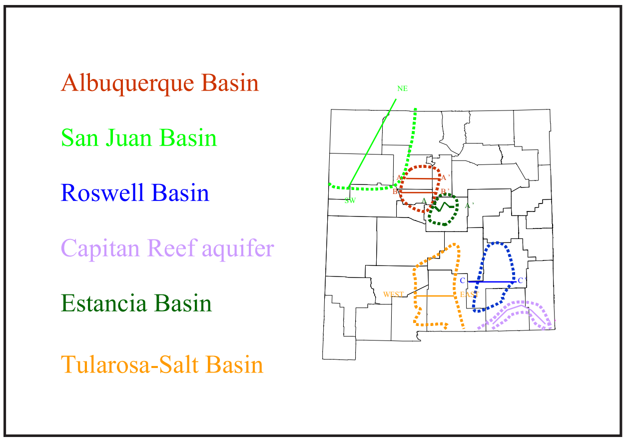

Figure 1. Generalized boundaries of selected ground water basins and aquifers in New Mexico including the locations of cross sections shown in figures 3-8.

Background

The importance of saline ground water resources is reflected in the number of studies on the results (American Hydrotherm Corporation, 1966a; 1966b; 1967) and feasibility (Morris and Prehn, 1971; Stucky and Arnwine, 1971) of desalination in New Mexico. Recently renewed interest in use of saline water resources is reflected in the works of U.S. Bureau of Reclamation and Sandia National Laboratories (2003), Whitworth and Lee (2003), and Huff (2004). A workshop was convened in 2004 by the New Mexico Office of the State Engineer, the New Mexico Water Resources Research Institute, and the U.S. Bureau of Reclamation to devise strategies for development of saline water resources in New Mexico. Results of the workshop can be viewed at http://wrri.nmsu.edu/conf/brackishworkshop/report.html.

Acknowledgements

This paper was prepared in cooperation with the New Mexico Water Resources Research Institute. The contributions to this effort of Jim Bartolino, Bob Creel, John Hawley, John Kennedy, Cathy Ortega Klett, and Peggy Risner are gratefully acknowledged.

SALINE GROUND WATER RESOURCES

Approximately three-fourths of the ground water in New Mexico is too saline for most uses without treatment (Reynolds, 1962, p. 91). Hood and Kister (1962), Hale and others (1965), Kelly and others (1970), Kelly (1974), U.S. Bureau of Reclamation and State of New Mexico (1976), Thompson and others (1984), and Lansford and others (1986) reported results of reconnaissance scale investigations on the distribution and chemical composition of saline ground water in New Mexico. Figure 2 shows areas of New Mexico that were known to contain saline ground water resources in 1965 as described by Hale and others (1965). The rest of this paper will summarize the available information describing our current state of knowledge concerning the hydrology of and the saline ground-water resources contained within areas shown in Figure 1. Sources of information summarized include works at regional, state, and local scales.

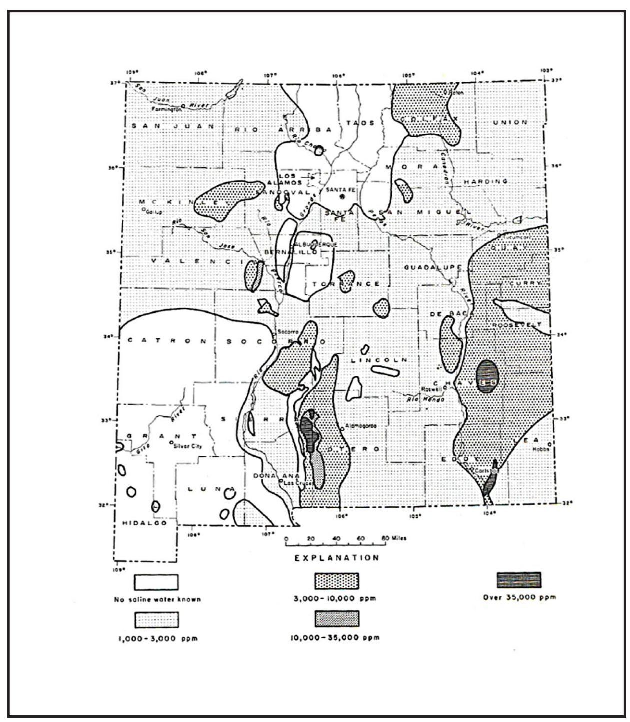

Figure 2. Generalized occurrence of saline ground water in New Mexico (from Hale and others, 1965).

Albuquerque Basin

The Albuquerque Basin covers about 2,100 square miles (mi^2) of central New Mexico (Fig.1) (Lozinsky and Hawley, 1992). Figure 3 shows geologic cross sections representative of the basin. The basin was formed by tectonic events in Pennsylvanian-Permian time, Jurassic-Cretaceous time, late Cretaceous-Tertiary time (Laramide Orogeny), and events in Oligocene-Recent time associated with opening of the Rio Grande Rift (Kelley, 1977).

The Albuquerque Basin contains geologic units of Precambrian through Quaternary age. Sedimentary rocks of Paleozoic through Cenozoic age, representing a variety of marine and non-marine depositional environments, overlie Precambrian basement (Kelley, 1977). The major aquifer in the basin is contained within the Santa Fe Group of Pliocene-Pleistocene age. The Santa Fe Group is up to 14,000 feet thick and is divided into upper, middle, and lower hydrostratigraphic units (Hawley, 1992; Lozinsky and Hawley, 1992).

Recharge enters the Santa Fe Group sediments by surface water infiltration, mountain front recharge, and as ground water flow across the northern boundary of the Albuquerque Basin. The total estimated recharge to the Santa Fe Group aquifer is about 268,000 acre-feet per year (ac-ft/yr) (Kernodle and others, 1995). Kernodle and others (1995) estimated that inflow to the Santa Fe Group aquifer and overlying sediments exceeded outflow (including ground-water withdrawal) by 920 ac-ft/yr under 1994 conditions.

Water having dissolved solids concentrations of 1,000 to 3,000 mg/L occupies the Santa Fe Group from about 3,000 to about 7,000 feet below land surface. The total volume of saline water in these sediments is estimated to be about 300 million acre-feet (Kelly, 1974).

Estimated values of hydraulic conductivity in the Santa Fe Group aquifer range from 40 to less than 0.3 feet per day (ft/d) (Kernodle and Scott, 1986; Haase and Lozinsky, 1992; Kernodle and others, 1995). Estimated values of transmissivity in the Santa Fe Group range from 7,500 to 600,000 gallons per day per foot (gpd/ft) (about 1,000 to about 80,100 square feet per day (ft^2/d)) (Bjorklund and Maxwell, 1961) with an average value near 221,000 gpd/ft (29,500 ft^2/d) (Kernodle and Scott, 1986). Hydraulic conductivity in the Santa Fe Group aquifer decreases with depth. Estimated values of hydraulic conductivity are 10-15 ft/d for the upper hydrostratigraphic unit, 4 ft/d for the middle hydrostratigraphic unit, and 2 ft/d for the lower hydrostratigraphic unit (Kernodle and others, 1995). Aquifers containing saline water in the basin may yield up to 500 gallons per minute (gpm) to wells (Kelly, 1974).

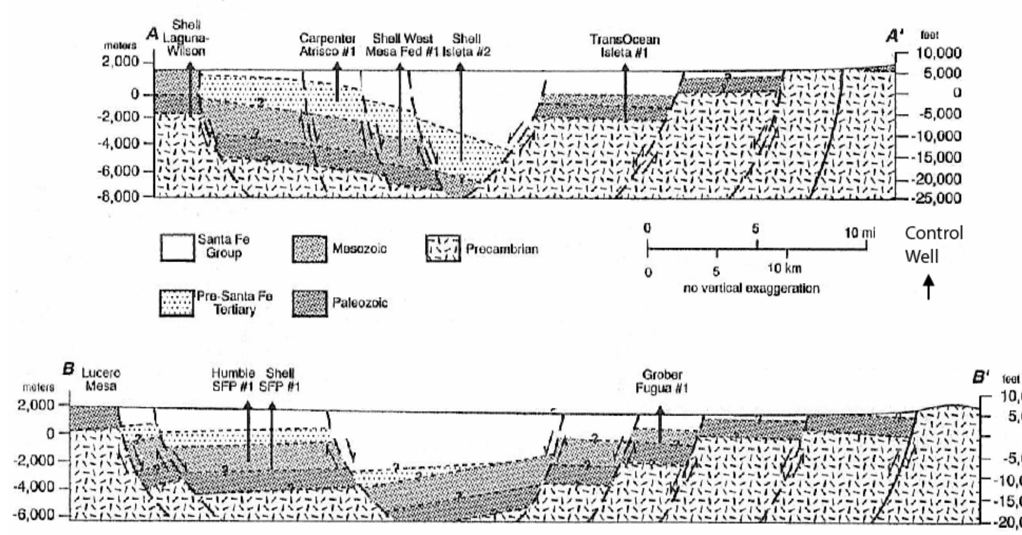

Figure 3. Geologic cross section through Albuquerque Basin (modified from Lozinsky and Hawley, 1992).

San Juan Basin

The San Juan Basin covers about 15,000 to 20,000 mi^2 of New Mexico, Colorado, Arizona, and Utah (Kelley, 1957). Figure 1 shows the area of New Mexico included in the San Juan Basin. Figure 4 shows a hydrogeologic cross section representative of the basin. The basin was formed principally by tectonic events in Late Cretaceous time (Laramide Orogeny) (Kelley, 1957).

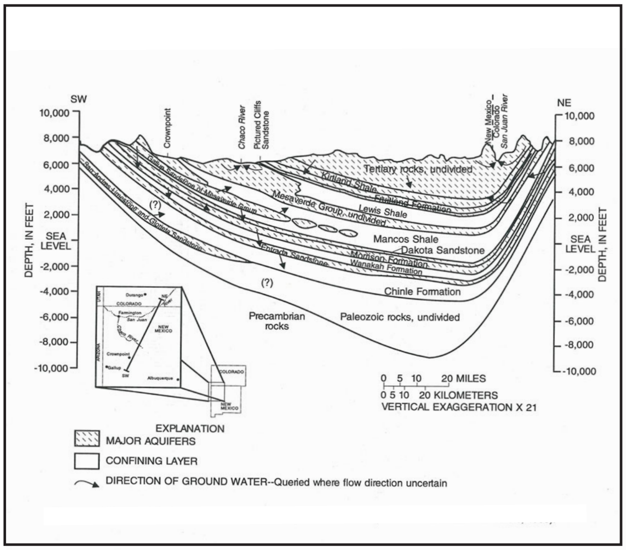

Figure 4. Hydrogeologic cross section through the San Juan Basin (modified from Dam, 1995; originally from Stone and others, 1983).

The San Juan Basin contains rocks of Precambrian through Quaternary age. Rocks of Precambrian age are overlain by maximum thicknesses of geologic units of Cambrian through Quaternary age that exceed 14,000 feet and represent a series of terrestrial and marine depositional environments (Stone and others, 1983). Geologic units that contain major aquifers within the basin include the undivided rocks of Tertiary age; the Kirtland Shale, Fruitland Formation, Pictured Cliffs Sandstone, Mesaverde Group, Gallup Sandstone, and Dakota Sandstone of Cretaceous age; The Morrison Formation and Entrada Sandstone of Jurassic age; and the San Andres Limestone and Glorietta Sandstone of Permian age (Stone and others, 1983).

Ground water recharge to the San Juan Basin takes place primarily through streambed infiltration and infiltration of precipitation in the basin-margin outcrop areas (Kernodle, 1996). Cross-formational flux in the basin is generally thought to be small (Frenzel, 1982; Dam, 1995). Total ground water recharge to the basin is about 85,700 gpm (138,300 ac-ft/yr) (Kernodle, 1996).

All the major aquifers in the basin contain areas of freshwater. All major aquifers in the basin, with the exception of the aquifer contained in the Gallup Sandstone, also contain saline water (San Juan Water Commission, 2003). Water with salinities of 3,000 to 10,000 mg/L occupies geologic units of the basin from about 500 feet to about 5,500 feet below land surface (Kelly, 1974). Water salinity typically increases basinward from outcrop areas and with increasing depth (Stone and others, 1983). Substantial areal variations in water salinity occur within the basin (Stone, 1992).

Transmissivities of aquifers in the San Juan Basin cover a wide range of values but generally lie between 5 and 4,000 ft^2/d (Stone and others, 1983; Kernodle, 1996). Reported yields to wells range between 1 and 500 gpm (Kelly, 1974; Kernodle, 1996) with locally greater yields possible (Hale and others, 1965). Aquifers containing saline water in the basin may yield from 100-500 gpm to wells (Kelly, 1974).

Roswell Basin

The areal extent of the Roswell Basin varies depending on the definition of its boundaries. The legal boundary of the Roswell Groundwater Basin includes 10,799 mi^2 of southeastern New Mexico (Pecos Valley Water Users Organization, 2001). The extent of the basin as defined by the presence of its principle aquifer (Fig. 1) is approximately 2,170 mi^2 (Welder, 1983). Additional definitions exist which yield various estimates of basin area (Welder, 1983). Figure 5 shows a hydrologic cross section representative of the basin.

The Roswell Basin has a complex history of erosion and sedimentation extending from Paleozoic through Cenozoic time. The result of this history is 4,000 to 5,000 feet of unconsolidated sediments and sedimentary rocks in the basin representing a variety of marine and non-marine depositional environments. The sedimentary rocks contain the well-developed geologic section of Permian age characteristic of much of southeastern New Mexico (Fiedler and Nye, 1933; Morgan and Sayre, 1942; Mourant, 1963; Havenor, 1968; Welder, 1983). The principle aquifer of the basin is contained in the upper part of the San Andres Limestone and the lower part of the overlying Artesia Group, both of Permian age. The principle aquifer is often referred to as the artesian aquifer. Alluvial

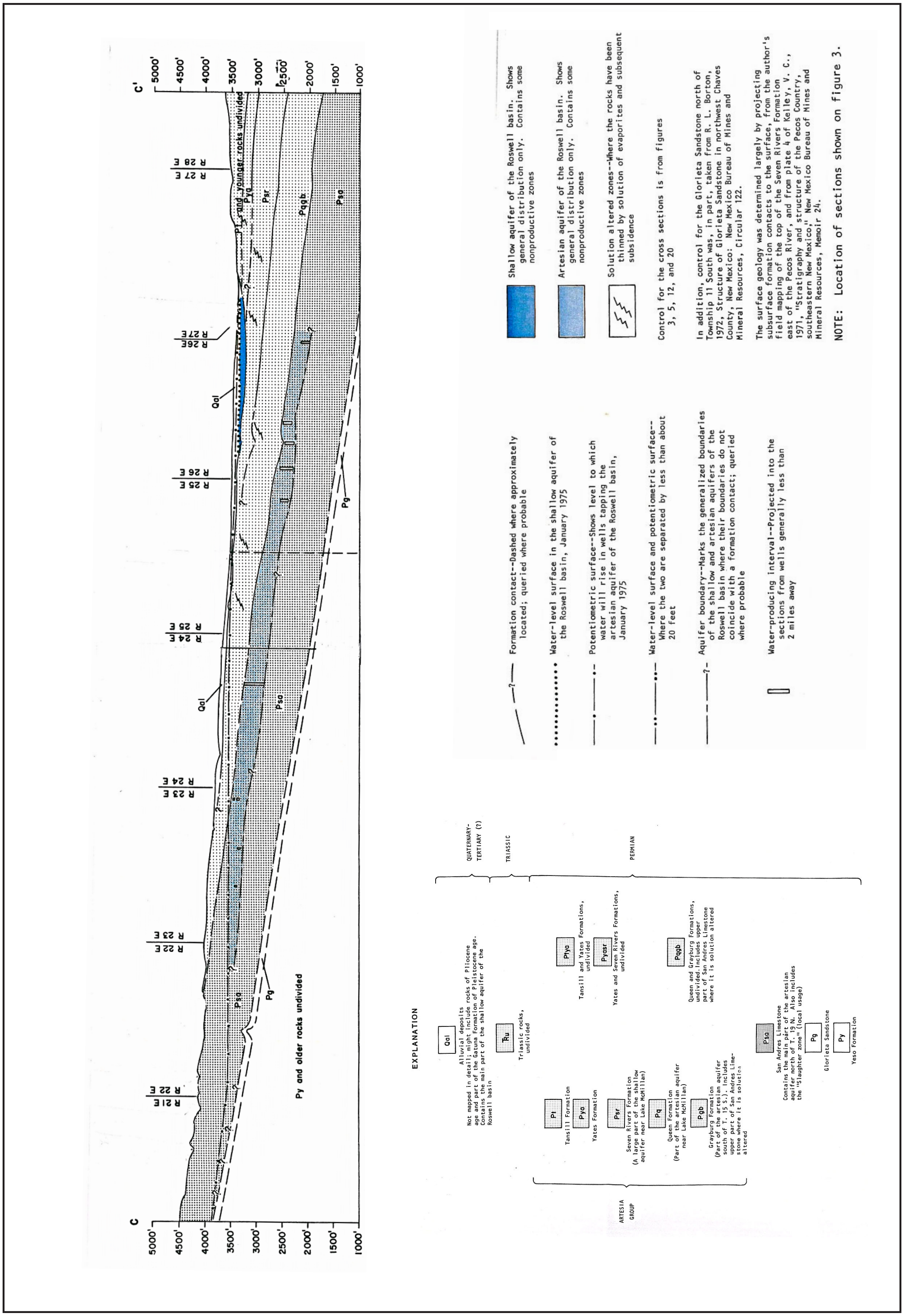

Figure 5. Hydrogeologic cross section through the Roswell Basin (modified from Welder, 1983.)

sediments of Quaternary age also contain an aquifer in the basin. The aquifers are separated by the Artesia Group that acts as a leaky confining unit (Havenor, 1968; Saleem and Jacob, 1971; Welder, 1983). The Yeso Formation and Glorietta Sandstone, both of Permian age, may also contain aquifers useable for the production of saline water.

Fisher (1906), Fiedler and Nye (1933), and Morgan (1938) completed early studies on the geohydrology of the Roswell Basin. Ground water recharge enters the aquifer contained in the alluvial deposits by direct infiltration of precipitation on the basin floor and by infiltration of surface water. Ground water recharge enters the principle aquifer from infiltration of precipitation and infiltration of surface water on the outcrop in elevated areas west of the basin (Fiedler and Nye, 1933; Theis and others, 1942; Mourant, 1963; Saleem and Jacob, 1971). Saleem and Jacob (1971) estimated average recharge to the principle aquifer to be approximately 240,000 ac-ft/yr between 1903 and 1968. Hydrologic modeling indicates that about 2 million ac-ft of water was depleted from storage in the principle aquifer between 1926 and 1968 (Saleem and Jacob, 1971).

The principle aquifer in the Roswell Basin contains both saline and fresh water. The eastern margin of the basin is marked by a facies change in the San Andres Limestone near the Pecos River from carbonate to evaporite and siliciclastic sediments (Morgan and Sayre, 1942; Welder, 1983). Ground water salinity increases in association with this facies change. Saline water has migrated westward into freshwater areas of the principal aquifer in response to hydraulic gradients created by ground water withdrawal (Hood and others, 1960; Hood, 1963). This induced lateral migration of saline water demonstrates the interconnected nature of fresh and saline ground water systems in the principle aquifer. Water having dissolved solids concentrations of 3,000 to 10,000 mg/L occupies geologic units within the basin from about 500 to 1,500 feet below land surface (Kelly, 1974). Water having dissolved solids concentrations of 10,000 to 35,000 mg/L occupies geologic units within the basin starting between about 500 and 3,000 feet below land surface and extending to about 3,500 to 6,000 feet below land surface (Kelly, 1974).

Transmissivity of the aquifer in the alluvial deposits of the Roswell Basin averages about 13,000 ft^2/d with specific yields of 0.10 to 0.20. Estimated transmissivities of the principle aquifer range between 800 and 187,000 ft^2/d (Theis, 1951; Hantush, 1957). The distribution of transmissivity in the principle aquifer is largely controlled by the distribution of dissolution-enhanced secondary porosity. Porosity enhancement took place through dissolution of carbonate rock on movement of large quantities of freshwater through the aquifer during periods of subareal exposure in Permian and Pleistocene times (Fiedler and Nye, 1933). Relatively less is known about the hydraulic characteristics of the remaining rocks of Permian age (Wasiolek, 1991). However, Kelly (1974) estimates that yields to wells of 100 to 500 gpm can be expected from saline water bearing aquifers.

Capitan Aquifer

The Capitan and Goat Seep Limestones along with the Carlsbad Facies of the Artesia Group make up an arcuate band of stacked and adjoining limestone facies that collectively form the Capitan aquifer in New Mexico (Fig. 1). The lithofacies forming the Capitan aquifer of New Mexico represent the shelf-margin facies of a carbonate shelf complex deposited during Permian time (Meissner, 1972). Figure 6 shows a hydrologic cross section representative of the Capitan aquifer. Aquifer thickness ranges from a few hundred to approximately 2,000 feet (Meissner, 1972; Hiss, 1975). The width of the aquifer varies, in part, as a function of which formations and facies are included. The width of the Capitan Limestone was reported by Dunham (1972) to be slightly less than 5 miles.

Hiss (1975) systematically studied the hydrology of the Capitan aquifer. Recharge to the Capitan aquifer in New Mexico comes from infiltration of precipitation in elevated terrain on the western side of the aquifer; from leakage from underlying, overlying, and adjoining geologic units; and infiltration of surface water (Bjorklund and Motts, 1959; Hiss, 1975; Richey and others, 1985). The dominant modern-day ground-water-flow pattern is from the west toward the Pecos River (Hiss, 1975).

Generally, freshwater occurs in the Capitan aquifer of New Mexico west of the Pecos River (Hiss, 1973; 1975; 1976). The distribution of fresh and saline water correlates with the history of fresh ground-water

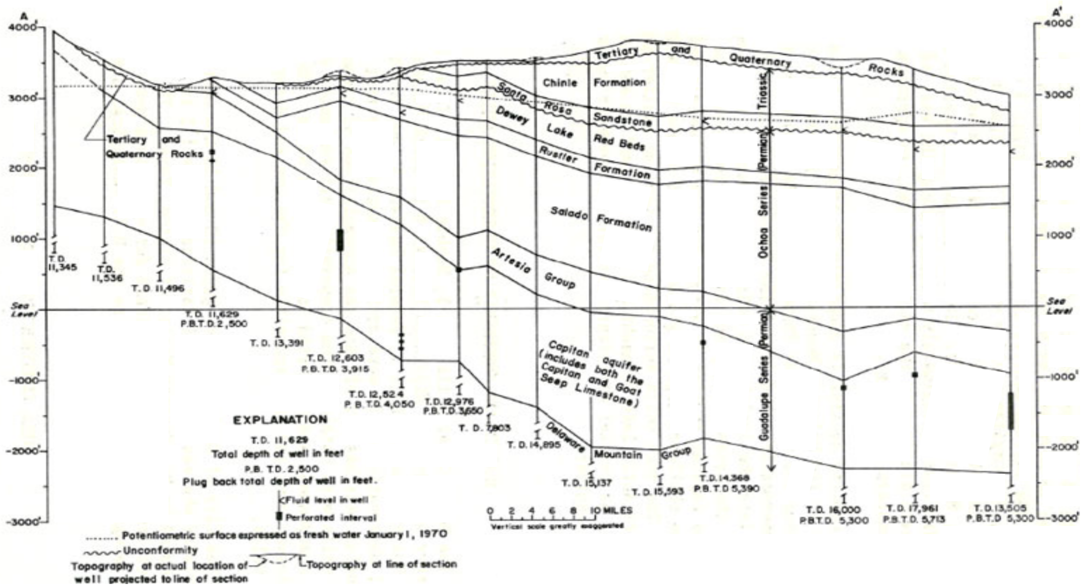

Figure 6. Hydrologic cross section through the Capitan aquifer (modified from Hiss, 1973.)

movement through the aquifer. Two major episodes of flushing of the part of the aquifer west of the Pecos River with freshwater are recognized; one in late Permian time and one in Pliocene-Pleistocene time. Periods of subareal exposure of the aquifer led to both flushing episodes. Flushing of the part of the aquifer west of the Pecos River, while removing a large amount of possibly connate saline water from the aquifer, also enhanced the porosity and permeability of the aquifer through dissolution of carbonate material (Gail, 1974; Hiss, 1975). Modern-day saline water in the aquifer west of the Pecos River could be, in part, the result of interformational leakage (Hiss, 1975; Richey and others, 1985). Extensive flushing of the aquifer with freshwater has likely not occurred in areas east of the Pecos River. Saline water in the aquifer east of the river is likely either connate or derived from interformational leakage (Hiss, 1975). Water having dissolved solids concentrations of 3,000 to 10,000 mg/L occupies the Capitan aquifer in New Mexico from between land surface and about 5,000 feet below land surface extending to about 1,200 to 6,200 feet below land surface (Kelly, 1974). The relatively lower porosity of the aquifer east of the Pecos River may limit the amount of recoverable saline water in storage in the aquifer (Leedshill-Herkenhoff and others, 2000). Depths to saline water in the aquifer east of the Pecos River range from greater than 300 to greater than 1,000 feet below land surface (Hiss, 1973).

Hydraulic conductivity of the Capitan aquifer in New Mexico ranges from 1 to 25 ft/d west of the Pecos River and averages about 5 ft/d east of the river. Transmissivities may be as much as 10,000 ft^2/d in thicker parts of the aquifer that have well–developed porosity (Hiss, 1975). The portion of the aquifer containing saline water may yield up to 500 gpm to wells (Kelly 1973). Huff (1997) summarized available porosity, permeability, and aquifer test data for the Capitan aquifer of New Mexico.

Estancia Basin

The Estancia Basin covers about 1,500 mi^2 of central New Mexico (Fig. 1). Figure 7 shows a geologic cross section representative of the basin. The basin was formed by tectonic events in late Pennsylvanian to Permian time, late Cretaceous to Eocene time (Laramide Orogeny), and Oligocene to Holocene time. The most recent tectonic event is associated with formation of the Rio Grande Rift (Barrow and Keller, 1994).

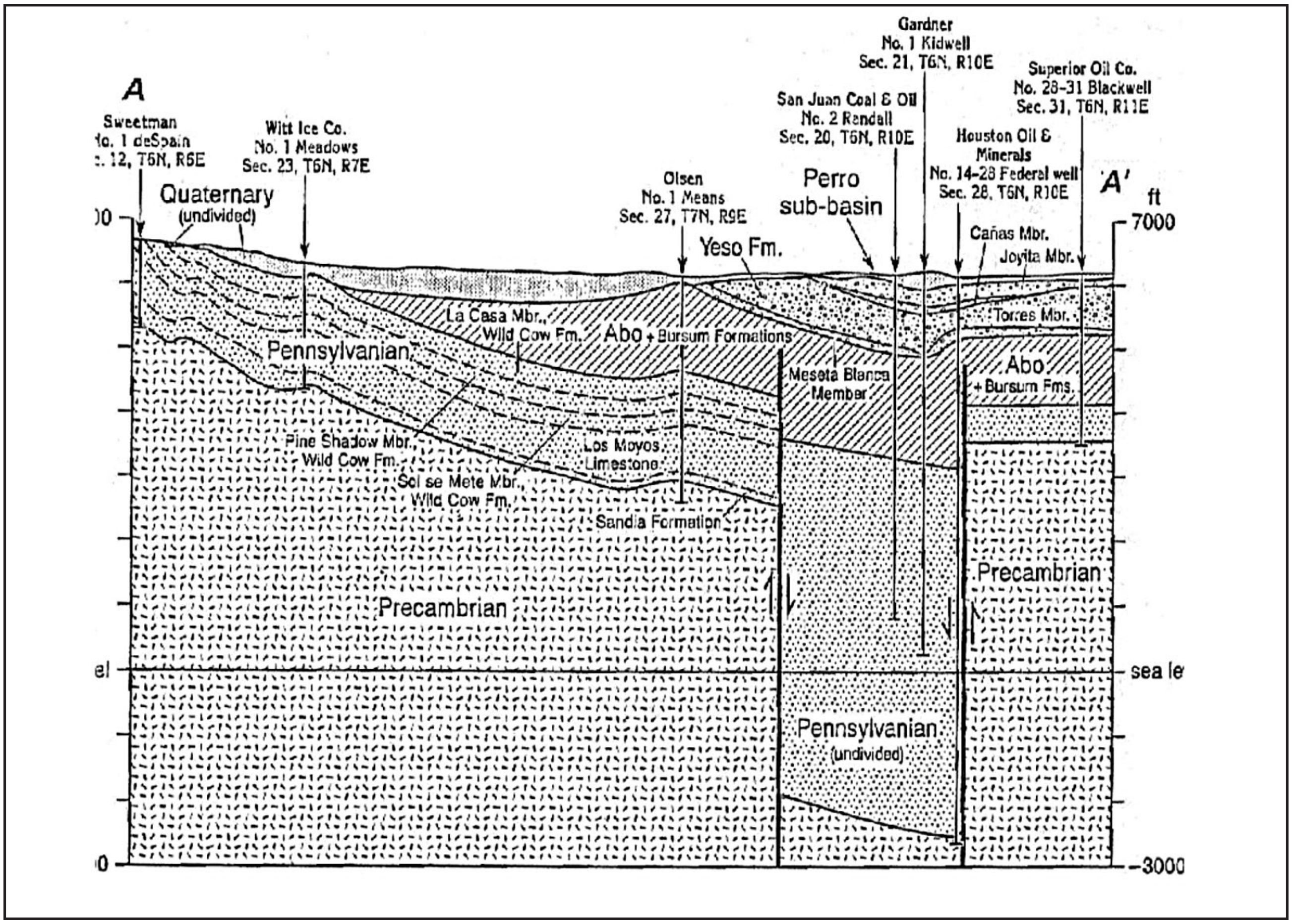

Figure 7. Geologic cross section through the Estancia Basin (modified from Broadhead, 1997).

Rocks of Precambrian age on the western side of the Estancia Basin are covered by up to 1,000 feet and on the eastern side by up to 8,500 feet of sedimentary rocks of Pennsylvanian to Permian age (Broadhead, 1997). Sedimentary rocks of Permian age in the central part of the basin are overlain by 300-400 feet of alluvial, lacustrine, and dune deposits of Tertiary to Quaternary age. The sediments of Tertiary to Quaternary age make up the valley fill deposits (Broadhead, 1997). Major aquifers within the basin are contained within geologic units of Pennsylvanian age (Madera Group), geologic units of Permian age (the Yeso Formation and the Glorietta Sandstone), and within the valley fill deposits of Tertiary to Quaternary age (White, 1994).

Meinzer (1911) initially investigated the hydrology of the Estancia Basin. Ground water recharge comes dominantly from infiltration of precipitation in mountains rimming the western side of the Estancia Basin (Titus, 1969; White, 1994). An unpublished estimate of ground-water recharge to the basin of 37,774 ac-ft/yr is cited by Shafike and Flanigan (1999). Hydrologic modeling suggests that approximately 2 million ac-ft of ground water was depleted from the basin between 1940 and 1996 (Shafike and Flanigan, 1999).

All the major aquifers in the Estancia Basin contain areas of fresh water. Generally, ground water salinity in the northern half of the basin increases as water moves basinward from the basin margins (White, 1994). Ground water salinity may follow a similar pattern in the southern half of the basin. Smith (1957) discussed the presence of saline water in geologic units of Permian age. Water with salinities of 10,000 to 35,000 mg/L occupy geologic units within the basin from land surface to about 500 feet below land surface extending to about 8,000 to 8,500 feet below land surface (Kelly, 1974). Hawley and Hernandez (2003) have begun a reevaluation of the saline water resources of the basin.

The presence of fractures and areas of dissolution-enhanced porosity largely control the hydrologic properties of aquifers in the Madera Group and the Yeso Formation (Smith, 1957; Jenkins, 1982). Estimates of transmissivity for the aquifer contained in the Madera Group range from 20 to greater than 1 million ft^2/d (Jenkins, 1982). Yields to wells have been reported as about 5 gpm from the aquifer contained in the Madera Group, 15 to 500 gpm from the aquifer contained in the Yeso Formation, greater than 1,000 gpm from the aquifer contained in the Glorietta Sandstone, and greater than 500 gpm from the aquifer contained in the valley fill deposits (White, 1994). Aquifers containing saline water may yield up to 500 gpm to wells (Kelly, 1974).

Tularosa/Salt Basin

The Tularosa and Salt basins together cover approximately 7,750 mi^2 of south central New Mexico (Fig. 1). Though hydrologically different, their proximity suggests they be discussed together as a potential source of saline ground water.

The Tularosa Basin covers approximately 6,500 mi^2 of south central New Mexico (Orr and Myers, 1986). Figure 8 shows a geologic cross section representative of the Tularosa Basin. The basin was formed by tectonic events over the last 10 million years associated with development of the Rio Grande Rift in southern New Mexico (Adams and Keller, 1994).

Consolidated rocks of Paleozoic and Mesozoic age are overlain by approximately 2,000 to 8,000 feet of sediments of Cenozoic age in the Tularosa Basin (McLean, 1970). Sediments of Cenozoic age range from coarse-grained alluvial deposits rimming the basin margin to fine-grained lacustrine deposits near the basin center. The major aquifers in the basin are contained in the basin-margin alluvial fans (McLean, 1970; Orr and Myers, 1986).

Meinzer and Hare (1915) initially investigated the hydrology of the Tularosa Basin. Ground-water recharge comes from infiltration of precipitation in the topographically elevated areas rimming the basin (Burns and Hart, 1988; Risser, 1988; Morrison, 1989; Huff, 2005). Estimates of total recharge to the basin include 143,000 meters cubed per day (m^3/d) (42,300 ac-ft/yr) (Huff, 2005) and 86,400 ac-ft/yr (Livingston Associates and John Shomaker and Associates, 2002). Hydrologic modeling indicates that approximately 101,500 m^3/d (30,000 ac-ft/yr) of ground water left the basin through evapotranspiration under 1995 conditions (Huff, 2005).

Generally, fresh ground water in the Tularosa Basin occurs only in alluvial fans that rim the basin. Ground-water salinity generally increases basinward from the basin rim and generally increases with depth (McLean, 1970; 1975; Thompson, 1984; Orr and Myers, 1986). The basin contains at least 90 million and perhaps over 400 million ac-ft of saline water having dissolved solids concentrations of 35,000 mg/L or less (McLean, 1970; Livingston Associates and John Shomaker and Associates, 2002). Only approximately 2 percent of saturated basin-fill deposits contain water

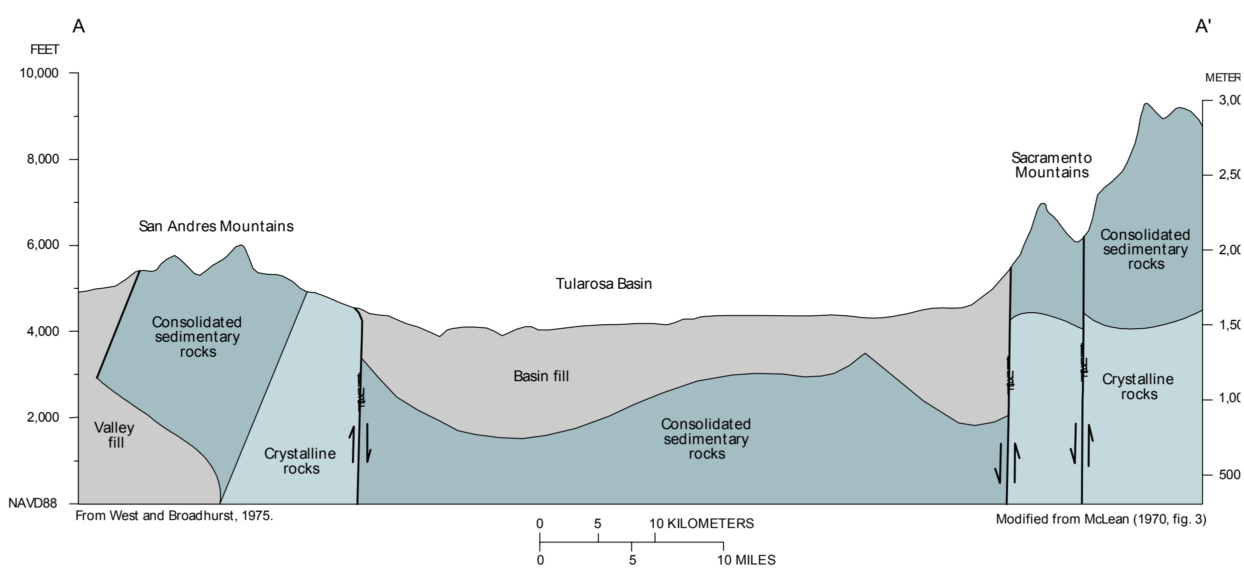

Figure 8. Geologic cross section through the Tularosa Basin (modified from West and Broadhurst, 1975; originally from McLean, 1970).

having dissolved solids concentrations of 35,000 mg/L or less (McLean, 1970). Data from Livingston Associates and John Shomaker and Associates (2002) suggest that approximately 25 percent of the water in the basin having dissolved solids of 10,000 mg/L or less may be recoverable.

Transmisivity of aquifers contained in alluvial fan deposits that rim the Tularosa Basin can exceed 10,000 ft^2/d. Transmissivity generally decreases basinward (Burns and Hart, 1988; Orr and Myers, 1986; Morrison, 1989). Typical specific yields of aquifers contained in the alluvial fan deposits range between 0.08 and 0.12 (Burns and Hart, 1988; Morrison, 1989). Parts of the aquifer containing saline water may yield up to 500 gpm to wells (Kelly, 1974).

Relatively less is known about the hydrogeology of the Salt Basin compared to the Tularosa Basin.The Salt Basin covers approximately 1,250 mi^2 of south central New Mexico. Major aquifers in the basin are contained in alluvial deposits of Quaternary age and in the 'bedrock aquifer' contained in the San Andres Limestone and the Yeso and Abo Formations, all of Permian age (Livingston Associates and John Shomaker and Associates, 2002). Ground water recharge occurs by infiltration of surface water and infiltration of precipitation (Livingston Associates and John Shomaker and Associates, 2002).

The Salt Basin contains approximately 31 million ac-ft of saline water having dissolved solids concentrations of 5,000 mg/L or less. Approximately 90 percent of this saline water is contained within the 'bedrock aquifer' which typically yields 50 gpm or less to wells (Livingston Associates and John Shomaker and Associates, 2002). Reported yields to wells from the aquifer contained in the alluvial deposits range from 10 to 3,800 gpm (Bjorklund, 1957).

SUMMARY

Increasing demand on limited potable ground water supplies in New Mexico has stimulated interest in saline water resources. Successful development of saline water resources in New Mexico will require information on the geohydrology of aquifers containing these resources. Substantial saline ground-water resources are contained within aquifers in the Albuquerque Basin, aquifers in the San Juan Basin, aquifers in the Roswell Basin, the Capitan aquifer, aquifers in the Estancia Basin, and the aquifers in the Tularosa/Salt Basin of New Mexico. Hydrogeologic characteristics of and the amount of saline water stored in these aquifers vary widely.

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Mike Hightower *is on the technical staff in the Energy Security Center at Sandia National Laboratories. He is a civil and environmental engineer with more than 25 years experience with research and development projects including structural and geomechanics research in support of space and weapons systems, research and evaluation of innovative environmental technologies for industrial and nuclear waste treatment and cleanup, and security and protection of critical infrastructures. Currently, Mike supports research and development projects addressing water and energy resource sustainability, and water and energy infrastructure security and protection issues and concerns. These efforts include developing new water treatment and water monitoring technologies, developing models and techniques to improve water resource use and management, desalination and produced water treatment, impact of water availability on energy security and reliability, and water, electric power, and natural gas infrastructure security and protection. Mike holds bachelor's and master's degrees in civil engineering from NMSU. He serves on the Executive Committee of the New Mexico Pollution Prevention Technical Resource Center, and is president-elect of ASME's Environmental Engineering Division.*

TULAROSA BASIN NATIONAL DESALINATION RESEARCH FACILITY DESIGN AND CONSTRUCTION UPDATE

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BACKGROUND

Access to fresh water is an increasingly critical national and international issue. Demand for fresh water in many regions of the world has already outstripped supply. Saline and brackish waters constitute over 97 percent of the water in the world. Supplementing fresh water supplies through cost-effective "revolutionary" desalination technologies could provide significant relief to the limited fresh water resources in many parts of the world.

To address the development of the "next generation" of desalination technologies needed to realistically impact future fresh water supplies, a federal partnership between Sandia National Laboratories and the Bureau of Reclamation was established by Congress in 2001 to evaluate and coordinate the development of a brackish ground water desalination research facility in the Tularosa Basin of New Mexico. While significant efforts have been devoted to address coastal or seawater desalination issues, no facilities currently exist in the United States to address the unique research needs, such as system performance and environmental impact, of desalination and effective utilization of brackish ground water in inland areas.

Therefore, the role of the Tularosa Basin desalination research facility is to become a national and international leader in the research, testing, evaluation, and demonstration of novel technologies for cost-effective ground water desalination and environmentally sound concentrate management.

ADVANTAGES OF THE TULAROSA BASIN

The ground water resources of the Tularosa Basin have been extensively studied for decades. The basin has extensive brackish ground water resources and has over 100 million acre-feet of recoverable brackish ground water. Within a 5-mile radius of several potential facility sites, water with salinity from 1000 ppm total dissolved solids (TDS), almost fresh water, to over 20,000 ppm TDS, almost as salty as sea water, is available. A wide range of water chemistries including sodium chloride, carbonate, and sulfate-based brine waters also exist in the basin.

The relatively easy access to these types of brackish ground water provides an opportunity to evaluate new desalination technologies over a wide range of water chemistries and water qualities in one location. Additionally, the Tularosa Basin is one of the world's leading areas of wind, solar, and geothermal energy enabling the assessment of renewable energies to help reduce future desalination energy needs, one of the biggest costs for inland desalination.

FACILITY STUDY DESIGN

An Executive Committee of water resource and desalination experts from around the country and large municipal water agencies from the Southwest was formed in January of 2002 to help guide in the evaluation of potential facility sites and identify the research attributes of the proposed desalination research facility. The conceptual facility design and location evaluations were focused on developing a facility to effectively conduct activities to support national and international research and education on inland brackish ground water desalination, concentrate management and reuse, and renewable energy research related to inland desalination.

Based on several evaluation criteria, including water availability, access to utilities, site costs, and ability for future growth, a site in the southwest part of Alamogordo, New Mexico near the intersections of US Highway 70 to Las Cruces and US Highway 54 to El Paso was proposed for the research facility. The recommendations from the Executive Committee were published in a Facility Study Report to Congress in September 2002.

Based on that report, Congress appropriated initial funding to begin final design of the Tularosa Basin National Desalination Research Facility in January 2003. Laguna Construction was selected by the Bureau of Reclamation as the construction manager and general contractor for the desalination research facility. Laguna subcontracted with Malcolm Pirnie for the final design of the facility. As part of the facility design process, the Bureau of Reclamation established a facility design review team from their Denver office to oversee the detailed facility design. The Executive Committee also supported the final design efforts by providing overall feasibility and useability perspectives during the design review process.

The final design was started in June 2003, with two different major elements, the water supply system including wells, storage, and piping, and the facility design. Water well drilling started in October 2003 and was completed in March 2004. The 90 percent design review for the facility was completed in April 2004. Based on the final facility design and water supply well construction, the general facility capabilities include:

Facility Location Features

- Within Alamogordo city limits and near existing utilities,
- Site location for easy access to saline and brackish waters of 2000, 4000, and 6000 ppm TDS,
- Access to Alamogordo water reuse line for treated water utilization,
- 40-acre site to allow for future expansion and concentrate and renewable energy applications, and
- Good access and visibility from major highways.

Facility Design Features

- Five site wells providing approximately 400 gpm water capacity from different producing zones,
- About 16,000 square-foot building for desalination research, that includes:
  - 6 research bays for pilot-scale desalination testing at up to 30 gpm each,
  - Office space for operations staff and visiting

researchers,
  - Control and conference rooms,
  - Areas for bench-scale system testing,
  - Water laboratory, and areas for equipment maintenance and chemical storage, and
  - A resource and learning area for visitors
- Three large outdoor research pads for larger-scale desalination system testing,
- 4-5 acres for evaluation of renewable energy desalination applications,
- 4-5 acres for concentrate disposal and minimization,
- 4-5 acres of concentrate reuse for agricultural applications, and
- Site layout designed for self-guided visitor tours of all research areas.

FACILITY CONSTRUCTION AND OPERATIONAL SCHEDULE

The Groundbreaking for the Tularosa Basin National Desalination Research Facility took place on Tuesday, June 29th, 2004. Representatives from the Bureau of Reclamation, Sandia, Laguna Construction, the City of Alamogordo, and Senator Domenici's staff spoke at the ceremony. Figure 1 shows the groundbreaking event with local dignitaries. The groundbreaking drew almost 150 attendees representing a diverse group of organizations including state and federal water agencies, water utilities, government officials, and Executive Committee members.

Site construction is ongoing, with plans to have all utilities and outdoor test pads installed by January 2005. This will be enable the facility to start testing a large portable desalination system in January 2005 that is being developed by the Office of Naval Research for possible expeditionary force applications. To meet the needs of the Navy system, all the source water wells for the facility will be utilized. Testing of the Navy system should last for 3-4 months. The funding for the facility construction needed by the Navy for their operations and testing is currently in place.

Construction of the research facility building is scheduled to begin in October 2004 and will continue through approximately April 2005. Funding for this phase of the project is expected in Congress's 2005 budget appropriations. The possibility of an FY2005 continuing resolution may impact the expected April 2005 facility opening date. Initial facility operations will be provided through FY2005 as part of an expanded design/build/operate contract. Operations of the facility following the initial operational capability in FY2005 will be through an operations and management contract renewed on an approximately 5-10 year basis.

John Stomp, III *was born and raised in Albuquerque and graduated with bachelors and masters degrees in civil engineering from UNM, and is a Registered Professional Engineer in New Mexico (#12015). He was recently appointed Acting General Manager of the Albuquerque Bernalillo County Water Utility Authority. The Water Authority provides water and wastewater services to more than 450,000 residents in the metropolitan area. At this time, John will continue his role as Manager of the Water Resources Programs including water conservation, water resources, groundwater protection and arsenic investigations. His primary responsibility is to implement the City Council adopted Water Resources Management Strategy to provide a safe and sustainable water supply for the City. The strategy includes making the transition from sole reliance on groundwater to renewable surface water supplies, namely, the City's San Juan-Chama water. The project includes the construction of more than $275 million in facilities consisting of a new surface diversion, water treatment plant, and distribution pipelines. He is also responsible for evaluating issues related to compliance with the new drinking water standard for arsenic. John has more than 16 years of experience dealing with water and wastewater issues in New Mexico and throughout the southwestern U.S.*

ALBUQUERQUE WATER REUSE INITIATIVES

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It's good to see so many familiar faces out in the audience today. I think most of us characterize ourselves as the usual suspects at the water conferences. Karl Wood and WRRI have been very generous to the City of Albuquerque in the past by allowing us to share some of the projects we have going on in Albuquerque and I wanted to thank WRRI upfront.

Today I want to talk about the water reuse initiatives in Albuquerque and I'm going to focus on one particular area of concern. When we started to develop reuse, one of our projects was the interface between the City's diversion and the flows in the Rio Grande; specifically, the flows and effects on the Middle Rio Grande Conservancy District.

I think everybody knows that in the 1960s, Albuquerque had a very simple water supply plan: we would pump water from the aquifer, the river would re-supply the aquifer, and we would pay the river back with San Juan-Chama Project water. In the early 1990s, we learned from the USGS that the aquifer is much smaller than we thought and the river was not directly connected with the aquifer. We would never use our San Juan-Chama water because the river would never leak enough to cause depletion requiring the City of Albuquerque to discharge or release San Juan-Chama water to offset those effects to our return flows.

Everyone has seen the map on Figure 1 over the years but I would like to point out that the map has changed. During the brief time that I've been Albuquerque's water resource manager, we have seen the aquifer change and now there is a cone of depression on the west side. We have always focused heavily on the cone of depression located on the east side of Albuquerque and it covers quite a large area, an area of about 40 sq miles and it has dropped about a 150 ft or so. We have known that the aquifer on the west side was much smaller and much more confined than the east side, and now we are showing the same level of drawdowns and the same effect from our pumping on the west side as we did on the east side.

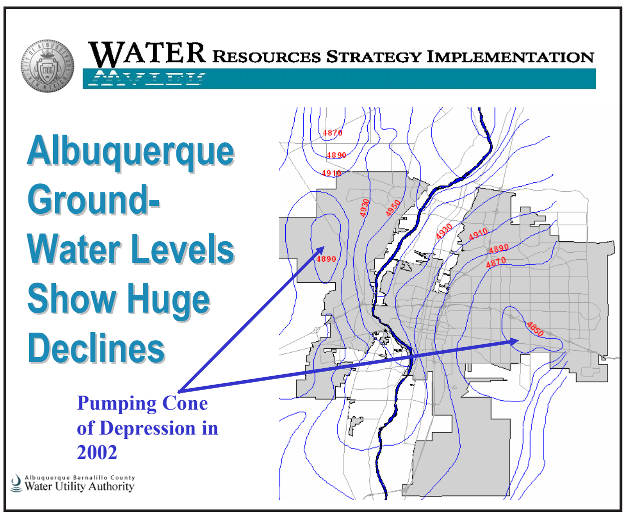

Figure 1.

The USGS developed a groundwater flow model to predict what would happen in Albuquerque if we continue pumping to the year 2060, even while reaching our original 30 percent conservation goal. Figure 2 shows the results of heavy drawdowns and land surface subsidence as predicted on the east and west sides of Albuquerque. I see Larry Webb from the City of Rio Rancho in the audience and I'm sure he doesn't want to hear this, but depletions in the Rio Rancho area are also predicted by the same groundwater flow model. The area encompasses about 90 sq miles of the City of Albuquerque on the east side and the Taylor Ranch area on the west side.

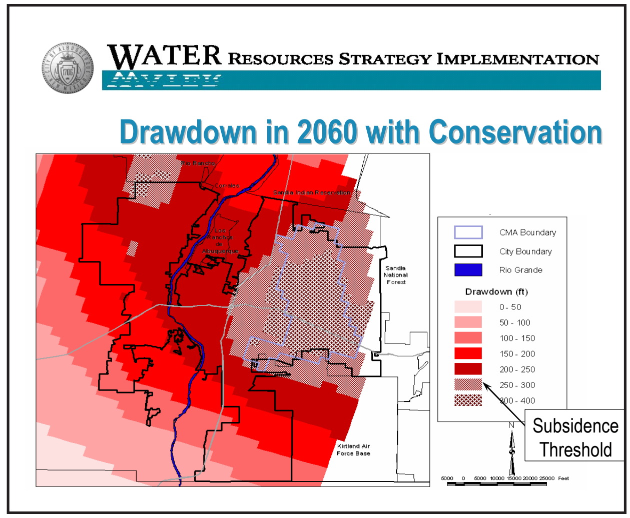

Figure 2.

We are looking at future groundwater depletions and land surface subsidence over the next 40 to 50 years. The USGS published a report last year showing that we are starting to see a response to the City's pumping right now. Figure 3 indicates a small area in purple on the east side of Albuquerque that represents a cone of depression, where we are starting to see the land surface above the pumps respond to our pumping. It has only dropped about 7.5 mm during a peak summer time period and 7.5 mm is hardly measurable, but the point is that we are looking at many years into the future and saying that if we continue to pump, we will have land surface subsidence. It is 60 years down the road and maybe 40 years, but it's not that far away and we are beginning to see that land surface subsidence even now. This is always a bit of surprise to many people.

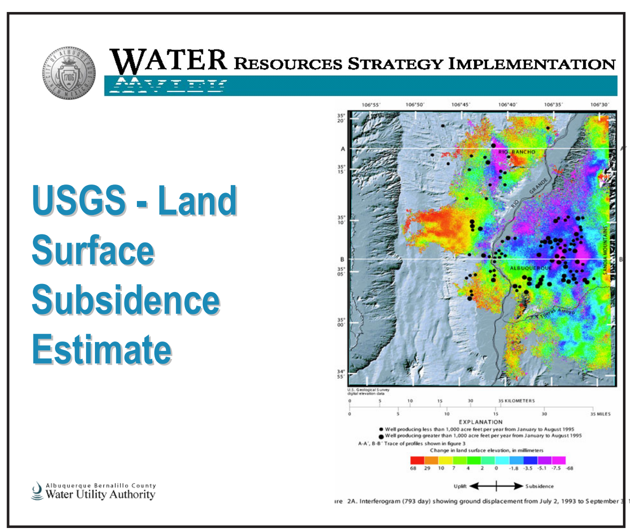

Figure 3.

Our original conservation goal was established in 1995 and our new water goal is to go to a 40 percent conservation reduction goal. The original goal was 30 percent over 10 years and we are in the last year of our 10-year plan. At the end of 2003, we had reached a conservation reduction of about 28%. This year we have pumped 1.2 billion gallons less than we did last year, so we are probably going to be able to say pretty soon that we have met our 30 percent goal, although we know the weather changes frequently and you hate too step out and predict it too quickly. The question now is how we are going to meet our 40 percent goal. We have established a new conservation committee and it will look at what our next steps should be. Everyone is saying that we have already picked the low-hanging fruit, we've done all the easy stuff, and we've had a lot of incentive programs. What will happen when we go to mandatory measures?

Figure 4 is a picture of our water supply plan. The red area is our *Aquifer Drawdown*, the water coming out of storage that causes our drawdowns. Our *Renewable Groundwater* drives some our groundwater hydrologists insane because, after all, "What is renewable groundwater?" We could argue about that sometime, but the key issue now is to show how the City is transitioning away from groundwater for its water supply. We are moving to our San Juan-Chama water, which we are calling *Surface Water We Own*. *Reuse and Recycling* may look like a small slice, but in fact it is not really all that small. If you add together all the large turf areas in Albuquerque in the transition to renewal supply, they account for about 12 percent of our total consumptive use, so it is not such a small piece.

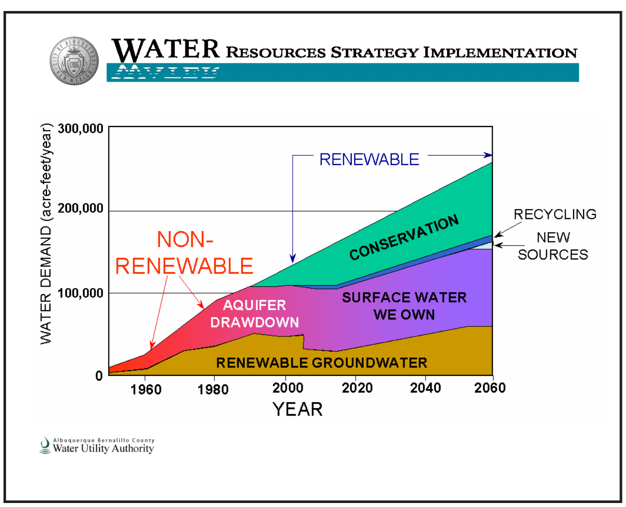

Figure 4.

Most people are aware of our San Juan-Chama Project (Fig. 5). The Reuse Project in the north I-25 area will use a combination of the Colorado River water that we own and industrial reuse water.

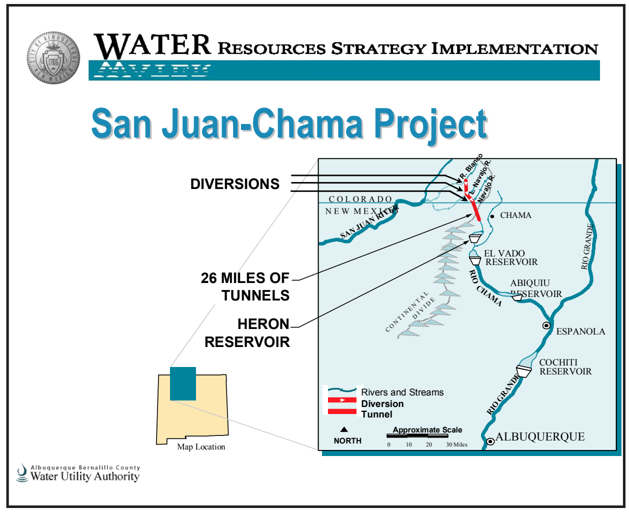

Figure 5.

Our projects to use renewable supplies include: (1) Industrial Water Recycling and Nonpotable Surface Water Reclamation; (2) Southside Water Recycling, and (3) the Drinking Water Project. The first two are reuse and recycling projects while the last one is the big one, the drinking water project, the San Juan Chama Project.

The North I-25 Corridor Reclamation/Reuse Project is an industrial reuse project. In the past, industrial water was purified, used for chip rinsing, and then discharged down the sewer. In 1998, someone came up with the idea of using the discharge water to irrigate Balloon Fiesta Park. The project has been operational since 2000 and now the park is all grass. For a few years, we took effluent from Sumitomo and Philips but since Philips is gone now, we are using discharge from Sumitomo.

The next phase of the project is to take San Juan-Chama water from the river. On Figure 6, the red star locates the diversion that is currently being built. If you have been out to the river at the Alameda Bridge, you can see the reuse facility sitting right on the side of the river. The entire project will cost about $25 million and all infrastructure for the project will be completed by the end of this year. We flipped the switch to begin operation last June and the City of Albuquerque started consumptively using its San Juan-Chama water last year. We were supplementing industrial reuse last year with some San Juan-Chama water.

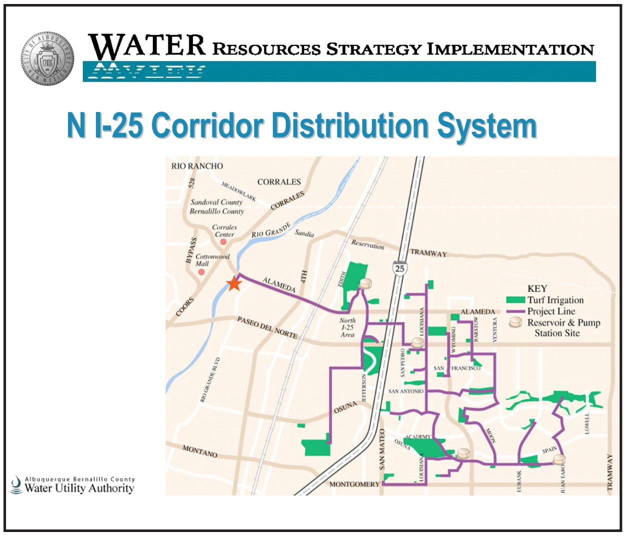

Figure 6.

The primary demand for reuse water is turf irrigation and industrial reuse including cooling towers, concrete production, and fire protection. Total reclaim water demand in the North I-25 Project is about 4,000 acre-feet a year. Originally we hoped to get about 3,000 acre-feet of San Juan-Chama water with about 1,000 acre-feet of reuse water from the industries and combine them to feed all the large turf areas in the Northeast Heights, basically north of Montgomery and in the north valley.

We established water quality standards and have agreements with Philips and Sumitomo on the quality of water they can discharge into the City's system. Because we are applying non-potable water, we had to obtain groundwater discharge permits from the state's Environment Department allowing us to land-apply the industrial reuse water. You would not imagine the regulations and how scared people are of water quality issues. When dealing with Philips, we were asked what would happen if acid were to get into the system. I told them that if Philips discharged acids into the system and it killed all the grass at Balloon Fiesta Park, people would be coming after me, not them. The fact of the matter is that the industrial process was actually separated: Philips and Sumitomo both invested about a million dollars between the two of them to separate completely and isolate their flows so no crossover or changeover could ever occur. The standards developed call for 750 mg/L of TDS so we could keep our ratio at about 4. We had to put limits on fluoride as they use hydrofluosilic acid for chip rinsing.

We are taking non-potable surface water from a new diversion on the river and I'd like to focus on some of the technical aspects of the project because it is a very interesting project in terms of analyzing the effects of the new caisson and new horizontal collector and the diversions we have placed underneath the river just off the Alameda Bridge and the effect on the river as well as on the Middle Rio Grande Conservancy District (MRGCD) facilities. We took borings about every tenth of a mile or so along both sides of the river from Rio Bravo all the way up to Alameda. We analyzed the borings, put together a field investigation and testing plan, drilled a temporary well, conducted testing to begin to characterize the aquifer, determined conductivities, and determined how much water we anticipated getting out of the project from the top 80-100 feet or so. We did additional soils work to characterize the soil and did some sonic borings around the site, specifically around where the caisson was located.

We developed a new groundwater flow model because the USGS model was too big with a grid area about a mile by a mile. I am not going to pretend to be an expert on the model, but it was called the Microsym groundwater flow model. The model looks at the facilities and characteristics in the area like the river and the drain. We developed the model to use as a predictive tool. We used an aquifer test to calibrate the model and used the results of this test to start formulating hydraulic conductivities both horizontal and vertical to try and figure out at what depth to stick the horizontal collectors and how big they should be.

Figures 7 and 8 depict the actual facilities that were built. A radial-collector that the City just built exists where the pump station is now. It is a 30-foot diameter casing that goes down 60 feet. Eight different arms come out of the caisson; only six are shown here, but there are two other arms that stick out underneath the river. South of the radial collector, buried 30 feet into the river, is the horizontal collector that has a well screened. We use the model to predict how much water we will be able to pump. We have a peak demand of about 10 mgd so we have looked at how we can meet that demand. We also used the model to determine the effect of pumping on the Bosque. What is the effect of the drawdown? What about the trees associated with the river around the drain? Would we have impacts outside the river in shallow aquifer home wells located around the facility?

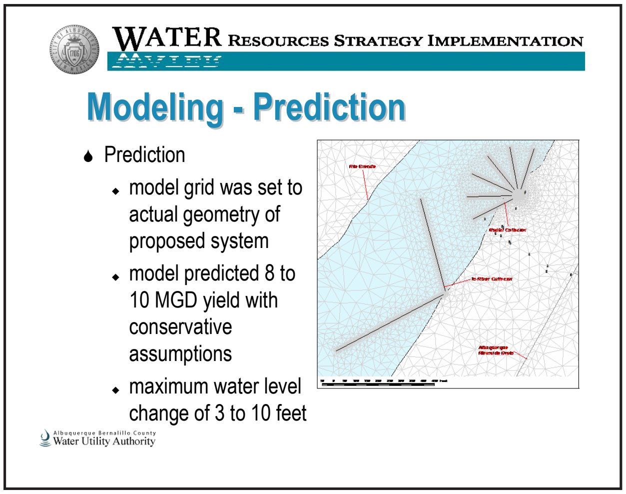

Figure 7.

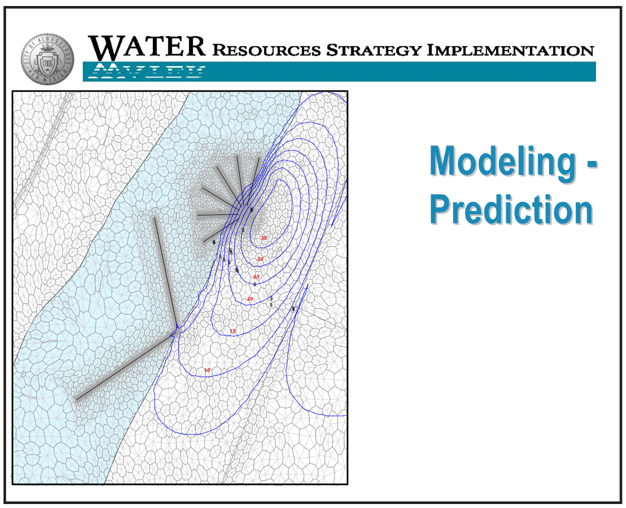

Figure 8.

One of the key issues was to try to develop the percentage and quality of the water coming out of the drain and out of the river. The MRGCD was specifically concerned about this. We modeled the effect of the drain, the facility, how much water would be coming from the drain, and how much water would be coming from the river. I'm happy to report that 90 percent of the water comes from the river and 10 percent comes from the drain, corresponding to the prediction we made when we did the original aquifer test. The scale on the left of Figure 9 is in cubic feet per day (CFD). The graph with percentages shows the same result: 90 percent comes from the river and 10 percent from the drain.

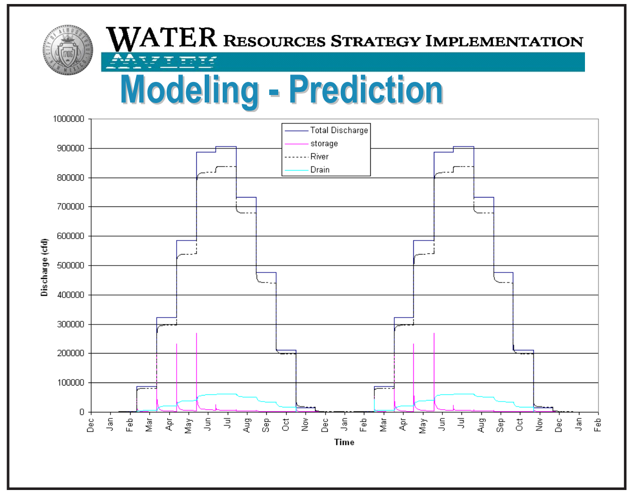

Figure 9.

Figure 10 is a picture of the caisson. The construction was very interesting because we were in groundwater at the time. The construction company, Rainy Collector Wells, came out and drilled in the middle of the winter and had to pour concrete at the bottom in 60 feet of water. We hired a diver who went down into the water, we dropped beams on top of him, and of course he was in the dark. Imagine this guy getting beams from above, placing the beams at the bottom, and then having concrete poured on top of the beams. Like I said, it was a really interesting construction project. We were told by the construction guys, who happened to be from Minnesota, that the water was the coldest they had ever been in.

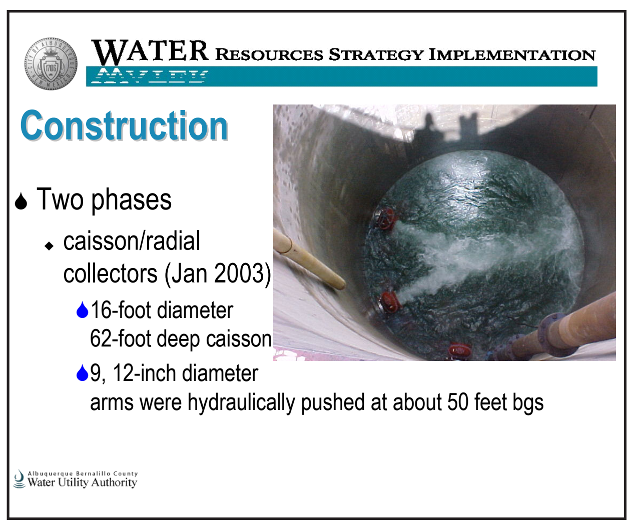

Figure 10.

One of the key issues to talk about is the silvery minnow. While building the San Juan River Project, we crossed the river with 254-inch diameter lines. We had to build a portable dam in the river to enable us to build half at a time in order to allow the river to flow. Staff from the Department of Fish and Wildlife was out there collecting silvery minnows and other fish that might get stranded once we placed the portable dam. We did the same thing for the horizontal collector arms. In fact, if you were out at the site a few months back, you would have seen the portable dam in the river.

Our original testing of the radial collectors found we could get about 2,500 gallons per minute (gpm) out of the collectors themselves (see Fig. 11). We then tested the horizontal collectors in an effort to make sure we paid the contractor to do what the consultant had designed. We got what we paid for. The final tests indicated we can get about 8,200 gpm from a combination of the radial collector well and the horizontal wells, which is about 10 mgd at peak day. Everything worked out even through there was a lot of sweating along the way.

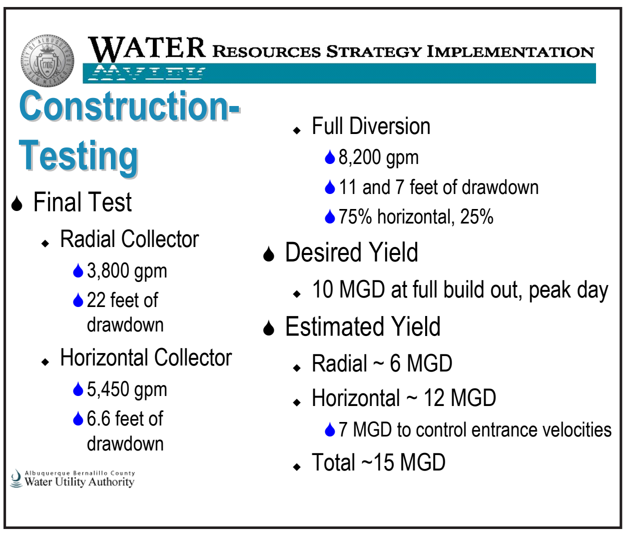

Figure 11.

Some brief construction costs of the caisson include the following. If anyone is interested, I'll be glad to give you individual construction costs.

Combined Costs:

- General - $1.140 M
- Pump Station - $1.95 M
- Radial Collector - $1.5 M
- Horizontal Collector - $1.8 M

Another project we are working on is the reuse project at the Southside Water Reclamation Plant (Figs. 12 and 13). The plant will use effluent from the wastewater treatment plant and will serve all the large turf areas in the Southeast Heights and the South Valley including the Puerto Del Sol Golf Course, UNM Championship Golf Course, Acoposo Power, located on Broadway, Mesa Del Sol, and a whole host of large turf areas and industrial uses.

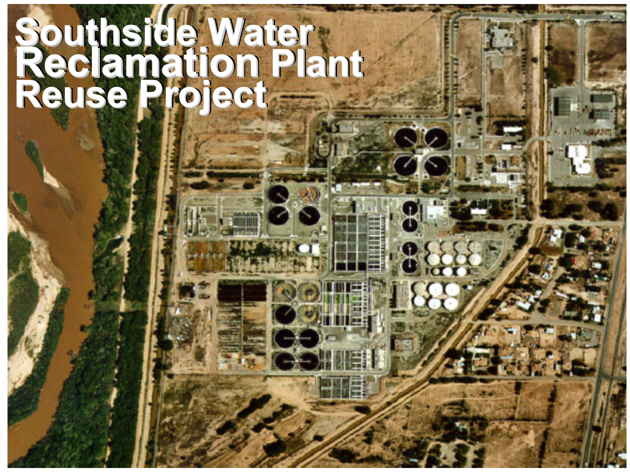

Figure 12.

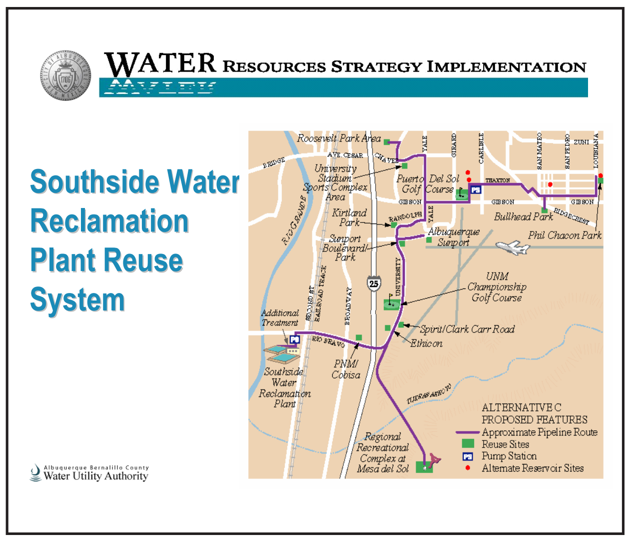

Figure 13.

Before the Environment Department had standards for reuse water, the City developed its own standards. We combined standards from California and Texas to come up with our own standards for the kind of water quality we wanted out of the reuse water. This was a very important effort because as we developed these standards, a lot of economic development opportunities presented themselves to Mesa Del Sol over the years. It has been advantageous from an economic development opportunity standpoint to know how much water is available as well as the water quality that we can predict coming out of the plant.

Our water quality criteria look like this:

Recommended Albuquerque Reclaimed Water Standards

pH range (S.U.)	BOD (mg/L)	TSS (mg/L)	Turbidity (NTU)	Fecal coliforms (cfu/100ml)	Chlorine Residual (mg/L)
6.0-9.0	5	5	2	Non-detect	1

The criteria are consistent with the Environment Department's regulations that have come out in the last couple of years.

The Project will provide about 5.5 mgd (maximum) or about 2,400 acre-feet of water per year. It is currently under design; we will start construction in December or January, and estimate that it will be complete in about a year. The North I-25 Project will also be completed by next year.

We performed a cost-benefit analysis as required by the Bureau of Reclamation when you utilize Title 16 funding. The Southside WRF Reuse Project will cost $16,000,000 in capital costs and $200,000/year in Operation and Maintenance costs, which comes to $6,700 per acre-foot. We drew the line at about $7,000 per acre-foot. Any large turf area outside this $7,000 per acre-foot was not considered economical, at least at this initial stage. When fully constructed, there will be approximately 35 miles of pipeline ranging in size from 24-inch to 4-inch in diameter and will include four storage reservoirs and five pump stations.

We have one other project in Albuquerque and that is an effort to transition the shallow groundwater use in the Albuquerque core area, the downtown and zoo area, where we have contaminated shallow groundwater. We want to use impaired shallow groundwater for irrigation at the bio-park, the zoo, and some other areas downtown. We will also be cleaning up our shallow groundwater resources in the area. The cost estimate for the project is $2 million. We are looking at combining this water with Fruit Avenue Plume, Superfund cleanup water, to provide a reuse water source for downtown Albuquerque.

Question: I'm Ari Michelson. You gave the $6,700 per acre-foot of water figure. How does this compare with your other water supply options?
Answer: We are purchasing water rights at about $5,000 or $6,000 an acre-foot right now, but that is just the cost of the water right. The $6,700 includes the infrastructure. When we originally did this, we were actually at about $3,500 an acre-foot. If you add this to the $3,500 infrastructure costs, you get the $7,000. The cost would be much higher now since water rights have gone up astronomically over the last few years; it would most likely be about $10,000 an acre-foot right now.

Question: The State Engineer, in approving your diversion project permit, set certain conservation and reuse considerations as conditions of approval. Are you going to be able to meet the State Engineer's requirement in that regard?
Answer: If you haven't seen the City of Albuquerque's Drinking Water Project Department, you should. I believe it will be the wave of the future. The State Engineer has put specific criteria that must be met with a number of significant points in the permit. One such criterion is that the City of Albuquerque attains its 175-gallons per person per day water conservation goal before we are allowed to divert the combination of native and San Juan-Chama water. Before we can take a drop of native water, we must meet the 175-gallons per person per day goal. Of course, there is some ambiguity in terms of how you calculate the 175-gallons per person per day. Everyone in this business knows that you never know the actual population served by your system, so it's kind of a guess. The answer to your question is, yes, in the initial phase. In the second phase, the State Engineer added to the permit approval that the City of Albuquerque reach a 155-gallon per person per day use within 20 years. Our goal is actually more aggressive than this requirement. Everybody understands that water use in New Mexico fluctuates from year to year. It will be very interesting to see what mandatory measures come along between now and the 20-year goal of meeting the155-gallon per person per day. Right now, our conservation plan has been primarily incentive based although we have penalties and fines that will probably change slightly over the next ten years.

Thank you very much.

__Richard N. Arnold__ is an NMSU Associate Professor of Weed Science in the Department of Entomology, Plant Pathology and Weed Science, and has been with the Agricultural Science Center at Farmington, New Mexico since 1980.

PRODUCED WATER TREATMENT PROGRAM: A COOPERATIVE EFFORT

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Farmington, NM 87401

I guess everyone wants to know why a weed scientist would be producing water-related work in the San Juan Basin on coal pressed methane produced water. Funding is not very good in weed science. We decided to veer a bit from our usual research with funding from the Bureau of Land Management (BLM), the oil and gas industry, and Sandia Labs. We have started some work on coal bed methane produced water to try to get grass seedlings, native and non-native, to establish quicker than they have in the last few drought years.

In the next 10 years, approximately 10,000 wells will be drilled in San Juan County, according to the BLM office. That means that 15,000 to 20,000 acres of land will be disturbed and reseeded areas will only get about 7 inches of annual rainfall, maybe 8 inches per year, and usually at the wrong time. We need to find ways to use our produced water. We must determine how much total dissolved solids (TDS) can be present before restricting seedlings growth. I am not a chemist but I'll do the best I can.

We looked at a couple of wells in the fall of 2003 and another one in 2004. The first we looked at was produced at Williams 159-A in the Rosa area about 90-95 miles from the experiment station. It takes about two hours to get there because the road is really rough, but that is where they wanted to locate it. Table 1 shows our results.

Produced Water Williams 159-A (Soil) Fall 2003

	pH	EC (mmhos /cm)	Ca (ppm)	Mg (ppm)	Na (ppm)	SAR	Tex
Before Sample	7.32	3.39	291	66.8	533	7.32	loam
After Sample	7.53	5.12	341	79.7	725	9.17	loam
Spring Sample	7.86	2.52	36	6.8	540	21.6	Silt loam

Table 1.

We took soil samples before and after and the bottom row gives results for a spring sample taken in an area adjacent to the well site on the same plot where we planted varieties of grass to see if Mother Nature would bring them up. Please pay attention to the SAR (sodium adsorption ratio) value for that soil. Our "before sample" had a soil pH of 7.32, EC (electrical conductivity) measured in mmhos/cm of 3.39, calcium (Ca) of 291 ppm, magnesium (Mg) of 66.8 ppm, sodium (Na) at 533 ppm, and a SAR value of 7.3 ppm. Most of the crops we grow in this country will not grow in the 7.3 ppm SAR range or an EC of 3. For example, alfalfa is usually around 1 SAR and the same is true for dry beans.

If we look at the "after sample," after water was applied, we get a pH of 7.53, a slight increase in pH, an increase in EC of about 2, both Ca and Mg increased, Na jumped to 725 ppm, and SAR went to 9.17. The texture of both samples was a loam.

In the spring sample, where we did not use the produced water, just Mother Nature, the pH was 7.86, a lower EC than the others, but a SAR of 21.6. This was a quite alkaline type soil. Later I will show you the Indian Ricegrass growing at that site.

In the fall of 2003, we again tested the water (Table 2). Remember that a barrel of water is 42 gallons and we used a 400-barrel tank that was located at the site and we pumped the water on with sprinklers. We applied water on August 13th and 19th and September 17th and 23rd, using 1.12 inches each time. The reason we only used about 1¼ inches was because the soil would not take more; it was pretty compacted and although I used a tractor to try to loosen the soil before planting, we could only get that amount of water on before it would start to run off. Thus, we applied basically 160 barrels per application, totaling 640 barrels, at 42 gallons per barrel.

Williams Prod Rosa 159-A Produced Water Schedule Fall 2003

Date	Amount of Produced Water Applied		
8-13-03		1.12 in	160 bar
8-19-03		1.12 in	160 bar
9-17-03		1.12 in	160 bar
9-23-03		1.12 in	160 bar
Total		4.48 in	640 bar

Table 2.

Table 3 shows results from the August/September analysis. In August we have a pH of 8.5 and in September a pH of 8.0, averaging 8.25. What was the TDS of that water? On August 19 it was 5540 mg/l. We only have two samples because we could not apply 400 barrels at once; every time we filled a 400 barrel tank, we took a new water sample.

Produced Water Analysis for W. Rosa 159-A Fall 2003

Date	pH	TDS mg/l	SAR	EC (mmhos/cm)
8-19-03	8.5	5440	71.1	16.1
9-17-03	8.0	10682	122.4	17.4
AV.	8.25	8061	96.7	16.8

Table 3.

The sample date of August 19 shows a TDS of 5440, SAR of 71.1, and very salty water with an EC of 16.1. You do not want an EC over 15. Our goal was to get a TDS of 8,000, which we got close to when averaging the two samples.

In 2004, we also looked at a well site (242-A) of ConocoPhillips. For those unfamiliar with Farmington, the site is on Middle Mesa, which lies between the two rivers that flow into Navajo Lake. It is located close to Colorado and they have had some problems with their water, also. At NAPI, where they do have wells on the Navajo Indian Irrigation Project, some wells are running 45,000-50,000 TDS, are on sandy soils, require a lot of water, and fertilizer is probably adding to some of the dissolved solids.

On Table 4, look at the "before sample" in the soil with a pH of 7.67, EC of 3.37, Ca of 324, Mg of 75, Na of 422, and a SAR of 5.49. That is a pretty good soil that is not bad for the grasses we are going to plant. After we put the water on the soil, we got a pH of 7.76. We did not run out there after the application to take the sample but waited for 2 or 3 weeks for the soil to dry in order to get a good sample. The EC went up a bit, CA went down, Mg went down, there was a slight increase in Na, and a SAR of 7.4. Both samples are from loams.

Produced Water ConocoPhillips 242-A Soil, 2004

	pH	EC (mmhos/cm)	Ca (ppm)	Mg (ppm)	Na (ppm)	SAR	Tex
Before Sample	7.67	3.37	324	75	422	5.49	loam
After Sample	7.76	3.59	282	61	526	7.4	loam

Table 4.

On April 28, 2004, at the ConocoPhillips site, we applied produced water and followed that with applications on May 10 and 18 (Table 5). On this site, we could apply one 400-barrel tank at one time because the soil was able to hold that much water; it is a very good soil, a bit rocky and somewhat porous. About 2.5 inches was applied each of three times, 400 barrels at a time. We were able to apply 7.5 inches of produced water on this sample versus only 4 inches on the Williams soil.

ConocoPhillips 242-A Produced Water Schedule

Date	Amount of Produced Water Applied	
4-28-04	2.5 in	400 bar
5-10-04	2.5 in	400 bar
5-18-04	2.5 in	400 bar
Total	7.5 in	1200 bar

Table 5.

We took water samples three times, each time we got pH readings ranging from 8.17 to 8.47, with 8.12 the lowest pH. TDS results ranged from just over 3600 to 4020, averaging 3836, very close to 4000. SAR results were very high, averaging 69. EC was basically in the mid-6's, averaging 6.81 (Table 6).

ConocoPhillips 242-A Water Analysis, 2004

Date	pH	TDS mg/l	SAR	EC (mmhos/cm)
4-28-04	8.17	3640	66.7	6.31
5-10-04	8.47	4020	75.7	7.17
5-18-04	8.12	3850	65.0	6.95
AV.	8.25	3836	69.13	6.81

Table 6.

Table 7 shows the varieties of grasses we decided to plant. I was born and raised on a farm in Farmington, went to high school there, and I've always wanted to work with grasses. Through the years, I have told people to raise San Jose Tall Wheatgrass wherever they have irrigation water and a high alkaline soil. It seems to do very well in soils high in alkalinity and with a pH up around 8 and 9. I was curious to try some other varieties of grasses at the Experiment Station to see how they would grow given enough water to germinate. We could watch them for a couple of years while applying an inch of water a month during the summer months to stress the grasses a little bit.

Most of the varieties of what we planted are included on Table 7. We had 32 varieties and chose 16 to plant. Paloma Indian Ricegrass is a very good native grass in this area.

Varieties Planted

Arriba Western Wheatgrass	Chief Inter. Wheatgrass	Luna Pubsc . Wheatgrass	Hy Crest Crested Wheatgrass
Canada Wild Ryegrass	Bozoisky Russian Wild Ryegrass	Critana Thicksike Wheatgrass	Bottle Brush Squirreltail
Redondo Arizona Fescue	Paloma Indian Ricegrass	Anatone Bluebunch Wheatgrass	Junegrass
Four-Wing Saltbush	Covar Sheep Fescue	San Luiz Slender Wheatgrass	Needle and Threadgrass

Table 7.

Figure 1 shows what we did with some of the funding I mentioned. Even the truck was included in the funding. We bought a pump with about 7.5 horsepower, 3-inch in/3-inch out. We simply bring a line from the tank to the pump and then set the lines out. The sprinklers, 9/32s, are adjustable. The pump will handle this size; if we go any smaller than that, we have trouble getting the sprinklers to work because of the coarseness of the water. So we went one size bigger to the 9/32s. The sprinklers are spaced 30 feet apart and irrigate only the plot; we tried to keep all the water on the grass seedlings.

Figure 1. Williams Rosa 159-A showing pump and 400 barrel tank

Figure 2 shows produced water being applied on Williams Rosa 159-A at about the time we were ready to shut off the sprinklers.

Figure 2. Produced water being applied on Williams Rosa 159-A on 8-19-03

Everyone wondered what in the world I was doing planting corn. "That's not going to last more than a year," it was predicted. What I wanted to show in Figure 3 is the salt content of the soil and that corn did all right. It is sweet corn, by the way. It was quite interesting to see that corn would grow in some of this salt-infected soil.

Figure 3. Williams Rosa 159-A showing corn tolerance to produced water

Figure 4 shows existing plant growth in the plot area, Williams Rosa 159-A. The grass shown was already there. It has no yellowing, nor chlorosis, nor salt burning. It is located in an area where salt water pooled. I believe the grass is Arriba Western Wheatgrass, which is a native grass.

Figure 4. Williams Rosa 159-A showing existing plant growth in plot area

Figure 5 shows Williams Rosa 159-A in 2004 when we took these photos. This is the area that was irrigated with the 8000 TDS. The top left photo shows Arriba Western Wheatgrass coming through, while on the right is Bozoisky Russian Wild Ryegrass. The bottom left photo shows Canada Wild Ryegrass and the right bottom photo is Hy Crest Crested Wheatgrass. When we chose these varieties, we wanted to pick some that would be palatable to most domestic animals and wildlife. One of them is not shown here, Bottle Brush Squirreltail. That grass does not seem to be as palatable as the others but we planted it anyway because it has to be in the BLM mix.

Figure 5. Top left: A. Western Wheatgrass; Top right: Bozoisky Russian Wild Ryegrass; Bottom left: Canada Wild Ryegrass; Bottom Right: Hy Crest Crested Wheatgrass

Figure 6 shows Paloma Indian Ricegrass planted in the spring 2002. We only had about 7.5 inches of moisture that year. This picture was taken on October 8, 2003. The soil has an EC of 2 and a SAR of 21.6. The Indian Ricegrass did fantastically well. Right now the Ricegrass is almost knee-high, flowering, and producing seed.

Figure 6. Williams Rosa 159-A showing Paloma Indian Ricegrass planted spring 2002, picture 10-8-03, EC 2.52. SAR 21.6

Figure 7 shows ConocoPhillips in the spring of 2004 and the soil conditions where we applied 7.5 inches of produced water with 4000 TDS.

Figure 7. Plot Area

At the top left of Figure 8 is an alfalfa variety called Ameristand 801 and is salt tolerant. It will grow in some high alkaline soils. It is a new variety that just hit the market a couple of years ago and some farmers do not know about it yet, but it does grow in highly salty soils. We also looked at Western Wheatgrass, just barely coming up; Bottlebrush Squirreltail is doing well; and Canada Wild Ryegrass.

Figure 8. Top left: Ameristand 801S Alfalfa; Top right: A. Western Wheatgrass; Bottom left: Bottlebrush Squirreltail; Bottom right: Canada Wild Ryegrass

Figure 9 shows other grasses at ConocoPhillips 242-A including Anatone Bluebunch Wheatgrass. Hy Crest Crested Wheatgrass looks like it will go ahead and come through and San Luiz Slender Wheatgrass is also doing very well.

Figure 9. Top left: Anatone Bluebunch Wheatgrass; Top right: Hy Crest Crested Wheatgrass; Bottom: San Luiz Slender Wheatgrass

Our research plans for 2005 include possibly using produced water of approximately 8,000 to 12,000 mg/l TDS on two sites in the spring. We try to keep consistent by planting in the spring on Middle Mesa because of its close proximity to the Experiment Station. We will continue to evaluate the 2002 and 2003 re-seeded areas.

I want to show you some photos of our reseeding efforts started in 2002 (Figure 10). We had difficulty getting anything to establish at the El Paso Tapasitas pipeline. You can see that Indian Ricegrass is coming in and a lot of Four-wing Saltbush. The El Paso Tapasitas plot on the right shows a lot of Four-wing Saltbush.

Figure 10. Left: El Paso Tapasitas pipeline showing Indian Ricegrass, planted 2002; Right: El Paso Tapasitas Plot area 2002

Figure 11 shows another reseeding area (Williams 159-A) where we applied produced water. The Paloma Indian Ricegrass soil sample was obtained here. Needle and Threadgrass are doing fantastically well, with a SAR of probably 20. Williams Bottlebrush Squirreltail is doing fine as are Russian Wild Ricegrass and Paloma Indian Ricegrass.

Figure 11. Top left: Bottle Brush Squirreltail, 2002; Top right: Bozoisky Russian Wild Ryegrass, 2002; Bottom left: Needle and Threadgrass; Bottom right: Paloma Indian Ricegrass

Figure 12 shows reseeding efforts at ConocoPhillips. We have developed a mix of Slender Wheatgrass, Arriba Western Wheatgrass, Hy Crest Crested Wheatgrass, and Four-wing Saltbush and you can see how the mix is coming up nicely with just Mother Nature and about 7.5 inches of moisture.

Figure 12. Left: ConocoPhillips reseeded site, 2002; Right: ConocoPhillips, reseeded site 2002

Our efforts seem to be showing some promising results. I am not sure whether we should plant in the fall or the spring or whenever we get the chance. We may plant most of our grasses in the summer and just wait for the weather to help us. In recent years, we have been very dry in this part of the country. Just this past week we got an inch of rain on Saturday and Sunday.

Funding and/or technical support for this project has been provided by Williams Production, El Paso Field Services, BP Americas, Burlington Resources, Pure Resources, XTO Energy, ConocoPhillips, BLM/FFO, Four Corners Cattle Association, and Sandia National Labs. I would like to thank them and I would like to thank the Water Resources Research Institute for inviting me to speak today. Any questions?

Question: During the time that you applied the methane produced water, did you have rainfall during that same time period?
Answer: No we did not, not that spring. The grass only received pure produced water. We do have rain gauges set throughout the reseeded area. We can get maybe 10-12 inches of rainfall in the spring and summer, but usually our precipitation comes during the winter.

Question: Is there any concern with putting all that produced water on the surface for irrigation regarding possible pollution to the shallow groundwater systems?
Answer: Not to my knowledge. It is being injected right now into the system. I think we need to look at beneficial use and if Dr. Lee and some of his colleagues at New Mexico Tech can find a way to remove the salt from this water, it will definitely be beneficial.

I know that PNM would like some of that produced water for use in their turbines for the process they use to make electricity. That would be fine because that takes away from some of the domestic water that we use for drinking water out of the river. There has to be a beneficial use for some of the water that is said to be hazardous. Hopefully, we will find ways to use this water.

PANEL: WATER RIGHTS ISSUES OF PRODUCED WATER

__Bill Hume__ was born in Albuquerque and moved to Socorro prior to fourth grade in school. He graduated from Socorro High School, attended the University of New Mexico, with a three-year vacation from 1960-63 spent in the U.S. Army, mostly in southern Germany. Bill started with the Albuquerque Journal in November 1966. He graduated from UNM in the spring of 1967 with a degree in journalism and minors in German language and economics. At the Journal, Bill served as police reporter, general assignment reporter, science and military reporter, state editor, investigative reporter, editorial writer and, for the last 18 years of his tenure there, editorial page editor. On January 1, 2003, he joined the staff of Governor Bill Richardson as director of policy and strategic planning. Bill is married to Elizabeth G. Hume and has two children, a son age 24 and daughter age 19.

__Mark E. Fesmire__ was raised in the area around Cloudcroft, New Mexico. He graduated from the New Mexico Military Institute and spent more than a year on an offshore seismic crew before attending NMSU. After graduating from NMSU with degrees in geological engineering and civil engineering, Mark spent 12 years as a petroleum engineer in the Permian basin. He then went to law school and worked for Criminal District Attorney's offices in El Paso and Lubbock. Mark spent six years practicing oil and gas, environmental, bankruptcy, and criminal law (including representing the defendant in several death penalty murder cases). Mark subsequently moved back to New Mexico and spent five years as the head of the Hydrographic Survey Bureau of the Office of the State Engineer. He has been with the Oil Conservation Division since May of this year.

***Matthew Lavery**, Director of Water Resources, has been an employee of PNM for 27 years, has held numerous positions of increasing responsibility at PNM, and is the developer of the Kirtland, NM Area Produced Water Project. In his current position, he is responsible for the negotiations and procurement of water supplies for the PNM San Juan Generating Station as well as the management of all other water resources for PNM facilities. Matt oversees the engineering and project management services in support of the gas and oil plants as well as other assigned projects. He serves on the Water Development Steering Committee of the San Juan River Recovery Implementation Program, served as a key member on the San Juan Basin Shortage Sharing Principles and Recommendations team, and helped develop and lobby for the passage of a piece of produced-water legislation that passed in the 2004 legislative session. He was a key developer of the San Juan River Selective Fish Passage.*

***Paul Saavedra** is a 1978 graduate of the University of New Mexico with a bachelor's degree in civil engineering. He is a Professional Engineer registered in New Mexico. Paul has been employed by the Office of the State Engineer for more than 25 years. His duties have included Dam Safety Program, National Flood Insurance Program, Acequia Rehabilitation Program, WATERS Program, Water Rights Administration, Hearing Examiner. Paul has been Director of the Water Rights Division for the past seven years.*

__Frank Yates, Jr.__ was raised working in the oil fields around Artesia, New Mexico from the age of fifteen. He earned a bachelor's degree in mechanical engineering from NMSU in 1979 and is a registered Professional Engineer in the states of New Mexico and Arizona. Frank has continued studies in environmental and geosciences and business administration. Currently, he is President of Myco Industries Inc. and a vice president of Yates Petroleum Corporation. Frank is past President of the Independent Petroleum Association of New Mexico and is currently a member of the executive committee of the New Mexico Oil and Gas Association. In addition, Frank has served on many other boards and committees including the boards of First National Bank of Artesia and the Community National Bank of Midland, Texas. Frank is an accomplished multi-engine, instrument-rated pilot with 17 years of experience and more than 2,600 hrs of total time. He enjoys many outdoor sports, primarily snow skiing, but also hiking, golfing, and bicycling. His wife, Mary, is an accomplished business professional. He has three adult children: Tyson, Tao, and Tevis.

PANEL: WATER RIGHTS ISSUES OF PRODUCED WATER

Bill Hume
(moderator)
Director of Policy and Strategic Planning
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I'm Bill Hume, Director of Policy and Strategic Planning for Governor Richardson and before that, longer than I care to remember, I was at the *Albuquerque Journal* where my specialties and interests were water matters and through that path is how I ended up here moderating this panel. I am pleased to be here to participate in what I think will be a very informative discussion on an issue long on backorder in the State of New Mexico water dialog. Here to discuss this topic are Mark Fesmire of the New Mexico Oil Conservation Division, Matt Lavery, of Public Service Company of New Mexico (PNM), Paul Saavedra of the Office of the State Engineer, and Frank Yates of Yates Petroleum Corporation. We approach this topic from the unique viewpoints of agencies and industry.

So when is water not water? When it is produced water. Strictly speaking, that is a fact under New Mexico water law as it has evolved. Produced water is that which emerges from the far depths of oil and gas wells presumed disconnected from the fresh water aquifers and surface water flows. It comes to the surface with a hydrocarbon as a waste product and usually with a witch's brew of contaminants. Historically, its disposition has been a chore and a problem for the oil and gas industry.

Why do I say it is not water? Because the state constitution provides that all waters of the state are the property of the state subject to beneficial use and priority use. If produced water were treated legally as water, oil and gas users might be obliged to obtain water rights to cover their wastewater that they pump up from below the surface. Heck, they might even face the task of putting that water to beneficial use instead of simply disposing of it as a waste product.

So instead it evolved as an issue under the control of the Oil Conservation Division rather than under the Office of the State Engineer. I think both offices were happy to see it go that way, but the story doesn't end there. I was presented with the produced water problem at the Decision-Makers Conference hosted by New Mexico Tech a couple years ago. We were told of the case where the Four Corners Mine serving the Four Corners Power Plant had made a deal to use produced water from an area hydrocarbon producer to water mine roads to suppress dust - tilt. If that produced water were put to beneficial use, dust suppression, it was transmogrified into wet water instead of a hydrocarbon contaminant and thus came under the aegis of the State Engineer. Oil and gas operations would have to acquire water rights to offset their depletions for their very deep wells. The situation was eventually worked out, but this illustrates exquisitely the contrasting legal treatment of water as wet stuff and water as produced water. We have come a long way in the last two years of modifying the law on produced water and in ways to make it usable as an asset instead of a waste product, but produced water like the conclusion of the Da Vinci Code is something people either know a great deal about or very little.

Consequently, we are going to start this discussion with Paul Saavedra with an overview of the history and recent legislation concerning produced water in the New Mexico oil and gas industry. With that background to work from, we will take questions from the audience, comments from the panelists, and, in general, to see if we can improve everybody's understanding of produced water and its evolving place in water use and conservation in the 21st Century.

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Thank you, Mr. Hume. Our panel got into it before we started and hopefully we have something left for you. I want to go over a completely neutral presentation. When I first put the presentation together, I put together arguments the State Engineer uses for produced waters. I then revised the presentation and will try to give you just the issues. I think we will all have something to say afterward.

In 1951 the first disposal well was authorized. In 1956 responsibility for inspection of oil drilling operations was delegated to the Oil Conservation Division (OCD). In 1957 the State Engineer did not require an application for brine water flooding but did for fresh water. OCD in 1959 required a permit for water flooding under Rule #701, and in 1961, OCD was given unquestioned jurisdiction over salt water disposal, and an order for lined pits was issued in 1968.

On April 13, 1967 the State Engineer designated all underground water in the State of New Mexico containing 10,000 parts per million or less of dissolved solids as fresh water. This relates directly to an OCD statute to protect fresh water and the State Engineer designated 10,000 parts per million as fresh water.

As Mr. Hume mentioned, the State Engineer has jurisdiction over the appropriation of public waters for beneficial use and a permit from the State Engineer is required to put water to beneficial use. This is reiterated in the New Mexico Constitution in Article XVI and is also reiterated in the New Mexico Statutes, NMSA 1978, Section 72-1-1 being the main statute, but 72-12-1 is the groundwater statute: "The water of underground streams, channels, artesian basins, reservoirs or lakes having reasonably ascertainable boundaries, are hereby declared to be public waters and to belong to the public and to be subject to appropriation for beneficial use."

The Oil Conservation Division has the authority to make rules and regulations and orders for the purposes and with respect to the disposition of any water that is produced or used in conjunction with the drilling for or production of oil or gas. This is in the New Mexico Statutes, NMSA 1978, Section 70-2-12.

There has always been cross jurisdictional rivalries between OCD and the Office of the State Engineer over produced water. Some of the recent legislation that was passed in 2002 was House Bill 388 that allowed for a tax credit for produced water to be delivered to the Pecos River. Once that water was delivered to the Pecos River, it transferred title over to the Interstate Stream Commission. This statute was passed for the purpose of trying to get water into the Pecos River, to give water to Texas, and to alleviate our problems with the Pecos River Compact. The law does still exist though it has never been used. Many, many problems have been encountered when trying to get it used, mostly regarding the National Pollutant Discharge Elimination System (NPDES) permit for putting water into the Pecos River. The facilities are there, the produced water is there, but the procedure for delivery of the produced water has never been worked out.

This year the main bill, Senate Bill 313, which passed in 2004 and was signed into law, says: "No Permit is required from the State Engineer for the disposition of produced water in accordance with rules promulgated pursuant to Section 70-2-12 NMSA 1978 by the Oil Conservation Division of the Energy, Minerals and Natural Resources Department."

We met with OCD and we are going to cooperate; rather, the State Engineer is going to be part of the process for the promulgation of rules for the oil and gas division. This legislation also spells out exactly what the produced water can be used for: to regulate the disposition of water produced in connection with the drilling for or producing of oil and gas or both. OCD and the new rules and regulations address direct surface or subsurface disposal of the water including: disposition by use in drilling for or in the production of oil and gas, and use in road construction, other maintenance, or other construction.

The OCD has authority to allow use of produced water in the generation of electricity or in other industrial processes, in a manner that will afford reasonable protection against contamination of fresh water supplies designated by the Sate Engineer as fresh water supplies of 10,000 parts per million or less of dissolved solids.

As I said before, the Oil Conservation Division and the Office of the State Engineer have been meeting with each other over the years trying to work out our problems with each other and the cross-jurisdiction. We have had discussions over when oil and gas related water becomes water put to beneficial use, and over whose jurisdiction it is.

We are both interested in understanding the effects on New Mexico rivers by oil and gas production. We both support research aimed at maximizing the usefulness of marginal-quality waters and are seeking solutions that will allow the administrative processes at the state level to make these uses possible.

We both, and I'm speaking for OSE and the Oil Conservation Division, and I'm sure Mark Fesmire agrees with me, realize the emerging technologies and physical realities of produced water, and we support the activities of the New Mexico oil and gas industry and at the same time need to meet the charge of caring for the water rights of the people of New Mexico.

This has been an overview of the conflict between the OSE and OCD over the years and Mr. Hume was right about the mine up in the San Juan Basin. At the time, it was used for gas production; they were pumping out water to get to the gas. The water directly affected the La Plata River so we required an offset. They put in another water pipe line to the river, and they dumped water into the river to offset the effects of pumping out the water for this gas production. About four years ago, we determined that what they were using the water for constituted beneficial use; we did require a permit to use the water and it created a lot of heartache for many people. With that, I'll let someone else talk.

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I think I agree with most of what Paul just said. The one part that I would point out right now is when he read the legislation that said "…the generation of electricity or other industrial processes…" I think he went over 'other industrial processes' kind of quickly. Our position is that it is essentially any beneficial use that you can put the water to. Now we can start by looking at the problem of a set of legislation, specifically, the conflicts between NMSA sections 70 and 72. The biggest thing that stuck out was that if we produce water with oil and gas, as long as we dispose of the water, there is no problem. But if we start putting that water to beneficial use, the water that we are going to have to produce anyhow, suddenly the jurisdiction by the Office of the State Engineer was brought in. So we ended up with a situation where as long as people were disposing of this water, as long as they were getting rid of it, there was no problem. But if they wanted to actually do something with the water, it generated a problem that we felt we had to address. And that was – at least since I have been involved – the idea behind the meetings we have been holding. The OCD actually has, as of Friday when I left the office, a first draft of a set of rules. Some of the things we are going to try to cover in the rules I want to lay out here for discussion: the people who put this water to beneficial use have to understand that the fact that they are putting the water to use will not create a water right in and of itself. The water right still comes under the jurisdiction of the State Engineer. OCD has the right to regulate the disposition of produced water, and that water right, as long as it is produced water, it can be used, but it does not create a water right. The other thing that we need to emphasize in our rules is that once the economic life of that petroleum well ceases to be, the right of the OCD to regulate that water ends. What happens after that, I am not sure, we are still trying to figure out where that goes.

The two points we must emphasize: no water right will be created and once the well ceases to be an economically viable oil or gas well, the jurisdiction of the OCD, because of the definition of produced water in the statute, no longer exists.

With that I think I will turn it over to…

Moderator Hume: One of our panelists is Matthew Lavery who is with Public Service Company of New Mexico and PNM's wish to use produced water in cooling at the Four Corners Plant was a prime mover behind the most recent law. That is one reason we have an interest in their expertise in this area.

Frank Yates, Jr.
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My name is Frank Yates and I am Vice-President of Yates Petroleum Company in Artesia in the southeastern part of the state. Our issues are a little different from what they are dealing with up in the Northwest. First of all I want to say, I am not a lawyer. I used to be an engineer in my past life. Now I know a little bit about a lot of stuff so that is really dangerous. I guess the reason I am here is that we have one of the few pilot facilities in operation in southeastern New Mexico. I use the term "operation" lightly because it has been somewhat sporadic, and having said that, I want to add to what Paul mentioned a while ago about one of the challenges of utilizing the tax credit for delivering water to the Pecos River because it is very technically challenging. So in addition to having to go through the NPDES permit process with the EPA, there are many technical challenges to cleaning up produced water and one of the points I would like to make with respect to that is that it may be quite sometime, perhaps decades, before we see a considerable utilization of produced water for agriculture or other uses like residential uses. Having said that, I would like to also suggest that that is not the reason we undertook this project. As was also mentioned earlier, down-hole disposal of produced water from the oil and gas industry is an extremely expensive process. It is a big expense for our industry. So to the extent that we can reduce our costs for the disposal of produced water associated with oil and gas production, it enhances our ability to produce more oil and gas out of those same wells. And that is good for the economy in the state of New Mexico; it is good for the state's budget, which currently, a quarter to a third of the budget is generated by revenues from the oil and gas industry. I will conclude with those remarks at this point and we will probably have some questions later.

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Good afternoon, my name is Matt Lavery. I am the Director of Water Resources for the Public Service Company of New Mexico. I feel kind of underdressed with these other gentlemen with whom I am sitting up here today. I don't wear a tie because I work for a living. PNM's interest in produced water came about because of a resource shortage that we were facing. In 2002, we were looking at having a 30 percent reduction in available water supplies at the San Juan Generating Station; not the Four Corners Generating Station, which has a senior right over part of the water supply that supplies the San Juan Generating Station. We were the junior water rights user for direct flow rights on the San Juan so we were at the highest risk. No shortage sharing agreement existed at the time and PNM is a 46 percent owner of the San Juan Generating Station and we are the operating agent as well. Eight other organizations stretching into California, Utah, Colorado, and Arizona get power from the San Juan Generating Station. We utilize about 22,000 acre-feet, fully consumptive, out of San Juan River. I think the San Juan River water usage is somewhere around 300,000 acre-feet a year. San Juan supplies about 60 percent of the power supply to PNM's New Mexico customers. Now PNM as a regulated utility is also a monopoly. But the flip side of that monopoly, which is a good thing from a business sense, is that you have an obligation to serve. So regardless of our water situation, we were obligated to serve our customers and provide electricity. That is demanded by the state law that gives us the monopoly powers. We would have to have gone out and replaced power at a premium price, probably with gas generation when APS and PNM were in a 30 percent shortage. Financially, that could have been catastrophic for an organization like the San Juan Generating Station. Thus, our interest in produced water was to diversify our resource base for the supplies of the San Juan Generating Station. Our initial look shows that there was about 8,000 acre-feet of water brought to the surface from oil and gas drilling in the San Juan Basin. Since 1981, the San Juan plant has been a zero discharge plant. We completely recycle and consume all the water on the plant site. We have several million dollars worth of equipment. We have some excess capacity remaining in that equipment. So our initial effort was to go out to see if we could quickly and easily gather that oil and gas wastewater and clean it up with existing capacity. It did not happen. It is expensive and it is complicated. The regulations did not allow for it so we are trying to work through that and still trying to get an economic, viable, alternative diversification for our water supply. That is our interest in this issue.

Moderator Hume: Does anybody have any questions or comments at this stage?

Question: This question is for Mark Fesmire. Mark, on your attempt to try to quote the rules and regulations, you potentially used statutory language to state, in essence, that you could apply produced water to beneficial use in New Mexico and not create a water right. How do you get around the Constitution with this provision?

Fesmire: That is a question we are going to have to address. The way we are going to get around it in the short-run is to not call it beneficial use. We are going to call it dispositional produced water.

Moderator Hume: I am no lawyer but I used to play one in the newspaper business. That is the crux of this whole thing. The Constitution is specific that all the water belongs to the people and the State Engineer is charged with determining who gets to use it. But the water coming out of these wells is an expensive by-product that the oil and gas industry has to dispose of. And so it is a harmonic convergence if we can figure out uses to put this water to. The legislation and regulations are always trying to shoehorn this in and trying to make it work with the Constitution and also serve the public interest in putting this water to beneficial use. One man's expensive wastewater is another man's back-up water supply for cooling and power. As the water situation in New Mexico goes forward, the produced water, like everyplace else, as the price of water goes up, the technology and the inclination to take water that heretofore was not worth anything to put it to use goes up. Our water supply gets larger as Mark described.

Saavedra: Produced water has a definite future in the State of New Mexico. We have our rules, regulations, statutes and our Constitution that we must go by. We must protect New Mexico's rivers. We must protect existing water rights. We want to work with OCD and the oil and gas industry to figure out a way to be able to use this water that would help everybody, that would help the State of New Mexico, within somebody's jurisdiction anyway. In 2003, there was about 6 billion barrels of produced water. At 42 gallons a barrel, I think it is around 80,000 acre-feet of water. Now obviously, not all of that water is in a good place to be used and not all of it is of great quality that can be treated and then used. Most likely some of it can be used. So it is a source of water and whatever our problems are, we will work them out.

Yates: I agree with that and I also want to emphasize that this water is very challenging to clean up. It is not something that we are going to be able to take tomorrow or next year or even maybe in five years and show that it can be widely utilized for whatever purpose. It is very challenging water. In our case, in our pilot project currently, we have as far as I am aware, the only 7-11 permit from OCD to properly dispose of that water on the surface of the ground after it has been treated. According to OCD rules, the 7-11 permit process that you go through to land-farm oily waste requires meeting a lot of criteria with respect to where to locate these facilities, to till the soil, and to remediate the oil so that no subsurface or surface fresh waters are contaminated. We must be very careful about that. In our case, we treat this water and then take the resulting fresh water and put it on the ground. We have been working on this project for three years and we haven't put any water on the ground yet but we are getting close. We are always that close. But we haven't yet because it has proven to be very challenging to clean this water up. One other question that I would like to address that popped into my mind was the issue of how this water might affect existing aquifers. Where are oil and gas found? I am not a geologist—my background is engineering, but in Oilfield Geology 101, you learn that in order to find oil and gas in the subsurface, you must have a source of hydrocarbons, which requires a reservoir. You must have rock with porosity and permeability and you must have a mechanism that will trap that oil and gas in the subsurface. By virtue of the fact that it is trapped gives you the opportunity to pull that water out of the ground without having an adverse impact on existing water rights in the subsurface or the surface. Now, certainly, there are questions of quality and we have quite a sophisticated set of rules and regulations that we have to comply with in order to ensure that we don't contaminate existing water sources. We have drilled some 70,000 wells in the state of New Mexico and by and large the vast majority of those wells have been drilled without any contamination problems. The point being that water comes from trapped reservoirs and doesn't affect existing water rights and water resources.

Moderator Hume: I have a question I would like to pose to Mr. Yates and Mr. Fesmire and it is a fact question. How much water do you get from a gas well and an oil well, the quality and the duration of the supply? The parameters of it would go toward how much you could invest in infrastructure to pipe that water somewhere and use it.

Yates: I think with respect to New Mexico, if I recall some of my numbers correctly, there is on the average about eight or nine barrels of water produced for every barrel of oil equivalent. Some wells make quite a lot more water than that and other wells don't make any water. Certainly if I am out drilling an oil and gas well, I would prefer to drill a well that doesn't make any water, just oil and gas. Unfortunately, that is not always the case. Having said that, oil and gas wells are not always conveniently located so as to facilitate their use and pipelines are extremely expensive. So generally, disposal wells are developed in the vicinity of a particular producing field in order to minimize the infrastructure needed to dispose of that waste.

Fesmire: Mr. Saavedra was very accurate. In calendar year 2003 in New Mexico, we produced a little over 636 million barrels of produced water. That compares to 67 million barrels of oil or about 9.5 to 1. In some places, operators reported disposal costs for water in the neighborhood of $4 to $5 a barrel. It doesn't take much math to figure out that could be a problem. The biggest challenge we are seeing right now is in coal-bed methane and the amount of water it takes to de-water a coal-bed methane well and get it producing gas. We have some in place where it takes as long as a year before they get any gas whatsoever out of the well. So the problem is that we have a lot more water than we have oil and gas. We are hoping that through discussions like this, we can come up with some ways to deal with the situation; $4 or $5 a barrel just isn't economical to dispose of that water right now. We have some projects that the operator really has to look at and if oil and gas prices start to fall, we are going to lose some production.

Moderator Hume: Any questions from our audience?

***Question*:** I want to pose a hypothetical question. My understanding is that you are spending millions of dollars getting rid of the water and you are spending millions of dollars trying to acquire the water or its economic market value. According to the desalinization process we heard about earlier…if that filter works with this nasty stuff that is coming out of the ground, which is possibly 30-40 percent of the cost for just getting the water to the surface and whether it is a desalination plant here or wherever….there is an energy cost that will be reduced and then there is more energy used putting it back into the ground. If we leave it on the surface and come up with a membrane that works… would this group even entertain the thought about legislation…whether it might be economic development capital or R&D money for the desalinization facility…and I am thinking particularly to the Clean Energy State Alliance…There was a piece of legislation introduced about three or four years ago that got smashed into nothing because of some environmental stuff…but it sounds like maybe that type of legislation [is needed] so that we could approach [the situation] from PNM's standpoint on the energy side and from the petroleum [industry] on cost savings…if we could come up with something…and from the State Engineer's standpoint for funding the millions and millions of dollars that Saavedra's organization needs to just implement…and get our arms around this huge problem. I would pose [the question] to [our moderator] Bill [Hume]. If we could draft some legislation that would be a cooperative effort….you have the millions and millions of dollars that will make this or break this. Either this is going to be a novelty industry that will continue to flounder or New Mexico can step on board with this facility and really make it something special for the country.

Moderator Hume: In response to that I would say it is my impression, and I will be corrected if I am mistaken, but it is not just a matter of taking subquality water and treating it for use. I think there is a lot of brackish water that could be extracted and cleaned up for a lot cheaper than this produced water. So if it were strictly developing water supplies we would go in that direction first. And with regard to going there, the Governor got a $10 million Water Innovation Fund from the Legislature last session…and the executive [branch] is in the process of going through a very interesting and varied set of applications from people who think that they have an idea that would work and be generally applicable to improve water supplies or water conservation in the state. I need to go back and find out how that is going because we should be getting close to an answer on that. Lastly, I learned a little bit –just before we started–about the nature of produced water. It varies considerably from one point to another, from produced water from the coal-bed methane wells, if I remember correctly, to relatively clean and relatively easy to treat water. Some water, from the very deep oil, is quite different and quite expensive. So in answer to your policy question, you are right, we should be and we are trying to get out in front of some of these technologies to help them develop and find better ways to make use of this water. With specific regard to produced water as a source of water for development, I think it ranks behind some other subquality water for development and treatment.

Lavery: I would like to respond to the question if I may. Purely from a legislative and regulatory perspective, there is a whole set of issues here. I have had the opportunity to spend the last two years working on a business case where we had a situation exactly like what you are talking about. Right away we went out and identified and estimated treatment that we think is currently the best in the industry, the lowest cost treatment. We have looked at the pipeline costs and the installation costs. We have looked at the regulatory costs and the legal costs and we came up with a project where it would take a 28-mile pipeline, about $37 million in capital, and about 18 months to actually get it into service. The price comes out to about $1,200 dollars per acre-foot. Today we have a water contract that was negotiated in 1972 in which we get water from the Bureau of Reclamation for $9 per acre-foot. PNM rate payers would have to pay the bill so what is prudent given the risk and given the cost of our current water? How far down the road do I look? One of the assumptions that I made in this case is that we would go out to the well producers and we would look at taking their water from them for 50 percent of their current cost. The current cost is about $1 per barrel to reinject the water. The other $3-$4 dollars per barrel is usually transportation costs so even if you could put a very high-cost capital facility in place that could manage this water, you are not going to reduce, by straight reduction, the cost of disposing of the water. You still have to get the water to the facility whether it goes through a pipeline or it is trucked. You will still see three-fifths or four-fifths of the cost of disposal remaining because we have over 19,000 wells in the San Juan basin with 10,000 acre-feet. You have to gather the water up before you can treat it and that results in very high capital costs. Two years of study have gone into this. Senate Bill 313 was introduced by Representative Joe Stell and I thought it was very insightful that many people recognized the tax credit benefits that we were asking for. The state does not have the kind of money needed; it didn't last year and I don't know what the budget is going to look like this year, but we were asking for a $1,000 per acre-foot. The people who are out in the field will have to develop the other half of the system with that $1,000 an acre-foot. Our cost-benefit analysis for the project indicates that if we got $6 million out of the $10 million that the governor has for water project development and IF we could get a tax credit, the best we could do would be to get the cost of this water down to about $250 an acre-foot. When we are currently paying $9 an acre-foot that begs the notion of being prudent for the rate-payers who ultimately must pay. So theoretically it is possible, but in reality, it is much, much, more complicated. We entered into a cooperative agreement with LANL and the Electric Power Research Institute. We have worked with them trying to get the best technologies, the best information available, and we think we have an optimized model but it is quite expensive still. But given the risk, what is your price tolerance?

Comment: Thank you. That is the dialogue that I am sure we were all hoping for. I don't know what the answers are. My only comment is, I would love to buy your $9 per acre-foot water…

Lavery: It is not for sale. (laughter)

Question: I understand you are protecting shareholders value. Santa Fe water rights are about $36,000 per acre-foot. In Albuquerque, I hear the numbers of about $6,800 to $10,000 per acre. I understand PNM's position. There are definitely economic models that will work quite well at $1,200 an acre-foot. And I believe there is a private enterprising gentleman here who would write you a check this afternoon if we can get this legislation through. I think that spending ungodly amounts of energy on pulling water up and putting it back down is just ridiculous. I think you need to be paid for it. I think it was very generous of them to pay half of what it takes to go in.

Question: For those of us who are real laymen here, I am from Arizona, and we don't have water. What contaminants are you talking about and which ones are most refractory? Are you talking about a handful verses thousands or would this equate to a chapter in an organic chemistry book?

Lavery: The short answer is to go to the PRRC website. Martha Cather has one heck of a good database and you can get all the information that you will ever want to know on produced water from around the state. The database is quite diverse.

Yates: I can tell you that in our water, one of the challenges is hydrogen sulfide gas dissolved in the water. It is dangerous and we go through great lengths to protect ourselves and employees from H_2S gas. We also see BTEX (benzene, toluene, ethylbenzene, and xylene) and other volatile organics. Once we have removed these organics, we have the typical challenge of what else you find in the water, typical minerals and so forth like calcium, magnesium, manganese, chloride, and so on. That is the short answer.

Fesmire: To lengthen that short answer, we have found that we can more easily treat the hydrocarbon content than we can the salts. The salts are more of a problem than anything else. Then besides the salts, you can have man introduced constituents like corrosion inhibitors, naturally occurring radioactive material, and such.

Question: Has anyone gone down the path of looking at what sort of water quality permitting issues we are going to have to deal with? How we are going to deal with the New Mexico Environment Department and the State of New Mexico in putting this water down as irrigation water or into surface water…[how do we deal] with the regulator and permitting issues associated with water quality?

Lavery: Yes, PNM has looked at it. We think a lot of this has to do with the one-year application and site-specific permitting. We already have water permitting at PNM. We do take river water right now, we do have an NPDES permit, but we are a zero discharge plant, so I think the particular circumstances around your use and your industry and current permitting is a major driver.

Moderator Hume: You are right. When and if you reach the point where there is water, it will come up against all the regulations for quality of water.

Yates: As I mentioned earlier, we have one of the first 7-11 permits from the Oil Conservation Division to land-farm this fresh water that we have treated in our facility. We have taken the position that this water, with the method that we are utilizing, is still oil waste. Having said that, the 7-11 permitting process is still fairly complex. It addresses location and we had to test and monitor the ground where the application would occur. It was quite an extensive process and we have not done any NPDES permitting at this point ourselves. We have prepared only the land application, but as we go further on down the line and we look at monitoring that process, we will call on individuals in New Mexico in our organization who have extensive NPDES permitting experience from the state of Wyoming. I suspect we may look at that once we have perfected the operation of our facility that will enable us to take this water to the Pecos River. We have looked at it in detail and it is an ongoing process.

Fesmire: We don't envision any changes in the NPDES permit requirements, NM Environment Department requirements or in OCD environmental requirements. All we have talked about to date is basically the right to use it and the right to permit that use.

Question Part I: I have a couple of questions. One is for Matt Lavery. Matt, you have mentioned that PNM is looking at leasing water to make up that risk difference and that new water that you have to lease for ground mitigation would cost more than $9 per acre-foot. Where is that in relation to the $1,200 for using the produced water?

Lavery: Yes, we have looked at all of that. The $9 per acre-foot goes away after the end of 2005. That contract will expire and then the cost will obviously go up. Our total drought relief package of our aggregated resource cost for our drought water, which we picked up another 10 percent (we went out and contracted), so we had another 110% of maximum demand. That amounts to about $228 per acre foot aggregated water cost for the plant. The cost of produced water is still significantly above that. However, the best case water project that we looked at produced between 8 and 10 percent of supply. That was the case I described earlier that requires $37 million in capital costs and a 28-mile pipeline. Now there is one more thing that is deceiving about this project. These costs take into consideration that we already have massive infrastructure at the plant for handling the water. If we went out and found a green field site, you would probably double the costs.

Reply by person asking Question Part I: All the more reason for PNM to act as a role model in New Mexico and take on this project.

Lavery: We are trying. (laughter)

***Question Part II*:** The second part of my question is directed to Mark's naturally occurring radioactive materials. This comes up at almost every conference that I've been to, but I've never heard anyone give a definitive answer as to whether or not the State has any regulations to deal with produced water that has naturally radioactive materials in it. Also, once we treat that water, what happens to those radioactive materials and how is it disposed? I guess that so far, since we dispose of them in wells, it hasn't been an issue, but since people are starting to develop a regulatory framework, have they considered this issue, and if they have, what is it?

Fesmire: Since I brought it up, I guess I better answer. It has not been a problem that we have paid a lot of attention to because where the radioactive materials are concentrated, it generally has to do with equipment retirement and we have been maybe a bit more lax than we should have been. Where it does show up in the water, like you said, most oil field waters are being reinjected (a significant percent). We haven't come across the problem to where we believe we have to address it further than the federal government does, but sometime in the future we are going to have to pay attention to it.

Moderator Hume: Naturally occurring means naturally occurent. I recall the case of the Church Rock Tailings Pond break some years ago with one of the most radioactive spills anywhere in the country. The state health people were catching animals and testing them for radioactive materials that were collecting in their organs. I remember asking them if this spill was contaminating all the animal life down there. They couldn't say with certainty because they have naturally occurring outcroppings of radium and no baseline for knowing what concentration of radioactive materials would have already been in the wildlife living there. This isn't too exciting, this is not a concern that we should followed very closely because this stuff is everywhere and is probably in all of us.

***Question*:** Just one question for Mark Fesmire. Mark, you mentioned early the number of barrels of produced water a year in New Mexico. How many barrels did you say?

Fesmire: During the year 2003, there were 635,744,000 barrels. This equates to about 82,000 acre-feet. That is statewide, not just Carlsbad. (laughter)

Moderator Hume: That's another factor with this produced water. You can't tap into it anywhere in the state. You have to be up in the northwest or down in the southeastern part of the state if you want to make use of produced water unless you want to pipe it a long ways. And that's on top of all the other expenses we have discussed.

***Question* from Lavery:** Bill, I have a question for my fellow panelists. I'm under the impression that produced water is just the tip of the iceberg when it comes to using degraded groundwater. This water is more economical because it is already at the surface and you don't have to pump it. I think it would be in the best interest of the State, when we begin drawing up rules and regulations dealing with produced water, for that water to transition into standard utilization of groundwater as a routine water supply. I would like to know what the others think about that.

Moderator Hume: The very first thing I would say is that standard degraded water around the state all very securely belongs under the control and supervision of the State Engineer. So it doesn't really overlap with produced water. The produced water, the definition that I understand, sets it apart from all other water because of the fact that it is water that comes up incidental to oil and gas production.

Lavery: Currently we don't regulate anything over 10,000 TDS or, I think, greater than 2,000 to 2,500 feet. We actually looked at going to that depth to get water around the San Juan Plant as opposed to going out and trying to gather the produced water. The aquifer there is very secure and traps all the oil and gas, but it does not yield much water. Going to greater than 2,500 feet, taking water greater than 10,000 TDS, I think, may become a viable opportunity for someone down the road.

Saavedra: The statute you are referring to is Section 72-12-25 and 26. It says that you can get water below 2,500 of which the top of the aquifer is 2,500 feet below the land's surface, but you must advertise it, and it is subject to anybody's protest and/or taking to court. It is a little more lax, but again the State Engineer will want to see those and you must file an application or information with the State Engineer. We would like to see those cases and make sure you are not impairing the aquifer above it or the aquifer next to it. We want to make sure that the rivers are protected and the existing water rights are protected. But it does give a little more flexibility in water rights and it is considered, so to speak, a separate underground water basin unregulated by the State Engineer.

Moderator Hume: It is important to keep in mind, too, of the one that is above 2,500 feet or running on the surface. If nobody out there is using it and its use is not impairing anybody else, all you have to do is go to the State Engineer and say that you have a beneficial use for this water and you can use it.

Saavedra: But an application still has to be filed and is subject to protest.

Yates: I think we must be very cautious in drafting new regulations or whatever we do, that we do not end up with unintended consequences, and perhaps the unintended consequence of jeopardizing the oil and gas production that we currently have in the state New Mexico. That is regardless of what you think we are going to be using oil and gas for in the years to come. The fact remains that it is a substantial revenue source for New Mexico's budget. We need to be very cautious that as we go through this process that we don't end up shooting ourselves in the foot, so to speak, and jeopardizing our ability to go out and explore for oil and gas. There is a side benefit to being able to treat and properly dispose of the water by whatever new and conventional methods might become available in this treatment process. There's the fact that we might be able to go into oil and gas reservoirs that are currently not economical to produce because of the excessive water disposal, as was mentioned earlier, in some case $3, $4, and $5 a barrel. We may be able to produce that natural gas and oil and have that produced water available to use or dispose of under OCD rules. There is still a tremendous amount of value to be realized in that production of oil and gas. I think we need to be careful that we don't jeopardize our ability to continue along that path for the state of New Mexico.

Saavedra: I just want to say at eight or nine barrels of water to one barrel of oil from these oil wells? (laughter)

Moderator Hume: I want to add to what Mr. Yates said. Certainly nothing in the regulation of produced water should stand in the way of the environmentally sound exploration of the oil and gas reserves in areas suitable for drilling. Again, what we are focusing on is produced water and it is not a new source of water. It is a new and different way of disposing of water that heretofore has been a disposal problem for the oil and gas industry. We are not talking about water that is defined by the virtue of being 2,500 feet below the surface. We are talking about water that comes to the surface attended through production of oil and gas and new and different ways to allow this waste byproduct to be put to some beneficial use in a matter that hopeful continues to skirt around the clear language of the New Mexico Constitution. It's safe to say that all the water from the center of the earth up is under the jurisdiction of the State Engineer.

Question: Again, Bill, is there dialogue going on at the Capitol that if we were successful in our desalination efforts and we are able to get through the Legislature's unwillingness to support a bill that will allow brackish water to be allocated in the proper context, from the economic standpoint of the state, what happens if you have a million acre-feet of water hitting the market on Day One? Have you created a kind of downward push on the value of water? Has there been any economic talk about that?

Moderator Hume: Actually, discussions have been going on in the Governor's Office in conjunction with people from the Office of the State Engineer on trying to help stimulate the development of water resources in the state. Yes, those discussions are going on and yes, we are trying to figure out ways to stimulate and assist in developing these supplies. Yet, these things happen irrespective of activities by governments. I remember back when El Paso sued New Mexico in the 1980s for the right to drill wells in New Mexico and pump that water to El Paso for M&I use. We said to them that you have lots of not-too-bad brackish water in the area; why don't you pump it up and use it? They said that it wasn't economically feasible. But today their water plan has 40 to 60 percent of their water supply in the foreseeable future coming from their desalination plant that they have up and running. So as the price of water rises, the availability of water increases with the application of capital and the stimulation to technology that it brings. This will continue, but we in the government are going to try very hard to get out in front and stimulate in a manner that really gets it going. The trick is in knowing which one is the ultimate computer package before you spring for the computer–or the ultimate desalination plant before you spend several millions of dollars on it. We are playing with those questions and trying to come up with procedures and ways to go forward.

Moderator Hume: Any more comments or questions from the rest of us on the panel?

Saavedra: The price of water will overtake the price of oil. (laughter)

Moderator Hume: Thank you very much.

__Karen Menetrey__ is a water resource specialist with the New Mexico Environment Department, Ground Water Quality Bureau. She has been with the department since 1993, working on regulatory programs for water quality protection, including managing the U.S. EPA Underground Injection Control grant. Prior to working for the Environment Department, she worked as a hydrogeologist with the Wyoming Department of Environmental Quality. Karen received a B.A. in geological sciences from the University of California at Santa Barbara in 1987 and has completed graduate coursework in hydrogeology at the University of Wyoming.

REGULATION OF BRINE DISCHARGES FOR PROTECTION OF GROUND WATER QUALITY IN NEW MEXICO

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Good morning everyone. My name is Karen Menetrey and I work for the Ground Water Quality Bureau of the New Mexico Environment Department and I have been working for the Bureau and Permitting Program for about 12 years. First I want to tell you about an interesting letter I ran across when I first started working for the department. The letter was written to a dairy man who had a dairy facility with an unlined lagoon that was probably leaking and getting into the ground water — a manure and water-filled lagoon. A letter dated 1983 from our department told him, "….well, Mr. [Dairyman], you stated that under your facility the water is all brackish and so nobody is ever going to use that water and so it does not need to be protected. But Mr. [Dairyman] this water is protected under the regulations in the state and we do not know what is going to happen in the future. Someday somebody may need to use that brackish water…." At the time I thought, "Who is going to ever use that brackish water?" That letter shaped how I thought about my job from day one, that we need to protect all water in the state for future use. Little did I think that 12 years later I would be here at a conference talking about how we can use brackish water. I don't know if any of you are also surprised at where we are right now.

Today I will talk about the permitting requirements for the disposal of concentrated water from the desalination process. In my presentation, this concentrated water is referred to as a brine discharge although in the program the title of my talk it indicates "concentrate discharge." I don't really know what the correct term is but I am going to call it "brine discharge." I will talk about the purpose of the Ground Water Quality Bureau and why we need to protect ground water quality, how we regulate the disposal of brine wastewater, and what is included in a discharge permit for different types of disposal.

The most feasible disposal methods we see are: Evaporation Lagoons, Class I Underground Injection Control Wells, and Class V Underground Injection Control Wells, although I will talk about a couple of other disposal methods too.

The Ground Water Quality Bureau protects ground water quality by regulating discharges that have the potential to cause ground water contamination. We regulate industrial, mining, domestic, and agricultural discharges and our authority comes from the New Mexico Water Quality Act and the Water Quality Control Commission regulations. The regulations are designed to protect all ground water in New Mexico that has a total dissolved solids concentration of 10,000 mg/L or less.

Scarcity of water is one of the biggest issues that faces New Mexico. About 90 percent of New Mexico's population is relying on ground water resources with 10 percent of the population using private wells and 80 percent using public water supply systems. *U.S. News and Water Online* reports that population growth in parts of New Mexico may outpace water supply by 2025.

The Ground Water Quality Bureau's role in regulating brine discharges is to issue ground water quality protection permits known as ground water Discharge Permits. With these permits we ensure compliance with a number of ground water quality standards and abatement of groundwater contamination. Compliance is ensured through inspections, sampling, and the permitee's submittal of monitoring reports.

A discharge permit has essentially four components: (1) an operational plan that includes construction and operating requirements designed to ensure that the facility is properly constructed so that it won't contaminate groundwater; (2) a monitoring plan that sets a schedule for sampling, analysis, and submittal of monitoring reports about the brine discharge into the ground water; (3) a contingency plan that outlines measures to be taken in the event of a system failure or in the event of ground water contamination; and (4) and a closure plan that outlines measures to be taken when a discharge ceases so that waste is not left on site to contaminate ground water.

If someone were to submit a Discharge Permit Application for Disposal of Brine to an Evaporation Lagoon, we would want to see the operational requirements for a double synthetic liner with a leak detection system as seen in Figure 1.

Figure 1.

I am going to discuss disposal to an evaporative lagoon, to a deep Class I Well, and to a shallow Class V Disposal Well, which we think are the most viable options for disposal. However, we will not preclude someone from submitting an application for a different type of disposal method. For instance, I know research is planned for the Tularosa Facility regarding crop uptake. If someone can demonstrate that crops take up salts and brine, we would be able to consider a permit for land application for brine disposal. Also if a project were proposed to discharge to a city sewer system, we would not need to be involved; we would just need to ensure that the city sewer system could meet their requirements for effluent disposal. If they were able to have holding tanks on the site for the brine, we would not need to have a Discharge Permit Application.

The monitoring requirements associated with the evaporation lagoon would include flow metering, effluent sampling, ground water monitoring, routine inspection of the leak detection system, and routine inspection of the liner and berms around the evaporation lagoon.

The contingency requirements for this type of permit would include liner repair or replacement if there is a problem with the liner, spill reporting and corrective action, and abatement of ground water contamination if it should occur.

The closure requirements would include: removing or plugging the conveyance system, perforating or removing the liner, filling the lagoon and grading for positive drainage, and two years of post-closure ground water monitoring.

The diagram on Figure 2 shows a Class I Well injection of hazardous and non-hazardous wastes into geological formations capable of confining the fluids. It shows a sector in the land surface where the well is extending through geologic layers beneath the drinking water aquifer that is pictured in blue. A Class I Well is generally a deep well designed so that the brine will stay there and be the final disposal location. Suitable areas for Class I Wells include the northwestern and eastern parts of New Mexico and perhaps in other parts of the state.

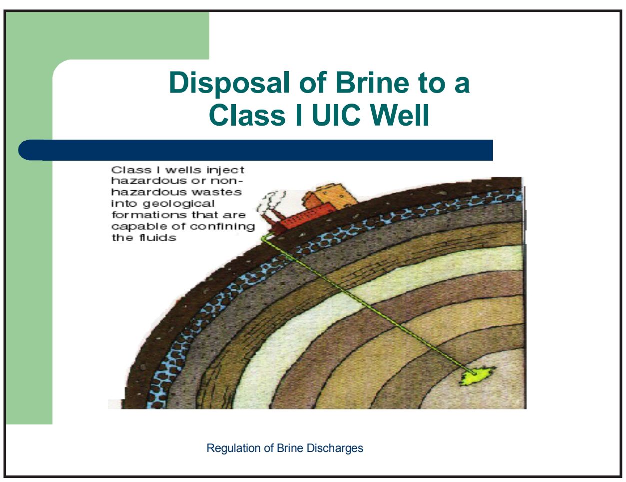

Figure 2.

The operational requirements for a Class I Injection Well include well-specific construction criteria to make sure that the well material and the aquifer are compatible with the brine being disposed. It includes a formation-specific injection pressure. Again, the idea of the Class I Well is that fluids are injected below the lower most drinking water aquifer and will stay there.

Monitoring requirements include: mechanical integrity testing, continuous pressure monitoring, continuous flow rate and volume metering, effluent sampling, and ground water monitoring of the drinking water aquifer that overlay the injection zone.

Contingency requirements include reporting and corrective action if fracture propagation occurs from the injection zone and if fluid migration occurs and abatement of ground water contamination of the drinking water aquifer if that occurs.

Closure requirements include: financial assurance, which is posted up front when we issue a permit; plugging and abandoning the Class I Injection Well; removing or plugging the conveyance system to the well; and two years of post-closure ground water monitoring, if necessary.

Figure 3 shows a picture of brine disposal to a Class V UIC Well. Class V Wells are wells not included in Classes I-IV. It is a catch-all category that EPA devised. Non-hazardous fluids are injected into or above an underground source of drinking water. The diagram depicts a farm with an irrigation run-off well into a shallow drinking aquifer that is in blue. A Class V Well could be either a vertical well or a subsurface fluid injection system like a leach field or an underground piping system.

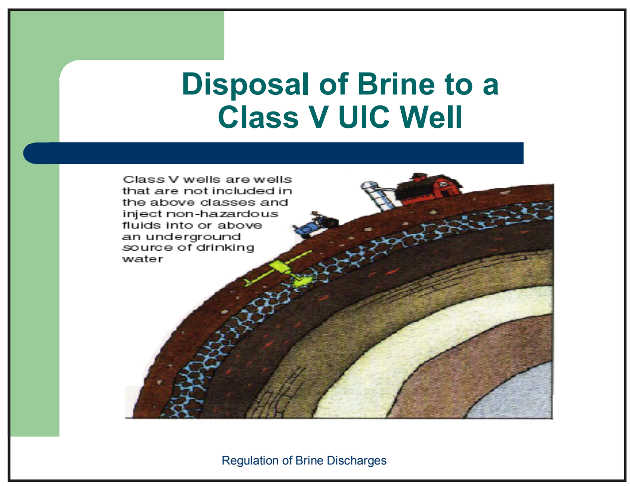

Figure 3.

For the Environment Department to consider a Class V Well for brine disposal from desalinization wastewater, it would have to be injected into a formation that contains 10,000 mg/L or more total dissolved solids, which you might actually have if you are working on a desalinization project. To use this disposal method, the permitee must demonstrate that ground water of higher quality would not be affected by the discharge. A detailed characterization of the hydrogeology would need to be done to determine if pockets of fresh water exist that might be affected if you discharged into this poorer quality aquifer. Monitoring requirements for a Class V Disposal Well would include flow metering, effluent sampling, and ground water monitoring of any fresh water areas around the discharge. Contingency requirements call for spill reporting and corrective action and abatement of ground water contamination if it occurs. Closure requirements include removing the conveyance system, removal or backfill of the subsurface distribution system, grade for positive drainage, and two years of post-closure ground water monitoring if required in the permit.

The permitting process for the ground water discharge permit takes about 180 days. A public notice process can extend that permitting time if a public hearing is required. A public hearing is required if there is significant public interest. We appreciate it when folks call us in advance for a planning meeting.

Our Program Manager, George Shuman, can be reached at (505) 827-2900 (George Shuman@ nmenv.state.nm.us) if there are any projects folks are considering and they would like to talk about permitting. Our website is http://nmenv.state.nm.us and on the website are Discharge Permit Applications and other information about the Bureau.

Question: Karen, in the State of Florida, one of the things they do is to classify desalination by-product concentrate as water treatment by-product for the reason that they are trying to get around classification of the waste as industrial waste realizing that it has the same components that water has in it initially but it is a little more concentrated, maybe five times more concentrated. Would New Mexico consider, if we had more desalination operations going on in the state, modifying or opening a class of waste disposal for only desalination by-products?

Answer: We do not have that classification yet; we have not had to consider it. I am not sure it would make a difference in terms of permitting. We have adopted EPA's classification for injection wells but the regulations are not different depending on the different types of waste. Some restrictions on injections wells require you to meet drinking water standards but the example you give I do not think would be necessary in New Mexico - it would not affect permitting. Certainly we would consider it when we receive an application.

Anthony J. Tarquin *has been at UTEP in the Civil Engineering Department since 1969 and is also an adjunct professor at NMSU. He received bachelor, master, and Ph.D. degrees from West Virginia University, with his doctorate earned in environmental engineering in 1969. Tony has received 52 grants totaling more than $2.3 million, most in the areas of water and wastewater treatment and a few related to teaching effectiveness. He has more than 100 professional publications in all types of journals and currently has three books in print, one in four different languages. Tony received UTEP's highest teaching award in 1993 and has a permanent endowment established at UTEP in his name, endowed by former students and others.*

THE SCIENCE OF CONCENTRATE MANAGEMENT

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INTRODUCTION

The vast improvements that have been made in membrane systems in recent years have led to increased use of this technology in all parts of the United States and the world. This trend is certain to continue because increasing populations inevitably result in greater demand for potable water. However, inland communities are faced with the major challenge of what to do with the concentrate from the membrane processes. This paper presents the results of laboratory and pilot plant studies regarding procedures for recovering some of the water from silica-saturated membrane concentrates.

CONCENTRATE HANDLING

At the present time, there are essentially two things that can *economically* be done with a membrane concentrate: (1) throw all of it away, or (2) recover some of it and throw the rest away. In order to recover some of the concentrate using membranes, a rather simple systematic procedure can be administered. The steps involved are as follows:

1. Concentrate the concentrate until the system fails (i.e., membrane fouling)
2. Determine what caused the fouling (by mass balances, membrane autopsies, etc.)

3. Identify and implement a treatment scheme
4. Go back to step (1)
5. Continue this process until disposal is cheaper than additional water recovery

SILICA CONSIDERATIONS

In the arid southwestern U.S., silica is often found in groundwater supplies because of the sandy soils of the region. At concentrations above about 100 mg/L, silica can precipitate from solution and foul the membranes. While silica chemistry is quite complex, it is known that hardness is a primary driver of silica precipitation. That is, the *combined* concentrations of hardness and silica (along with other factors like pH, of course) determine when silica will precipitate. Thus, even when the concentration of silica is high (say, above 200-300 mg/L), it will not precipitate if the hardness is low. On the other hand, when the hardness is high, silica will precipitate even at concentrations below 100 mg/L. Therefore, two of the obvious methods for recovering water from silica-saturated brine would be through (1) reduction of the hardness, or (2) reduction of the silica. The project discussed here investigated both methods at the pilot plant level.

PROCEDURE

The first method studied was hardness reduction, and it involved using nanofiltration to remove hardness, followed by reverse osmosis (RO) to remove silica and the other constituents that passed through the nano membrane. The second method employed lime treatment to reduce the silica concentration, followed by reverse osmosis for recovering some of the water.

The concentrate that was used in this study was generated in a 25 gallon per minute (gpm) pilot plant (identified as RO-1) that was operated by CDM, Inc to acquire design data for the 27.5 million gallon per day desalting plant that they were designing for Fort Bliss and El Paso Water Utilities. At the time this study was conducted, the brackish water supplied to RO-1 came from a mixture of wells in the 500-series well field of El Paso Water Utilities. The quality of the brackish water changed somewhat during the course of the investigation because different wells were operated at different times. This, in combination with RO-1 being operated at different recovery rates, resulted in changes in some of the characteristics of the concentrate. Nevertheless, the silica concentration remained fairly constant. The average values for some of the parameters of RO-1 concentrate (e.g., the water supply for this study) are shown in Table 1.

RESULTS

Parameter	Value
Alkalinity	310 mg/L
Chlorides	1310 mg/L
Conductivity	4380 uS/cm
Hardness	710 mg/L
pH	7.3
Silica	122 mg/L
Sulfates	540 mg/L
TDS	3090 mg/L

Table 1. Characteristics of RO-1 Concentrate

Membrane System

The nanofiltration unit was operated at flow rates between 2.0 and 2.5 gpm, with recovery rates that were gradually increased from 50% to 86%. These conditions generated a permeate flow rate of 1.0 to 2.1 gpm, and this served as the influent to the RO unit, which was operated at recovery rates ranging from 40% to 65%. The characteristics of the flows from each unit are shown in Table 2, with the higher values generally associated with the higher recovery rates.

It is believed that the maximum recovery rate in both units was limited by the combination of hardness and silica concentrations in the respective concentrates. As shown in Table 2, most of the hardness that was in the feed to the nano unit (i.e., RO-1 concentrate) stayed on the concentrate side of the nano membrane, as expected. This resulted in increased hardness in the nano concentrate, with the concentration averaging about 2650 mg/L at the highest recovery rate. The silica concentration averaged about 125 mg/L at that time, and the system performed well under these conditions. At higher concentrations of hardness, however, fouling of the nano membrane occurred.

The permeate from the nano unit was the influent to the RO unit and, although most of the hardness was rejected by the nano membrane, about 20% (150-210 mg/L) passed through with the permeate, along with the silica (95 mg/L). When the nano permeate was concentrated in the RO unit, the silica and hardness concentrations increased to 250 mg/L and 460 mg/L, respectively. Fouling began to occur above

Parameter	Concentration, mg/L (except pH and Conductivity)			
	Nano Perm	Nano Conc	RO Perm	RO Conc
Alkalinity	70-250	200-750	10-20	200-750
Chlorides	750-1650	1200-2300	30-50	1800-2800
Conductivity[1]	2900-4600	5700-9100	60-130	5200-9900
Hardness	150-210	1300-3300	5-10	280-590
pH[2]	6.1-7.5	6.3-7.9	4.6-5.9	6.2-7.5
Silica	91-174	108-226	2-21	101-311
Sulfates	0-5	1400-3900	0	0-5
TDS	1570-2860	4000-7850	30-150	3270-6320

1 – Units are uS/cm   2 – Units are pH units

Table 2. Values for Selected Parameters for Flows from Each Membrane Unit

these values. Thus, it appears that hardness plays a very significant role in determining the extent to which silica-saturated brine can be concentrated.

The maximum recovery rate achieved in the nano unit was 86%. This recovery rate, when coupled with the maximum 65% recovery rate in the RO unit, resulted in an overall concentrate recovery rate of about 56% for the membrane processes.

Lime Treatment System

The lime treatment system consisted of a 3-compartment flocculator, a tube settler, sand filters, and the RO unit. A degasification system was added later. Initial lab and pilot plant studies had shown that silica removal via lime treatment could be modeled reasonably well as a first-order reaction. Later studies showed that after the alkalinity was removed, the degree of fit of the model improved significantly. Figure 1 shows the general shape of the silica removal curve. In this study, the first-order portion of the curve (i.e., after the alkalinity was removed) was described by the equation

A lime dosage of 200 mg/L would reduce the silica

$$C = 131e^{-0.0043x} \quad \text{Eq (1)}$$

Where: C = Silica concentration, mg/L
x = Lime dosage, mg/L

concentration in the degassed concentrate to 55 mg/L. A higher dosage would remove more silica, and vice versa, per equation (1). If alkalinity is present (i.e.,

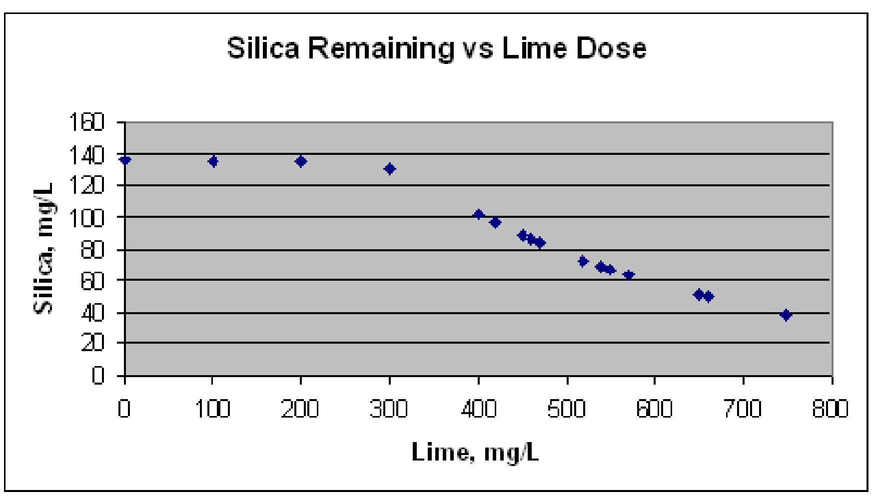


Figure 1. Effect of Lime Treatment on Silica

concentrate not degassed), then the lime dosage has to be increased accordingly as shown in Figure 1.

Reducing the silica concentration in the concentrate would obviously allow for recovery of more water through additional RO treatment. The extent to which the silica should be reduced is dependent on several factors related to cost, including concentrate disposal options, the incremental cost of obtaining new water, sludge disposal costs, and so on. In any case, this study has shown that lime treatment can be used to control silica effectively in brine concentrates so that silica will not be the limiting factor in desalting operations.

CONCLUSIONS

Based on the results of this project, the following conclusions can be made with reasonable certainty:

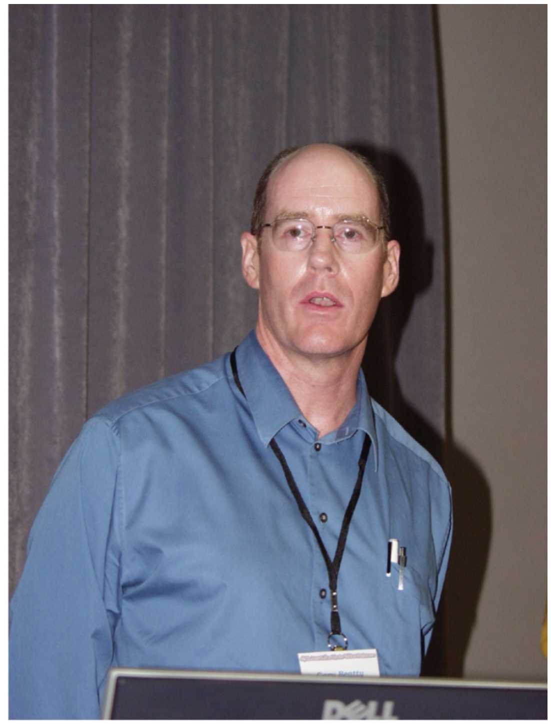
1. The membrane processes of nanofiltration and reverse osmosis can be used to recover water from silica-saturated brine. The extent of the water recovery appears to be related to the concentrations of hardness and silica in the nano and RO concentrate streams.
2. Lime treatment of silica-saturated brine is effective for reducing the silica concentration in the brine. The dose-response relationship for silica removal appears to be first-order with respect to silica after the alkalinity is removed.
3. By using lime treatment for silica-saturated concentrate, the silica concentration can be reduced to virtually any level that is desired. Factors such as concentrate disposal alternatives, sludge handling options, and overall treatment costs will dictate the extent to which silica should be removed for economically recovering water from the concentrate.

This project has shown that options are available for effectively dealing with silica-saturated brine concentrates.

ACKNOWLEDGEMENTS

This project was funded by the U.S. Bureau of Reclamation and El Paso Water Utilities. Special thanks goes to Fernie Rico, Robert Riley, and Tony Hernandez of El Paso Water Utilities for their unwavering support and willingness to help in all aspects of the project.

__Gary Beatty__ received a B.S. degree in professional chemistry from Eastern New Mexico University and is a Level 4 Certified Wastewater System Operator. He worked for more than 18 years for the City of Roswell as the City Chemist. Currently, Gary is the Liquid Waste Specialist for the New Mexico Environment Department, District 4.



GRAYWATER USE IN NEW MEXICO

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Good morning. In the summer of 2003, New Mexico adopted regulations concerning graywater reuse for domestic systems. Our guiding principles to conserve water include: save fresh water; irrigate with graywater or wash water; relieve the strain on septic systems; and achieve the highest level treatment with little or no energy and chemicals.

What is graywater? Defined by New Mexico, it is any wastewater used in the home except water from toilets, kitchen sinks, and dishwashers. Shower, sink, and laundry water comprise 50 to 80 percent of the residential wastewater. This water may be used for other purposes, especially landscape irrigation. Let us be clear when we talk about wash water: wash water that has a large amount of fecal material, for example, if you were washing baby diapers, is not acceptable. That water is considered to be black water, not graywater.

Why use graywater? We are used to irrigating with large quantities of drinking water when plants thrive on water that is used containing the micronutrients that naturally end up in the graywater. The benefits of graywater include:

- Lower fresh water use; could be used in some areas, like Ruidoso, with real water problems in the not so distant future.
- Less strain on liquid waste systems. You can extend the life of your disposal field by not putting so much water in it, lessening the hydraulic load.

- Highly effective purification and natural attenuation through the top layer of the soil.
- Less energy and chemical use; although there are some ways of using graywater that actually use more energy.
- Groundwater recharge. Eventually everything we put into the subsurface system, whether it is through the disposal field or as graywater, is going to end up back in the groundwater.
- Plant growth. Plants love this type of water. It helps their growth. If you have ever used graywater from your washing machine on part of your yard, you will notice that it will be the greenest area in your yard.
- Reclamation of otherwise wasted nutrients that end up in your drain field. The nutrients are not taken up by the plants because of the deeper dispersal.
- Just because it feels good to use graywater.

Examples of wastewater amounts of an average family of four per week:

Washer	160 gallons
Showering	450 gallons
A tub	60 gallons
Bathroom sink	60 gallons
R.O. unit	56 gallons
Total	800 gallons

Here are some sample residential irrigation needs on a weekly basis. You can see that you could do quite a bit of landscape watering with a typical flow from a 4-bedroom house.

Three large trees	345 gallons
Smaller trees	100 gallons
Hedges	230 gallons
Flower bed	130 gallons
Total	805 gallons

The following study reports on overland treatment of wastewater by the bacteria present on the surface of the soil. This presumably would be indicative of the treatment level graywater would receive it if ran over the surface. The studies deal primarily with Texas and Arizona. You can see the BOD reduction is very high, phosphate removal is high, and nutrient removal is pretty high. In the case of Texas, they did not perform a coliform analysis, but in Arizona, data show virtually all the coliform was removed.

Removal rate studies:

	Texas	Arizona
BOD	99.1%	98%
Phosphorus	90.0%	87%
Total nitrogen	91.5%	40-80%
Coliform	N/A	100%

Keep in mind that graywater may contain infectious organisms. Therefore, there is a health risk associated with graywater. You want to keep contact to a minimum. Regulations do not directly prohibit it, but it is not a good idea to run it directly on the ground where you can come into contact with it, or kids can play in it, or dogs drink it. You must understand that this is the water you just bathed in and used to wash your clothes. You would not consider it dangerous, but it can contain pathogens.

Some safety guidelines are not directly addressed in the regulations. The graywater must pass slowly through healthy top soil for natural purification to occur. Graywater systems should be designed so that no contact takes place before purification, which means it should be applied to a mulch bed type situation or to a bit in the subsurface in a (dome) type system to keep direct contact away. I have seen trailer houses that have their sink water running out onto the ground and forming puddles in the yard. That is not acceptable.

The current liquid waste regulations are as follows. These regulations cover discharges under 2000 gallons a day of domestic wastewater.

- A. "graywater" means untreated household waste that has not come into contact with toilet waste and it includes wastewater from bathtubs, showers, wash basins, clothes washing machines, laundry tubs, but does not include wastewater from kitchen sinks, dishwashers, or laundry water from washing material soiled with human excreta such as diapers.
- L. shall not require a permit for applying less than 250 gallons a day of private residential graywater originating from a residence for the resident's household gardening, composting or landscape irrigation if:
  (1) a constructed graywater distribution system provides for overflow into the sewage collection or on-site wastewater treatment and disposal system;
  (2) a graywater storage tank is covered to restrict access and to eliminate habitat for mosquitoes or other vectors;
  (3) a graywater system is sited outside of a floodway;

(4) graywater is vertically separated at least five feet above the groundwater table;
(5) graywater pressure piping is clearly identified as a nonpotable water conduit;
(6) graywater is used on the site where it is generated and does not run off the property lines;
(7) ponding is prohibited, application of graywater is managed to minimize standing water on the surface and standing water does not remain for more than twenty-four hours;
(8) graywater is not sprayed; and
(9) graywater used within municipalities or counties complies with all applicable municipal or county ordinances enacted pursuant to Chapter 3, Article 53 NMSA 1978

Graywater can be used for gardening, composting, and landscaping. Construction of a graywater distribution system provides for overflow into the sewage collection or on-site wastewater treatment and disposal system. This means if you design a system for graywater, you still must have the connection that runs back to your septic system or into the domestic sewer, if you live in a municipality. That is a requirement. Setting up a graywater system will not reduce the size of the drainfield as required in the regulations. If you have a tank, your graywater must be covered to restrict access, primarily for vector control.

A graywater system is sited outside of a floodway. Graywater is vertically separated at least five feet above the groundwater table. I am not sure why they instituted that requirement. For three-quarter acre lots, the liquid waste system and disposal field must be separated by four feet.

Graywater pressure piping must be clearly identified as a non-potable conduit. You must make sure it is clearly marked either with spray paint, colored differently, different type of faucets on it, or similar.

Graywater is generally used on the site and does not run off the property lines; it cannot run down the hill into your neighbor's yard. Ponding is prohibited. Application of graywater is managed to minimize standing water on the surface and standing water cannot remain for more than twenty-four hours. As I mentioned before, the regulations do not specifically say that you cannot have graywater on the surface, but it is not a good health practice. It is recommended to run the graywater under a mulch or subsurface. Graywater is not to be sprayed. Graywater use within municipalities or counties must comply with all applicable municipal or county ordinances. These regulations do not supersede any other entities', whether county, city, or state.

How can we use graywater? A number of different ways are acceptable. The lower cost systems are branched drains to mulch basins; drain directly to a mulch basin; mini leachfield, a subsurface discharge; and gravity drum. More costly systems include a drum with pump and filter, which will require filtration and additional maintenance. One potential problem with domestic systems is that maintenance can be challenging. Since homeowners do not see what is going on with the system, they tend to forget about it.

Figure 1 is a picture of a typical mulch basin with a pit around a tree that is being watered. The picture includes a subsurface addition to that pit with a mulch entering the fixture.

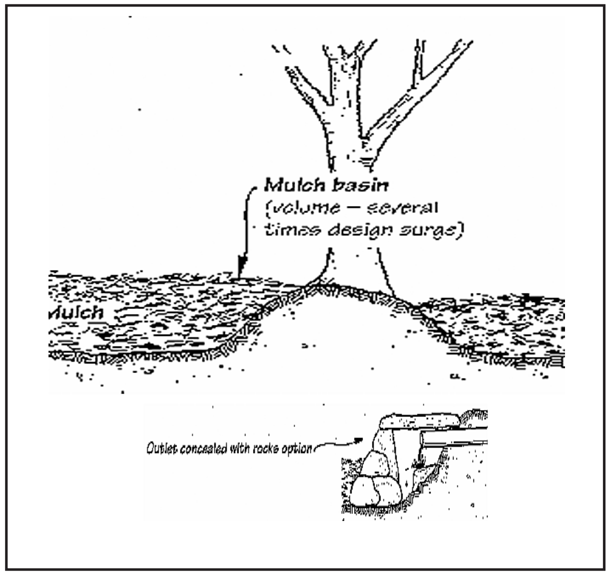

Figure 1.

Figure 2 depicts a direct system where you have one connection, in this case a sink, going to a mulch basin outside the house. No tank is required. The minimum set back from the building is five feet. A P-trap is used to keep insects and other vermin from entering the fixture.
watered.

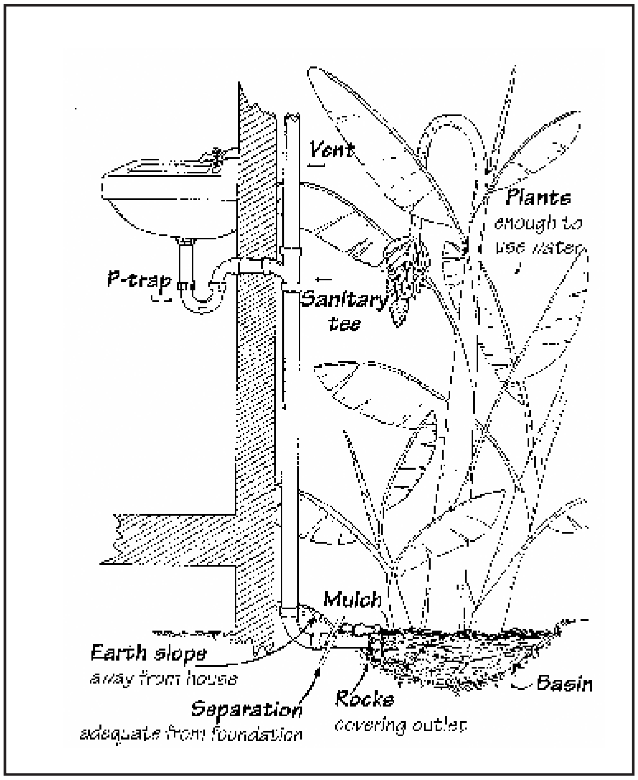

Figure 2.

Figure 3 depicts another drain to mulch basin system, in this case, a washing machine. The system is designed with an anti-siphon valve to deal with "pull-back" when the washing machine cycles, something you definitely do not want. As you can see, graywater is discharging via the subsurface to a mulch area around the tree.

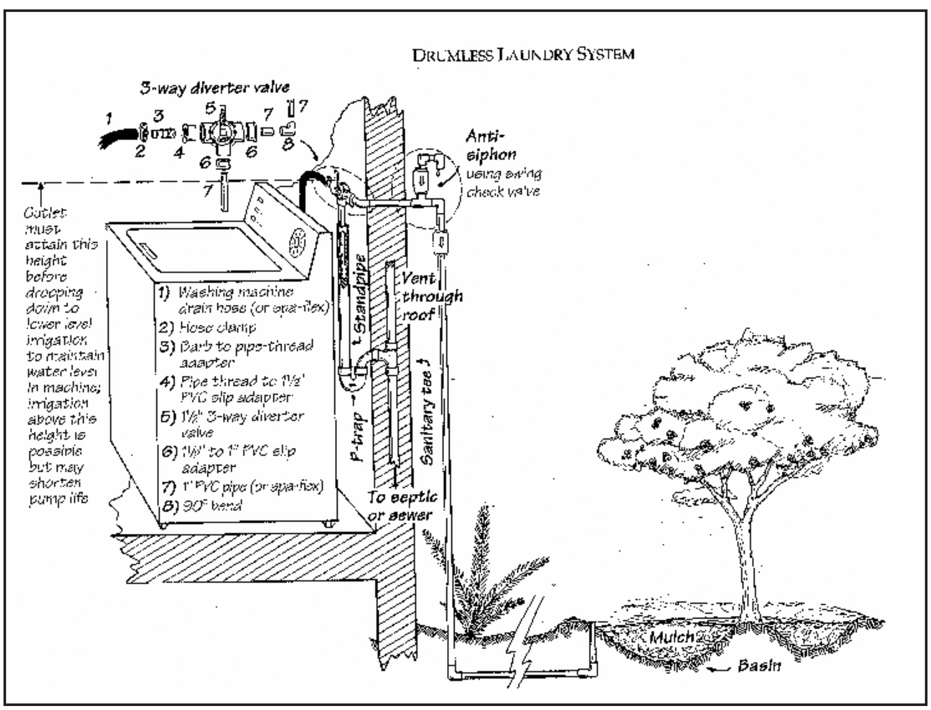

Figure 3.

The next Figure (4) shows two examples of branched drains to mulch basins. Again, no tank is required. Graywater flows are split by using tees or double ells. The mulch basins are down gradient from the source, although in some cases, this is not possible. Basins around plants are filled with wood chips or other mulch in order to avoid contact with the graywater.

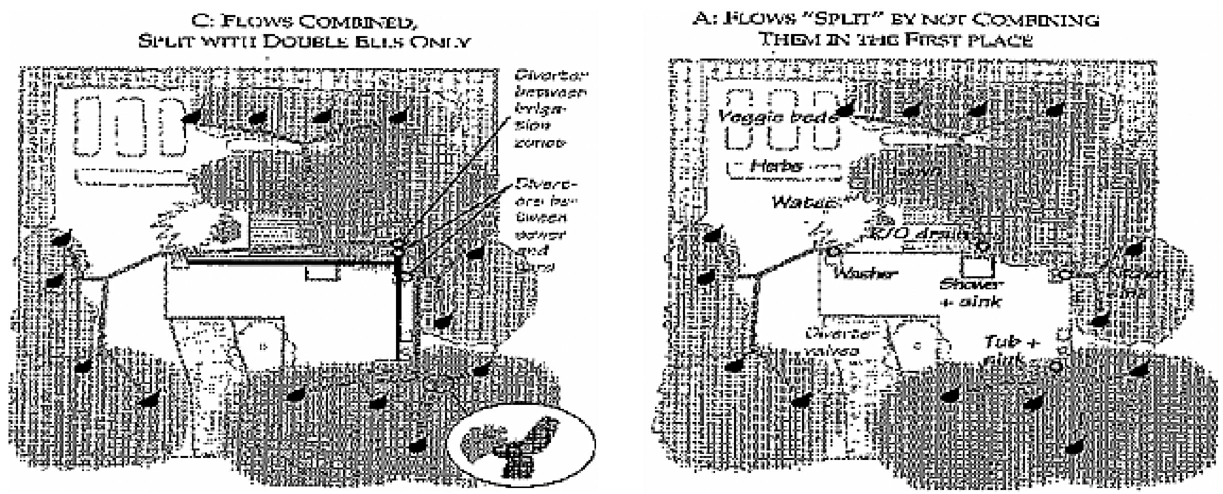

Figure 4.

Another system that uses mini leachfields is shown on Figure 5. Again, no tank is required. Pipe and gravel or gravelless chambers are used as in a standard system. The graywater could even be reverted to five gallon drums in some cases. Maintenance would be the main consideration for this system especially to prolong its lifetime. Depicted in the figure are gravelless chambers; a couple around each of the plants or trees being watered.

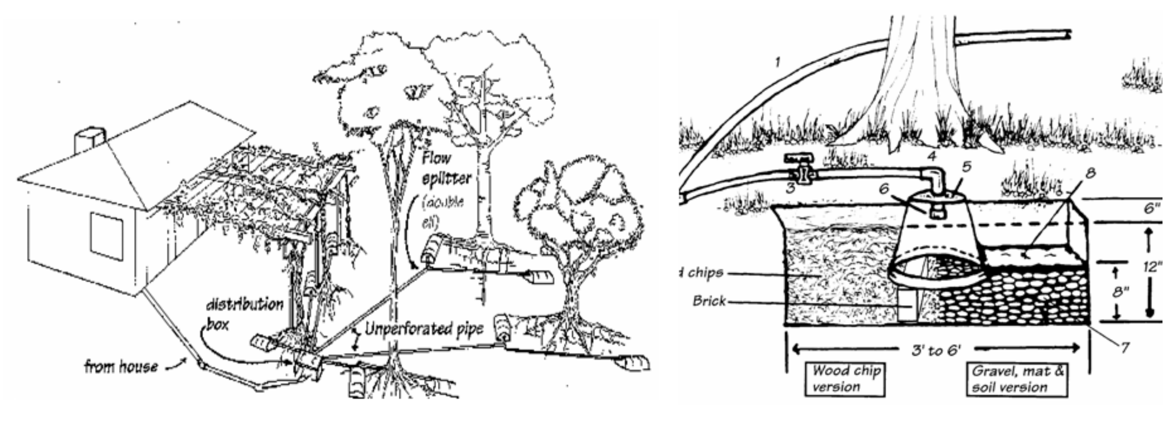

Figure 5.

Figure 6 shows a gravity drum or tank. This requires a tank (drum) but no pump. Graywater exits the tank from the bottom of the tank, above the ground. The tank must be covered. This system allows for batching of the water. You could switch fields and run a batch.

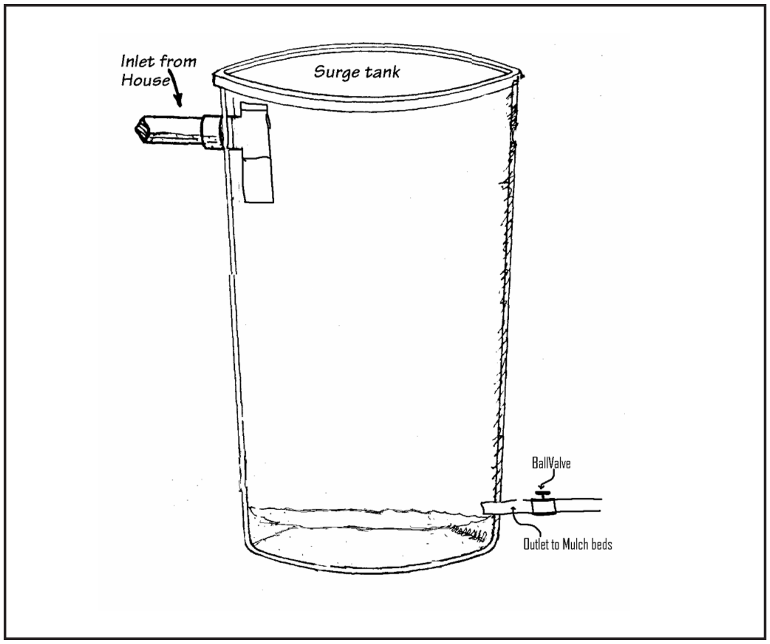

Figure 6.

A tank with pump and filter is shown on Figure 7. This is used when you want to discharge to two exits, both above gradient. Many situations call for this type of system, especially in the mountains. This system requires continuous maintenance and that can prove difficult to get from property owners.

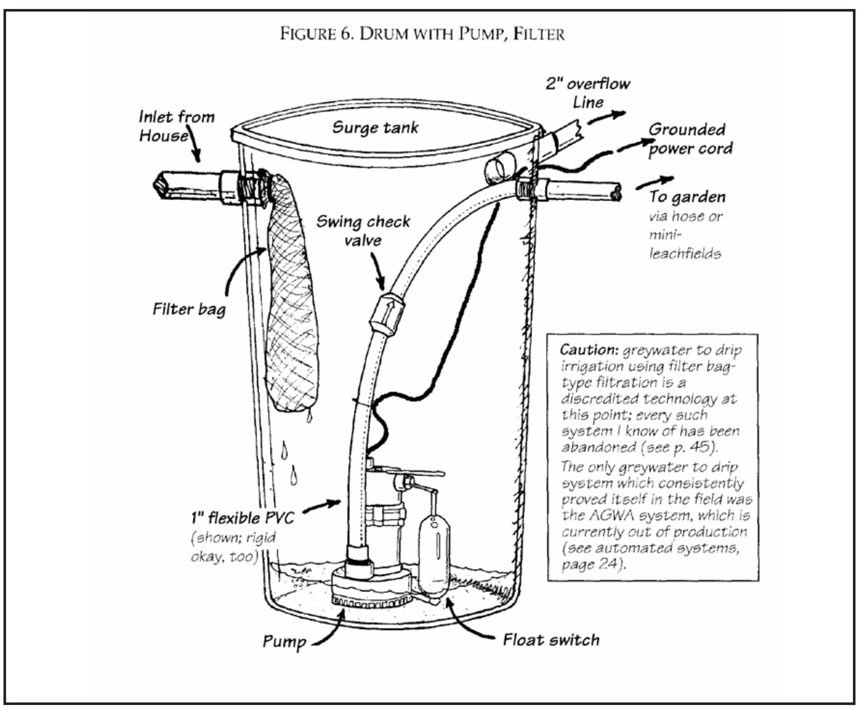

Figure 7.

An example of an infiltration bed is shown on Figure 8. Infiltration beds are nothing new and have been commonly used for septic systems drains. The bed does require a tank and must be pressurized. This system would be used where you do not have suitable soil for attenuation. You supply the suitable soil and then apply water to that suitable soil.

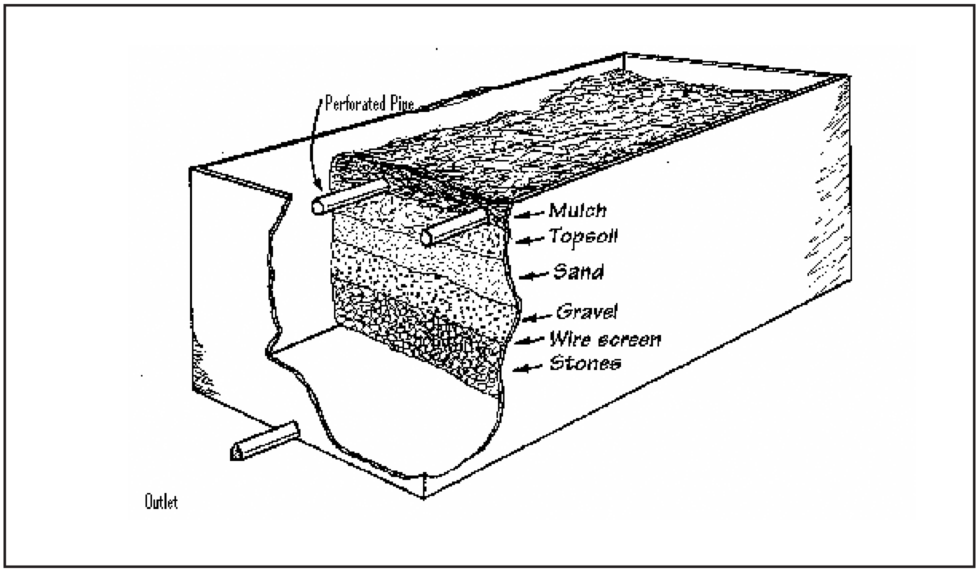

Figure 8.

The final figure (9) depicts plumbing connections and how to modifiy existing plumbing to run the graywater. Keep in mind that you must be able to run your graywater back to your septic system or the collection system in the house.

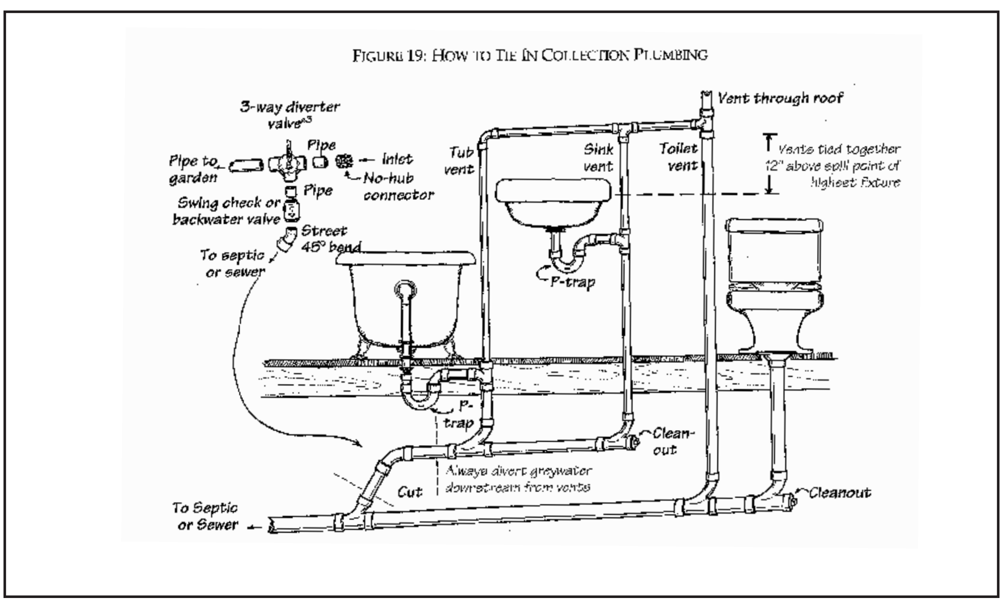

Figure 9.

In summary, graywater is safe to use. In New Mexico, I think it is one of the better ways that we have to cut down on our need for fresh water. Using graywater to irrigate will lessen the impact on the liquid waste system, and will lessen the amount of water that you actually have to buy, provide, or pump for yourself.

__John E. Balliew__ is the Water Systems Division Manager for El Paso Water Utilities. He has worked for EPWU for 21 years in a variety of positions including Plant Engineer, Planning and Development Manager, and Environmental Compliance Manager before obtaining his present position. John is a graduate of Texas A&M University with a degree in chemical engineering. He has authored or coauthored many papers related to water reuse, arsenic, membrane treatment, surface, and groundwater treatment.

EL PASO'S WELL-HEAD DESALTING PROGRAM

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As you may know, El Paso gets a substantial amount of its water, about fifty percent, from the Rio Grande. We are subject to the same drought conditions that the rest of New Mexico faces in terms of water supply. In order to do something about the situation, we needed to obtain additional water. At the same time, we have an arsenic issue with which to deal. Like many cities in New Mexico, we are faced with a new arsenic standard. I am sure many of you are familiar with this issue. Of the 152 groundwater wells we had at the time the new standard was imposed, our average arsenic concentration was about 12 parts per billion (ppb) in a range of up to about 30 ppb. The problem is that even though the average is 12 ppb, there are some areas of the city that are served by particular wellfields that might have levels as high as 16 ppb. Arsenic is a concern for us.

Figure 1 shows the concentration of arsenic with dots representing the wells in El Paso. In the northwest portion, we have a wellfield that is substantially impacted by arsenic. On the east side, the arsenic issue is more scattered. There are some wells that have arsenic and some wells that do not though some are adjacent to each other and coming out of the same aquifer. We have a wellfield in the Lower Valley area but most of the wells have not been used in about twenty years due to brackish water intrusion. Of the Lower Valley fresh-water wells that are in use, three wells have an arsenic problem and were selected for treatment for arsenic removal. The rest of the wells require some sort of treatment for salt content. Twenty-six wells are located in that wellfield and the TDS ranges from freshwater, 524 ppm (parts per million) – that is as good as we get – to 1,974 ppm. The arsenic in those wells ranges from 6.5 to 19.5 ppb, while the total capacity of those wells is 38 million gallons per day (mgd). From the time these wells were drilled, which was as late as the 1960s to the 1980s, we have lost 38 mgd primarily due to the intrusion of brackish water.

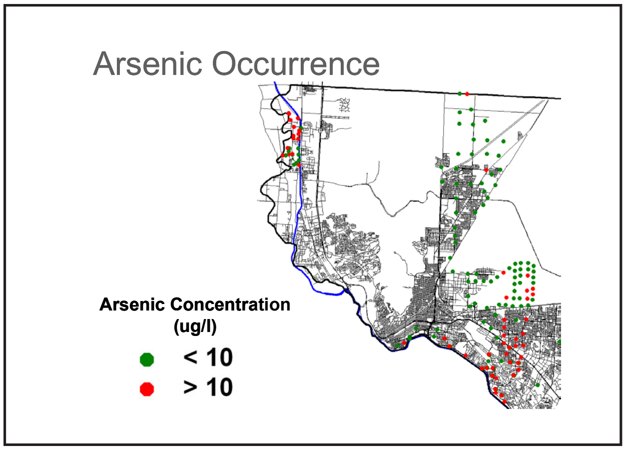

Figure 1.

Figure 2 depicts most of the wells in the Lower Valley and is color coded. Two wells in service meet the standards for both arsenic and total dissolved solids (TDS) and are shown with black diamonds. The light blue diamonds indicate the two wells that do not meet the TDS standard but do meet the arsenic standard. Fifteen wells do not meet either standard, and seven meet the TDS standard but not the new arsenic standard.

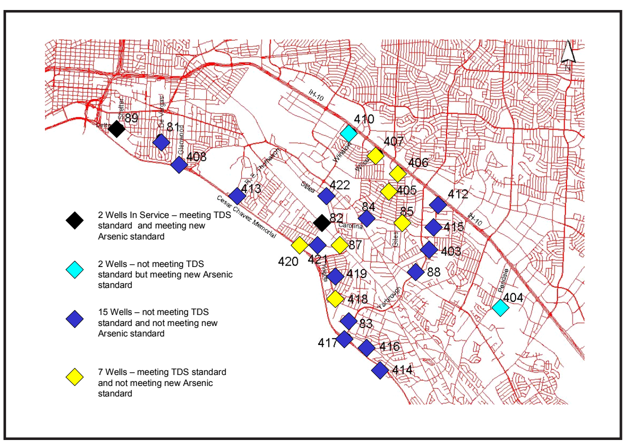

Figure 2.

While dealing with the arsenic issue, we have gained knowledge from our desalination pilot plant, the work that UTEP has been doing on concentrate management issues, and on technological advancements in membranes. We now feel it is practical to deal with both arsenic and TDS at the same time, allowing us not only to address the arsenic problem in the Lower Valley, but also to augment our water supply. We conducted a supply versus demand analysis to see how much water we would need to treat our supply and augment supplies during a drought. We focused on the critical months of May, June, and September. May is a critical month because during the course of a drought year, we are not getting water from the Rio Grande in May although municipal demand has picked up. June is typically our peak month. September also presents a situation where the ambient temperature can still be high, creating a demand for water, and yet because of the drought, we anticipate there will be no water from the Rio Grande. The Bureau of Reclamation forecasts whether we will be in a drought the following year and this year, the Elephant Butte storage is expected to be at a record low.

Figure 3 depicts water demand and supply in El Paso. The red line indicates 135 mgd well capacity. We could have some wells out of service and still be producing 135 million gallons per day, continuously. With surface water included, we could have as much as 260 mgd. But based on our drought projections, we were looking at a total capacity of 185 mgd, with 135 mgd of surface water included. You will note that in the summer months, without the surface water, there is no way that we can meet our demand.

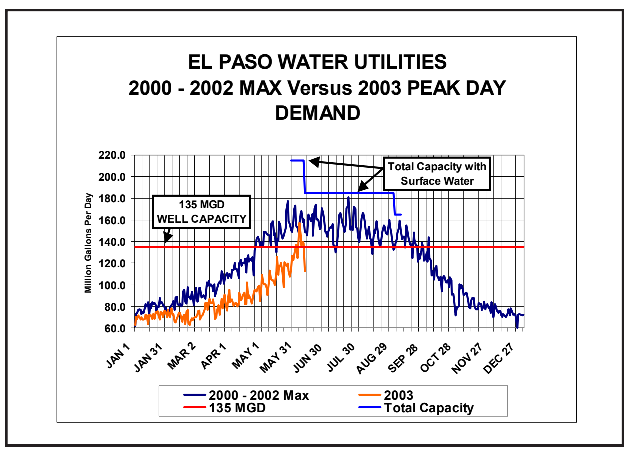

Figure 3.

The dark blue line represents the 2000-2002 average. The orange line represents 2003. In 2003, we had a drought year where we implemented Stage II drought restrictions, which were in addition to our normal day-in and day-out water restrictions on time of day and day of week to water. Stage II restrictions limit people to watering one day a week for two hours. We were able to save a considerable amount of water, yet in May, the water demand was still over 135 mgd. The question was, "How much additional water could we get to supply them?" We looked at the condition of the wells, and as I mentioned earlier, many of these wells had not been turned on in 20 to 30 years, so it took us some time to evaluate their condition. We determined that we needed up to 8 mgd to make up for demand during Stage II drought restrictions. We also determined that we could come up with 8 mgd from conjunctive treatment of arsenic and TDS from the Lower Valley wellfield. We will need the Joint (Ft. Bliss/El Paso) Water Desalination Facility by spring of 2006. Additional long-term desalination or importation should also proceed as scheduled. The 8 mgd of supply from the Lower Valley wellfield is a stop-gap drought supply that we can continue to use in the future, but we still need the desalination facility and other imported water.

Let me describe the typical wellhead treatment system. You can purchase a typical reverse osmosis system from several different manufacturers capable of treating a well with a capacity of one- to two-million gallons per day and the system can be delivered to you very rapidly. Figure 4 shows a typical system; a GE/Osmonics system that we purchased through a competitive bid process.

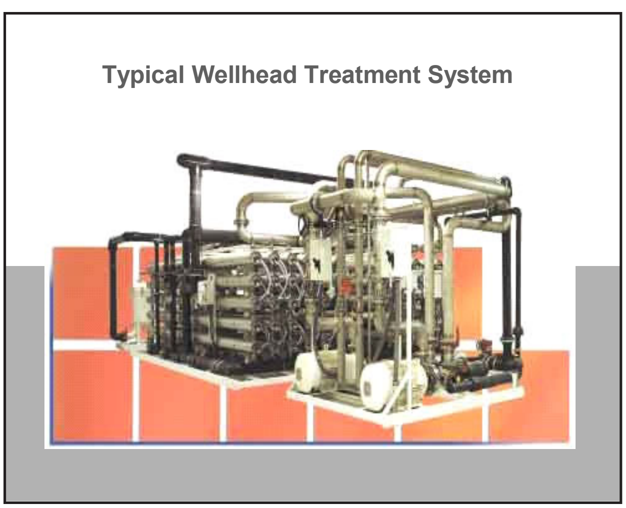

Figure 4.

The two wells highlighted by black diamonds in Figure 5 did not have any problems and will remain in service. We selected three of the arsenic wells for arsenic removal only, 11wells were selected for reverse osmosis systems, and we decided not to do anything about nine of the wells because they either had condition problems or the site was not big enough for the installation of the Reverse Osmosis unit or for some similar reason.

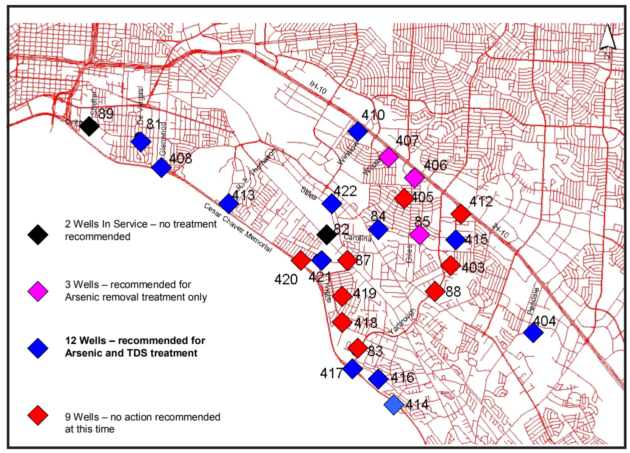

Figure 5.

We used the 11 highest capacity wells and had capital costs of $8.7 million, which included $3.5 million for membrane package units and $5.2 million for site improvements. Site improvements consisted of bringing the electrical system up to code, putting in a metal building and a slab to house the skid, fencing improvements, and the usual things needed to improve a deteriorated site. We are estimating operating costs of $1.8 million annually to produce 8 mgd of water into the distribution system, which is about 8,960 acre-feet per year capacity. We did not feel it is practical, for a variety of reasons, to treat the remaining wells at this time.

Our estimate for life cycle costs, that is, capital and operating costs, is $2.66 million per year. We compared that cost to other alternatives and one possibility is to group those 11 wells and pipe that water to a central point where the water would be treated. The treatment area could be adjacent to our Jonathan Rogers Water Treatment Plant. The advantage here is that you would have the treatment plant infrastructure in place in terms of the high-lift pump stations and distribution lines to get the water back out of the system.

The other alternative was the Surface Water Forbearance Contracts. We obtain water from the Rio

Grande through leases and ownership of land with water rights that we get primarily from farmers. As a city urbanizes and expands, a farmer often wants to subdivide his land and he has the capability of either selling his land outright to us and we keep the water rights and do something with the land, or he can lease the water rights to us and he can subdivide the land. Those occur typically as 75-year contracts. A forbearance contract will be for a short period of time, one or two years. For instance, if a farmer knows that next year there will be a drought, he might decide not to plant anything this year. But if he wants to retain the ability to plant once the drought is over, he could enter into a contract with us for just that one or two year period to give us the water right for a sum of money. He will then not farm for that time period and we would take that water into a treatment plant.

So basically, a farmer is at greater risk when farming during a drought because of the uncertainty of the water supply. Typically at the beginning of the year, the Bureau of Reclamation and the irrigation districts get together and try to figure out when the water is going to be available and when the farmers are going to need it. All that planning takes place before there is any run-off in the spring. So farmers are forced to plan based on water that may or may not show up – so that is an additional risk factor for the farmer. We will pay the farmer not to farm and have him sell his water rights to us and thus avoid that risk.

We need a timely execution of an implementing contract. In fact, we do have an implementing contract right now. We will need a five-month supply at 8 mgd. One problem that can arise is that you must have some carriage water, especially in the case where no other farmer is irrigating at that particular point in time. Possibly early or late in the season, we could be the only "farmer" ordering water at that time and we would have to have some carriage water to go with it. Another question is whether the water is going to meet potable standards. If we are ordering water at the beginning or at the end of the season, there is a possibility that either sulfate or TDS will be too high to be put into the potable system through our conventional treatment plant.

In terms of costs, we are talking about $216 per acre-foot paid to the landowner with some other fees that bring the total cost up to $263 per acre-foot. This puts the life-cycle cost at $5.10 million.

In order to take advantage of existing infrastructure, central desalination must occur at the J.W. Rogers site. This would require a new treatment plant, brine disposal facilities and supply wells at an estimated capital cost of $20 million and an estimated operating cost of $2.1 million. The main problem is the 36-month design and construction period. When you talk about a single plant to treat 8 mgd, it is a different matter than buying a plant that will treat 1 mgd. You can just about get those plants off the shelf. We have gone ahead and ordered and received through the bidding process the GE/Osmonics system in a matter of two to three months and that included a bonus of an early delivery payment that they did collect of $105,000. Even so, the life-cycle cost of $3.69 million per year is still more expensive than individual wellhead treatment units.

Table 1 provides a summary comparing the three options. The important thing to note is the last line of the summary: the Drought Forbearance is not a permanent supply – it is just a temporary agreement between the farmer and El Paso to take that water.

Comparison Summary

	Drought Forbearance	Central Lower Valley Desal	Wellhead Treatment
Annual Cost	$5.10 million	$3.69 million	$2.66 million
Cost per Acre Foot	$1,357	$982	$708
Cost per Thousand Gals	$4.16	$3.01	$2.17
Online by April 2004	No	No	Yes
Permanent Supply	No	Yes	Yes

Table 1.

Table 2 provides a decision matrix with other factors that we considered. In terms of the Central Project, you must get water from the wells to the treatment plant and that involves property acquisition right-of-way. You must get two TCEQ approvals, and in some cases you need Bureau of Reclamation's approval, particularly for the Drought Forbearance alternative, and from EPCWID #1, which is the El Paso County Water Improvement District #1. This is the farmers' irrigation group in El Paso that controls the supply of water to the farmer and to us as a contractee. Looking at other non-cost decision factors, the wellhead treatment is the more advantageous system. While arsenic treatment will not be required until January 2006, treating these wells now to remove total dissolved solids and remove arsenic produced the additional water supply needed to avoid Stage II drought restrictions in 2004.

Decision Matrix Other Factors

	Wellhead Treatment	Central Lower Valley Desal	Drought Forbearance
Cost	3	2	1
Online by April	3	1	1
Property Acquisition	3	2	3
Right of Way Acquisition	3	1	3
TCEQ Approval	2	2	3
EPCWID#1 / BoR Approval	3	3	1
Water Ownership	3	3	1
Implementability	3	2	1
Operational Issues	2	3	3
Total	25	19	17

Point Scoring - Most Favorable (3) - Least favorable (1)

Table 2.

In terms of financing, we have already issued $65 million in bonds to finance arsenic improvement and our total arsenic bill for El Paso is around $75 million. We were going out for $65 million in bonds and could add these projects to that bond issue. At the time of the original bonds, we were at a 42-year low in interest rates and it was a very attractive time to issue those bonds. We prepared specs during the summer of 2003 and issued bonds at the same time.

The terms of the contracts involved several different things. We had a general contractor come in and complete the site work, including the slabs and the buildings. We had an electrical contractor, mechanical contractor, and, of course, the supplier for the individual treatment units themselves. It took from August to December to do the actual site improvements. Then we installed and tested the units from December through April and had them online in April of 2004.

In summary, advancements in membrane technology have resulted in RO treatment applications for other than salt removal. Several manufacturers now offer package RO treatment plants. We sent bid packages to 11 different manufacturers and received four bids. Those four bids were from manufacturers that could produce the 11 units for El Paso in a four-month period of time. These are good sized manufacturers. After a lengthy national debate, the EPA finalized the Arsenic Rule in 2002. The Texas Commission on Environmental Quality has still not to this day finalized their regulations on arsenic. We had to proceed anyway because we had to meet the January 2006 deadline.

We have initiated pilot plant studies on treatment alternatives to meet new standards. Like Dr. Tarquin pointed out earlier today, he is taking a concentrate from another pilot plant that we are running for the Ft. Bliss/El Paso Joint Desalination Facility. Even after the facility is constructed, there will be a built-in pilot plant specifically for concentrate research. Throughout this process, whether we get the injection well permit or we have to go to the evaporation plants, we will continue to test various technologies for membrane concentrate reuse. We also have various ongoing arsenic and desalination pilot testing that indicates very favorable results at reasonable cost. We are testing various types of media such as iron-based media and aluminum media for arsenic removal. The early results indicate that both the arsenic and salt level can be dealt with very cost effectively.

With that, I'll open this up for any questions.

Question: Mr. Balliew, I'm John Hernandez from upstream in Las Cruces and I like what you guys are doing and think it is a good deal. The water that comes through that RO unit is much better quality than what you typically had in the system. Are you blending right there in the RO unit?
Answer: It's blended right there on the Reverse Osmosis unit. The skid includes a bypass pipe and an electrically operated valve. That system is designed automatically to produce a water of a given quality blended back into the system. We are talking about water being put into the system around 600 mgs per liter TDS.

Question: (John Hernandez, cont.) I wondered if you had any compatibility problems because you chose to remove some of the material out of there, calcium carbonates vs. sulfates or something like that.
Answer: We do have to add sodium hydroxide on the water that is leaving the facility just to bring the pH back up to the same pH as in the distribution system.

Question: (John Hernandez, cont.) Is that after blending?
Answer: Yes, that is after blending.

Question: (John Hernandez cont.) I think that's good. Did you tell the folks what happens to the concentrate?
Answer: That is a good question. This particular concentrate is just going into the sewer. The reason

we are doing this is because it is a relatively small volume where we can split it between two wastewater collection treatment systems. One treatment plant has 27 mgd flow and the other 39 mgd. The effect on both treatment plants is the TDS increase is absorbed within the daily fluctuations. We are talking about maybe a 100 mgs per liter increase on average, but within a given day, the TDS fluctuates more than a 100 mgs per liter per day at those treatment plants. Both are still operating well below the stream standard for the particular segment to which they discharge.

Thank you.

__Eddie Livingston__ is President and Principal Engineer of Livingston Associates, P.C., a consulting engineering firm specializing in water resources and headquartered in Alamogordo. Eddie has a B.S. degree in civil engineering from NMSU and an M.S. degree in water resources engineering from UNM. Eddie has more than 20 years of experience in various aspects of water resource planning, design and construction/ operational phase services for more than 75 projects, including: water and waste water treatment, wells, pumping stations, storage, distribution systems and supply source development. His experience includes domestic as well as overseas assignments.

WHITE CLIFFS MUTUAL DOMESTIC WATER USERS ASSOCIATION REVERSE OSMOSIS WATER TREATMENT

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This morning I'd like to present to you a success story of the first water system in the state to use desalination in their drinking water supply: the White Cliffs Mutual Domestic Water Users Association (MDWUA). The White Cliffs MDWUA is a small water association just east of Gallup. They have about 40 connections, about 40 families, and serve 150 residents. It is a low-income Navajo community and their demand is about 15,000 gallons per day. Before the desalination facility was put into use, the majority of the residents purchased bottled water for drinking and cooking because of the poor quality of their water supply. Also, most residents have water softeners at the same time to treat the water for use within their households.

The water quality of existing wells is about 5,000 uS/cm of E-cond., total dissolved solids (TDS) of 3,400 mg/L, pH of 7.9, hardness of 172 mg/L, and sulfates of 1,720 mg/L. You can see this is not very palatable drinking water. Their water supply comes from three groundwater wells. Two wells are used primarily and are at 5,200 uS/cm with high TDS and high conductivity. Well 3 is used only occasionally because of its low production rate. The TDS and conductivity of Wells 1 and 2 tend to vary throughout the season depending on how much and how long they are being pumped. The wells pump into a storage tank that is gravity fed into the system. Occasionally the wells experience a sediment problem when they get plugs of sand and turbidity increases in the water supply.

About a year ago, the new owner of the water supply realized something needed to be done to make things better for the residents and he wanted to reduce the expense the customers were experiencing by purchasing bottled water and using water softeners. Given the high level of total dissolved solids and the variable water quality in their supply, along with a concern about arsenic in their water system, they decided to have their water supply treated. They came to us with their problem and we decided to use reverse osmosis to reduce their TDS as well as to reduce the arsenic. We found reverse osmosis showed excellent TDS reduction, greater than 80 percent recovery as well as a reduction in arsenic. This was done at a reasonable capital cost and a reasonable overall cost of water.

For those of you unfamiliar with reverse osmosis (RO), let me describe the process. In the natural system there is a process called osmosis where fresh water permeates through a semi-permeable membrane, such as a cell wall in plants and animals, into a more salty environment. It does so through osmotic pressure. If you go the other way, you reverse that osmotic pressure by putting a salty solution through a semi-permeable membrane to get fresh water. Figure 1 depicts these two processes.

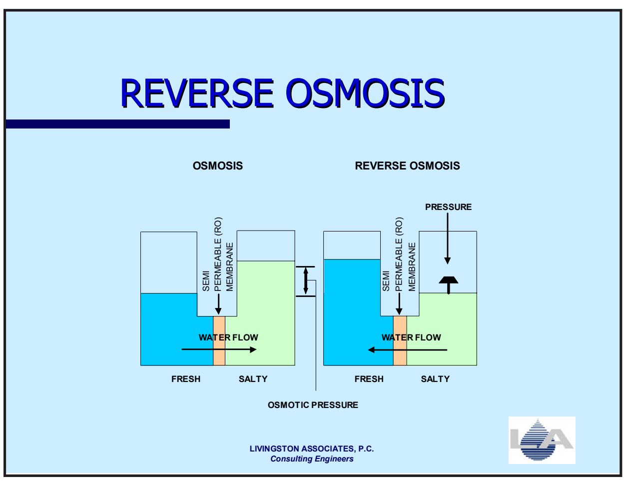

Figure 1.

Typically in a RO membrane situation, you have the RO membrane that is represented by the yellow line in Figure 1. That is a plastic material, a polyamide material. The mechanisms for removing salts or minerals out of the water are a number of different processes but the primary one is called a screening process where the holes in the membrane surface are small enough to let water molecules pass through, but salts and minerals, being large, cannot pass through the membrane. On the feed side of the membrane, which is where you are applying the water supply, you force the water through the membrane under high pressure and you get what is considered drinking water quality (similar to bottled water) out of the permeate side of the membrane. On the feed side of the membrane, the concentrated salts remain. This is a general description of how the reverse osmosis process works. Some terms that you may need to be familiar with:

1) Feed water is the supply water to the RO membrane system
2) Permeate is the drinking water quality that comes out of the low pressure side of the membrane, the drinking water.
3) Brine, or the more widely accepted term, concentrate, which has a less negative connotation to it than brine, is the terminology for the rejected salt stream.
4) Recovery is the amount of the initial water you get back as product water. If you put 100 gallons of water through the system and you get 75 gallons of treated water back out, the recovery is 75 percent.
5) Rejection is the percentage of the salts that do not pass through the membrane and are rejected by the membrane.

Figure 2 shows a typical RO system. You would pump your groundwater well water through another high pressure pump and send it through some pretreatment before it goes to the RO system. Typically, sediment filtration removes any sediment that could potentially plug the membrane. You would feed some chemicals to the feed stream, either acids or scale inhibitors, to pre-treat the water. The water is then sent through the RO assembly and the permeate comes out the other side. The permeate then is often treated with a buffering chemical and the pH is adjusted. It then goes to the distribution system where the concentrate would come off for disposal. You might also have a bypass line that would pass around the treatment process and blend back into the permeate because you might not necessarily want to supply the system with “bottled water” quality water. The bypass will blend in some untreated water to get the salt level or mineral content back up to an accepted level, thereby increasing the overall recovery of the RO system.

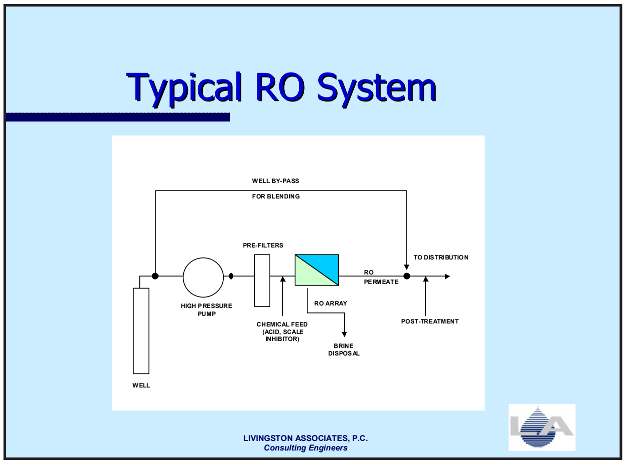

Figure 2.

Figure 3 shows what a typical small RO "Skid" looks like. In this particular case, you can treat about 30 gpm through the skid. This skid has six tubes that house the 18 reverse osmosis elements. This is set up in a 2:2:1:1 array, which I will talk about in a minute. The RO elements are 4" x 40" and each one of the RO tubes or housings will hold three elements. It has a Clean-in-place (CIP) System that is very operator friendly and low-tech type controls that are also easy to operate. It is not a very complicated or big system.

Figure 3. Typical Small RO "SKID"

The typical 2:2:1:1 RO array (Figure 4) is used for high recoveries. The feed water comes in and is split between the first tubes 1 and 2, and the permeate (or drinking water) comes off and is collected in the permeate tube. Coming out of the first two tubes is the concentrate that then gets fed as feed water into the next set of tubes, so you are continually retreating the concentrate until you get the desired water quality. Once again, the permeate comes off from tubes 3 and 4 and is collected; then the concentrate comes back out as feed water into tube 5; the concentrate comes out and is finally fed into tube 6 resulting in the final concentrate that is then disposed. The final permeate is collected and blended from all the tubes.

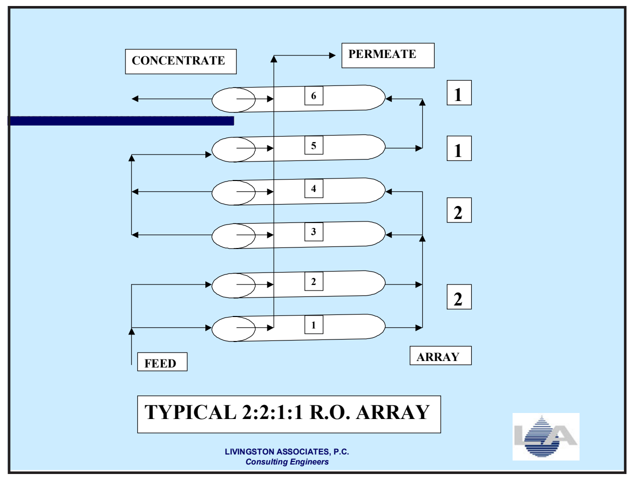

Figure 4.

Figure 5 shows Patrick, the operator of the White Cliffs RO Plant, taking data. He doesn't spend a lot of time at the plant, but does take data on a daily basis. You can see that this is a small plant and a building has been built to house the RO skid.

Figure 5. White Cliffs RO Plant

So how does the system perform? The TDS went from about 3,400 mg/L to less than 150 mg/L. It is operating at a feed pressure of about 115 psi, which is a low feed pressure for brackish water. The feed flow is at 12 gpm and the product flow is at about 10 gpm and is unblended; they use a straight permeate. The concentrate flow is at about 2 gpm and their recovery from the system is at 85 percent with the overall salt rejection of about 95 percent. This system performs very well.

Figure 6 shows a graph with the conductivity of the feed water, which is about 5,000 and product water of about 200, with the concentrate at about 15,000 or so. You can see where the salts were removed and where they were collected in the smaller stream. The product water shows a tremendous reduction of TDS and minerals in the water. The water did need to be pre-treated before the RO array and a scale inhibitor was added to control the saturation levels to allow for a higher recovery in the water. Pre-filtration was used through some five-micron filters to reduce the silt density index and any colloidal material that would be in the water so that the membranes would not plug up on the front end.

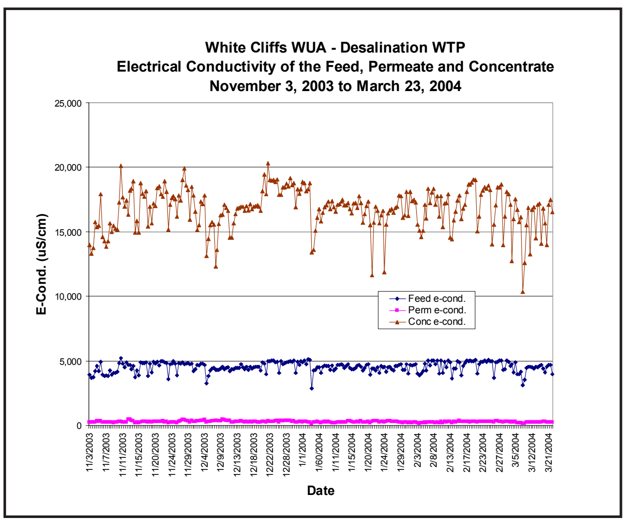

Figure 6.

Membrane scaling is really what controls what you can obtain from an RO system. If you think about a glass of tea (and I like to use this example because it is very descriptive), and pour a package of sugar into it and stir it, the sugar disappears. Then you add another package of sugar and if you are like some of us, you keeping adding sugar until the sugar doesn't dissolve anymore and it accumulates at the bottom of the glass an inch deep, and then you quit adding sugar. What happens is that the tea has been saturated with sugar and can't hold anymore so it stays on the bottom or it precipitates out and doesn't allow any more sugar to be dissolved into the tea. This is similar to what happens in an RO system when you get to the final stage: that final last tube #6 and all the salts that have been concentrated in the stream as feed. If you go beyond the saturation of those minerals, it will precipitate and you can get scaling on the membrane surface. This particularly happens with calcium sulfate and calcium carbonate, and it would cause scaling on the very last set of membranes. This will cause the operating pressures to increase and your recoveries to decrease.

RO membranes are cleaned with a low pH (pH 3-4) cleaner to remove scale build up in the tail-end elements. The high pH (pH 10-14) cleaner is used to remove any organics or colloidal fouling in the front-end of the system. Cleaning takes place at 6-month intervals. This system started up last November and they are just getting ready to do a second Clean-in-Place.

So what is done with the concentrate? The electrical conductivity as I've mentioned is about 15,000 and they generate about 2,500 gpd of brine flow a day. This is being discharged into the sewer system and they are making the overall conductivity of the wastewater "whole" again. If you think about it, you are taking high TDS water, treating it to basically bottled water quality, and that water goes through to the residences. There is very little landscaping to speak of, so the water is used almost exclusively for internal domestic use. That water comes back out as domestic waste and the RO concentrate is put into the sewer. When you combine it back again, the overall TDS is almost the same as it was when they started the process. Actually, they are finding that in some cases, the overall salt balance is less because many people are now off of their water softeners and the regenerate from those softeners was where the extra chlorides got into the wastewater stream. Treated effluent is sent into an evaporation pond where the wastewater is disposed of. The evaporation pond uses natural evaporation to dispose of the discharge and every so often, a series of sprayers are used to enhance the evaporation.

Figure 7 shows the disposal pond with the sprayers operating. Currently, the wastewater treatment system is being upgraded and they may decide to split the

Figure 7. Concentrate Disposal

streams and do something beneficial with the concentrate from the RO system.

The capital costs for this project was about $60,000, which included the complete RO system, the building, and a storage tank. That comes to about $2.50 per gal/day capacity for the installed plant. Operational costs amount to about $2.31/1000 gals, with most of that attributable to power costs of $1.89/1000 gals. The power cost is an estimate because they combine the power for the supply wells with the power used at the treatment plant. They don't have separate meters for each.

Patrick, the operator, spends about a half an hour a day at the plant checking the chemical levels in the scale inhibitor tank and recording data for that day. He comes back in the evening and checks the readings again. The estimated life of the membranes is about five years with proper care and cleaning performed at 6-month intervals.

The White Cliffs MDWUA is to be congratulated. They recently were awarded for having the best tasting drinking water in New Mexico by the Rural Water Users Association at their annual conference in March. The association is very pleased that they have done something right and that the residents are happy with their water. I have been told that water use is starting to increase because the residents are so happy with it – I guess this is to be expected. This is a success story for White Cliffs and they are now looking at possibly expanding and bringing in another system.

Thank you.

***Bill Hutchison** has more than 20 years of experience as a hydrogeologist and is licensed as a Professional Geoscientist in Texas. He has been with El Paso Water Utilities for about three years. Bill has a B.S. degree from University of California at Davis and an M.S. degree from the University of Arizona. Bill has worked on several water resource management issues throughout the western U.S., including Owens Valley and Mono Basin in eastern California.*

EL PASO'S DESALINATION EFFORTS

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Thank you for the introduction. Today, I would first like to give you an overview of El Paso's water supply. Then more specifically, I will talk about the Hueco Bolson, which is where a lot of our water comes from. I will describe how we are managing groundwater in the basin, mainly in the context of the groundwater budget and what that budget tells us about how we are managing the basin and how we used that information to design the desalination plant. It represents a very unique opportunity in groundwater management.

As many of you probably know, we get our water from three sources: the Rio Grande; the Hueco Bolson, which is on the east side of the Franklin Mountains; and the Mesilla Bolson, located on the west side of the Franklin Mountains. El Paso has two surface water plants: the Canal Plant in downtown El Paso and the Jonathon Rogers Plant in the southeastern part of town.

Figure 1 shows the Hueco Bolson, east of the Franklin Mountains, which on this map is the greenish/reddish area. The small red dots represent wells in the area, of which there are several. We started pumping water in the Hueco in 1903. On the west side of the Franklins in the Canutillo area, we have a few wells in the Mesilla Basin, represented by the yellow dots.

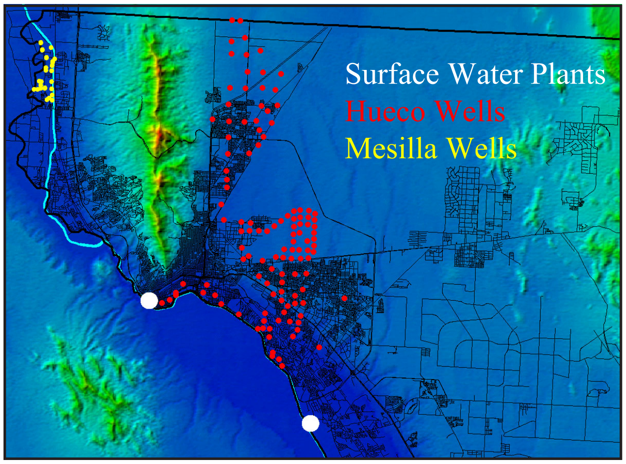

Figure 1.

Figure 2 provides the amount of water we have taken out of these three sources since 1967. Note a couple of things here. Red represents the Hueco and notice in 1989 we had peak pumping at about 80,000 acre-feet/year. Since then, the pumping in the Hueco has dropped over time to where it hit a low of a little less than 40,000 acre-feet/year in 2002. Also note that during that period, surface water diversions increased. Note that the overall demand had been flat or declining somewhat. The year 2003 is a bit of a unique situation because of the drought. Since 1989, our demand has been flat at about 120,000 acre-feet/year. But during that time, our per capita demand has dropped from over 200 gallons per person per day to less than 150. That is largely a result of a new rate structure and conservation programs that have been put in place as well as our increased use of reclaimed water.

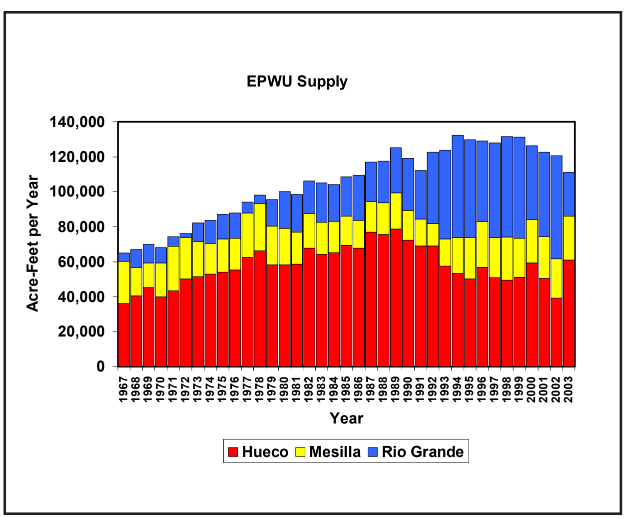

Figure 2.

In terms of the Hueco and the groundwater management programs with which we are dealing, we are facing two major issues: declining groundwater levels and brackish water intrusion. Figure 3 shows the Hueco Bolson extending up into New Mexico and down into Mexico. In Texas, the Hueco includes most of El Paso County and extends a bit into Hudspeth County.

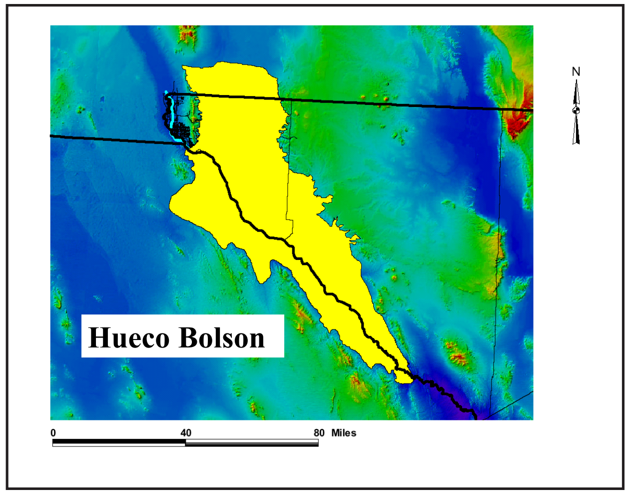

Figure 3.

In the cross-section on Figure 4, we see that the Hueco Bolson is a very deep basin bounded by the Franklin Mountains on the west and the Hueco Mountains on the east. Note that in the upper zone, there is a fairly thin lens of fresh water that seems to be the deepest at around 1200 feet thick. We have not touched the bottom of the fresh water in some places but it is thought to be about 1200 feet thick at its deepest; below that is brackish water. To the east is brackish water.

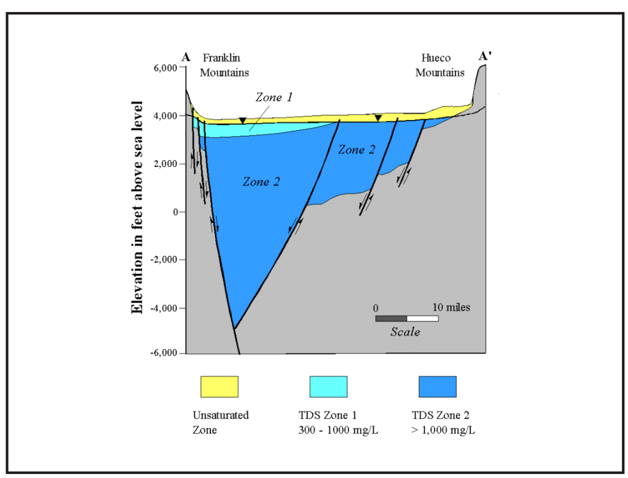

Figure 4.

Over time, a lot of pumping has been done in the Hueco since we started pumping in 1903. The result has been a decline in the water level. Along the airport area, we have had a decline of over 60 feet since 1960. But in that area, since 1990, the water levels have been relatively flat. That coincides with the period when we reduced our pumping in the Hueco. Many wells in the area have exhibited similar stabilization of water levels since the reduction of pumping started in 1989.

Historically, we can look at the drawdown in the Hueco in terms of the water level between any particular year and 1903. The map on Figure 5 shows four classes of drawdowns. Prior to World War I, little pumping took place. Then suddenly we started seeing between 10-15 feet of drawdown in El Paso as the city developed. As we get into the World War II, Juarez begins to put wells in and water levels begin to decline. By that point, we see the 50-ft contour starting to extend outward and we start seeing 50 to 100 feet declines, which are now 100 to 150 feet drawdowns. Juarez is now pumping quite a bit of water and has considerable drawdown. In 2002, Juarez had between 150 and 200 feet of draw-down in comparison to 1903 water levels, although a good chunk of El Paso declines have been in excess of 100 feet based on 1903 levels.

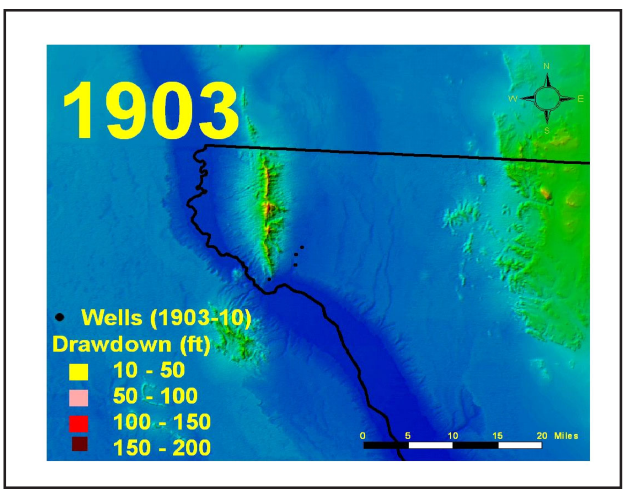

Figure 5.

What has happened as a result of this draw-down? Brackish water surrounds the fresh water as we saw in the cross-section on Figure 4. When water levels are lowered, water is drawn into it causing brackish water to seep into wells that had historically pumped fresh water (Figure 6).

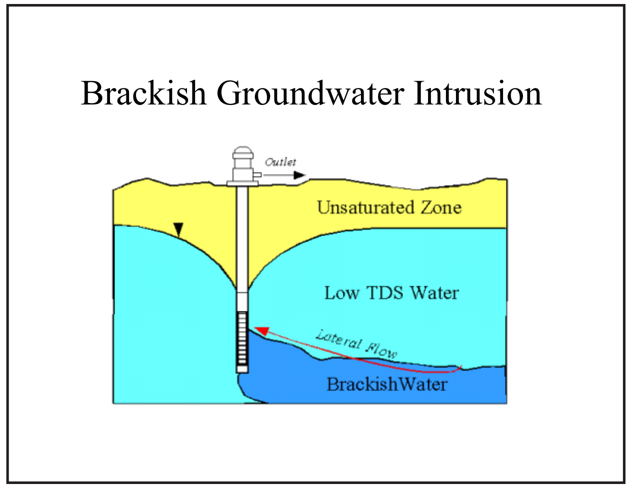

Figure 6.

For example, wells in the airport area have become brackish over time. Figure 7 indicates wells (in red) that have not been in operation over the last five years as a result of brackish water intrusion. The wells in yellow still operate, primarily in the northeast as well as some at the airport. Brackish water intrusion continues to be a challenge and a problem.

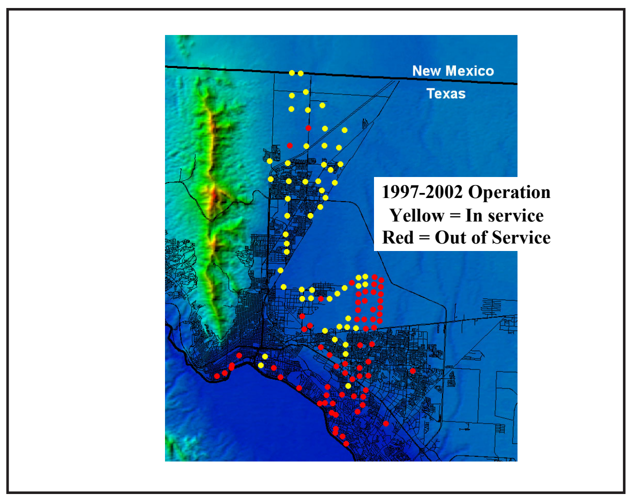

Figure 7.

Also, chloride concentrations have increased over the years. For example, Well 39, which is located near Fort Bliss and the airport, had chloride concentrations between 50 and 100 back in the 60s and 70s but since that time, the concentrations have increased steadily. If you use a scientifically appropriate approach and drop a straight line on a trend like that of Well 39, you get a sense of when the chloride concentrations will hit the 250 mg/L mark and that turns out to be around 2020. In other words, if we do nothing, Well 39 is going to go brackish in about 20 years.

In terms of our overall groundwater management efforts, we have taken many steps to stabilize groundwater levels in a lot of areas but brackish water intrusion remains an issue. Our groundwater budget is a result of developing a groundwater model of the area to help us understand what opportunities exist for additional groundwater management. A groundwater budget is an accounting of all the in-flows, out-flows, and storage changes in a system.

I want to present a brief summary of the El Paso portion of the Hueco (Fig. 8). We receive inflows from across the state line, coming in from the east along with a little bit of recharge from the Franklin Mountains. Outflows go to Juarez. Thus, to the east, during pre-development times from 1903 through the 1950s, water was actually moving out toward the eastern boundary. But as pumping increased, water levels were drawn down, the flow reversed, and flow was drawn in to the point where now, about 8,000 acre-feet of water is being drawn.

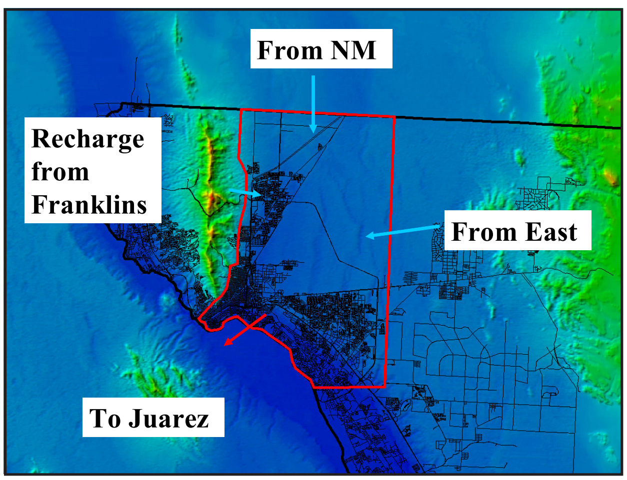

Figure 8.

What are the implications? Figure 9 contains a map of freshwater with dark blue representing chloride under 250. You can see where the water is being drawn in, the source of the brackish water intrusion. That represents the groundwater management challenge that we face.

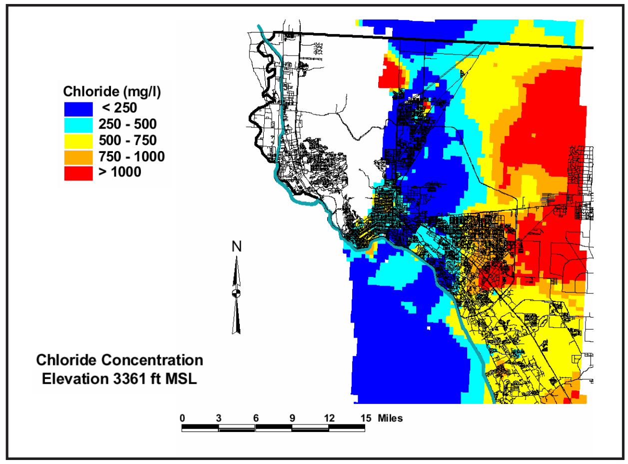

Figure 9.

In terms of storage decline, very slight declines occurred through the 40s and 50s. A spike occurred to about 50,000 acre-feet/year of storage decline up until about 1989. In more recent years, we have backed off that decline so that storage declines have become less of an issue. The inflow increase from the east is the source of the brackish water intrusion.

Storage declines have been reduced and now we have to deal with the question of what we are going to do with the brackish water. We do not want to increase pumping; we have that under control. But how do we deal with the brackish water?

Enter the joint desalination facility with Fort Bliss. At one time, El Paso looked at building a 20 mgd plant and Fort Bliss was contemplating a 7.5 mgd plant. People started talking and decided it might be a good idea for us to build a 27.5 mgd plant together. The plant is currently in design and will be located along with some of the wells at Fort Bliss. The concentrate disposal method, described earlier by Tony Tarquin, will be used in which the concentrate will either go through an injection well or be evaporated.

Figure 10 shows the area where the facility will be located. Note the source wells (in yellow) that will be used to supply the plant. The water from those wells (about 18 mgd) will go through the plant with the permeate blended with water from wells along Route 375 on Fort Bliss (indicated as blue dots on the map). The plant is located at the bottom of the figure. Blended water will go to the distribution system with the concentrate either going to a very large 700-acre evaporation pond or will follow a route to an injection well site. As I mentioned earlier, 15 feed water wells will generate about 18.5 mgd. The 16 blend wells located on Fort Bliss will blend with the permeate of about 12 mgd. The yield will be about 27.5 mgd of water to the distribution system and about 3 mgd of concentrate.

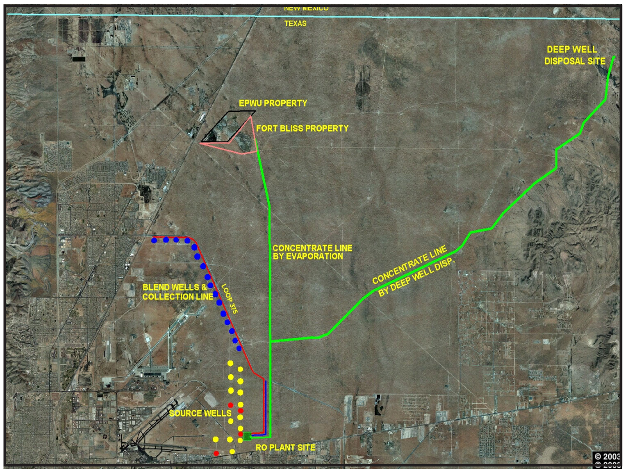

Figure 10.

We looked at two basic scenarios when planning for desalination development. What happens if we do nothing? What happens if we put in a joint desalination facility with blend wells at the Fort Bliss location, in terms of the groundwater flow patterns? Figure 11 shows the flow pattern in the base case, if we basically continue to do what we are doing now. The black dots represent our current wells. Note where the state line is and we can see that water is still going to be drawn toward these wells from basically all directions. The blue area represents fresh water with the lighter blue area still representing basically fresh water but now getting more brackish. The brackish water will continue to move in this direction (darker blue area) and continue to cause salinity increases in those wells. If we take the same amount of pumping of about 40,000 acre-feet/year and instead of spreading it over all these wells, we concentrate about 75 percent of it into the wells associated with the Joint Desalination Facility, notice that the water from the outskirts will still be drawn in (Fig. 12). However, on the back side, we now have a situation where the wells in the airport area will be fed from the north, which is fresh water. Essentially, we create a trough that intercepts the brackish water, treats it, and uses it in the system thereby saving the wells. The groundwater in this area will then be available for future contingency use and droughts.

The question then becomes, what do we do with the concentrate? The cost estimates (even with Tarquin's concentrate) of evaporation are quite expensive. If you could find a suitable geologic

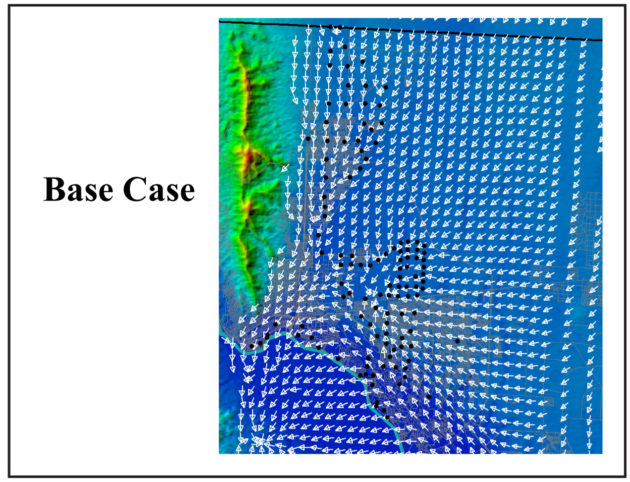

Figure 11.

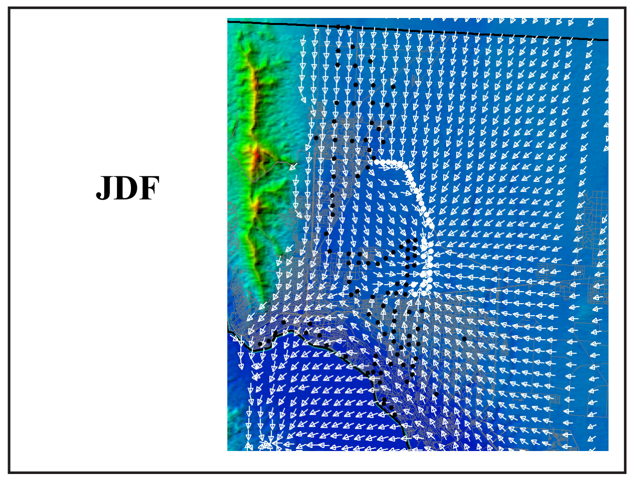

Figure 12.

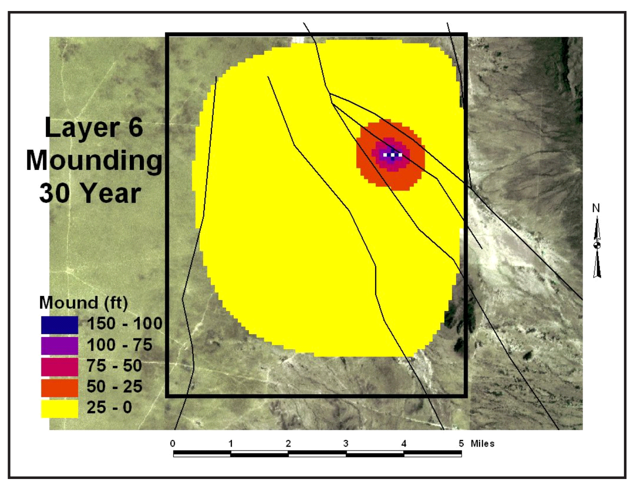

Figure 13.

formation, assuming you could obtain a permit, it is a much more economically viable option for disposal. We have focused our efforts on an area by the state line and completed a pilot well in the area last month. The well was located based on test hole drilling that was done in 2003 under a contract with the Army. We completed the well to 3,770 feet within dolomite limestone in the Fusselman Formation, which is of Silurian age. The perforated casing is a liner between 2,300 and 3,770 feet.

We obtained some nice pieces of the dolomite that we carry around and show people. They often say, "Well, this is nice but where does the water go?" The dolomite samples were fairly non-representative. Most of what we found was busted-up rubble as this is a pretty nicely fractured formation. Our testing indicated that it was quite permeable and took the water quite well. Our preliminary results encouraged us to use the testing results that we did in the well to simulate full injection of the operation on a preliminary basis. We are still in discussion with TCEQ about getting a permit. Based on test results, it looks like we can take care of all the concentrate in three wells in this area. We assume an injection rate of 4.5 mgd instead of the 3 mgd that the plant is supposed to have. A lot of that has to do with the potential need to dilute. A variety of reasons exist for us to be conservative but we decided to run the simulation at 4.5 mgd. The simulation consisted of putting in wells in an area of 5x6 miles. The geology that has been worked out shows these fault block structures at depth.

After 30 years we are seeing something on the order of less than 150 feet of build-up and the static water level is 500 feet below the surface (Fig. 13). We see about a 150 foot rise after 30 years and basically less than 25 feet of rise through a good part of this area.

We have already written the Environmental Impact Statement (EIS) for this project. Because this is a joint project, the Army will grant us easements to build the plant and run pipelines. This project is considered a federal action so the Army is preparing an EIS. The EIS is currently out on the street with the comment period ending on the 27th of this month. We hope to get a Record of Decision turned around by early 2005 and to get a TCEQ permit for the injection well sometime in the spring of next year. Once the Record of Decision is issued, we can start on the construction of the plant, pipelines, wells, and so on. We hope to get the plant started up in the fall of 2006.

Question: What do you have left to do to get the Class I permit from TCEQ? At one time there was an option to go through the Railroad Commission. Do you wish you had done that at the time?

Answer: The decision on Class I or Class V permit has not been formally made. We found that in the receiving formation, the Fusselman Formation, the TDS is about 8,700 ppm, which is below the magic number of 10,000, which means it is an underground source of drinking water making it eligible for a Class V permit. The Class V permit process is a lot less cumbersome in terms of the hearing reviews. Another bit of good news associated with a formation of 8,700 ppm: since our concentrate going in right now is at about 6,800 ppm, we would actually be improving an underground source of drinking water. We hope TCEQ agrees with us on that score. As far as the Railroad Commission question, if we can get a Class V permit through TCEQ, we would be thrilled.

Question: This question is for both you and Tony Tarquin. Tony mentioned costs per 1000 gallons for taking the concentrate and further working it down….. How do the costs of evaporation ponds and injections wells compare to the additional treatment Tony mentioned? What was it $1.50 per 1000 gallons?

Answer: I have not broken it down in terms of dollars per 1000 gallons. What I can tell you is that right now, we are looking at the potential for something on the order of $8 million for the wells. I think Tony's evaporation process is on the order of $17 and I think the actual full-scale evaporation is closer to $20. On a capital basis, this is by far the best way to go.

Gerald (Jerry) Johns *was appointed Deputy Director of Water Resources Planning and Management of the California Department of Water Resources (DWR) by Governor Arnold Schwarzenegger on August 2, 2004. He had been serving as the acting Deputy Director since January 2004. He was the Assistant Division Chief of the Division of Water Rights for the State Water Resources Control Board for 14 years prior to joining DWR. Jerry has many years of experience in both water rights and water quality. During his more than 26 years at the Water Board, he worked on numerous issues, some that were controversial. In June of 2001, Jerry left the Board to become the Chief of the newly created Water Transfers Office of DWR. Jerry was also responsible for programmatic activities related to DWR's Environmental Water Account and the State's Dry Year Program. As Deputy Director, Jerry oversees statewide programs for DWR including Water Supply Planning and Local Assistance and the four DWR Districts, Bay-Delta Office, Environmental Services, Water Use Efficiency, and Water Transfers, Colorado River and Salton Sea. Jerry earned both his M.S. in freshwater ecology and B.S. in zoology from the University of California, Davis.*

STATEWIDE WATER SUPPLY: WHY DESALINATION?

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Introduction

Brackish water and seawater desalination has evolved into a viable water supply alternative in over 120 countries around the world. Figure 1 shows the worldwide trend in desalination technology.

Desalination is becoming an integral part of California's future water supply portfolio. It is estimated that California's population will increase by 12 million by the year 2030. Other factors contributing to California's water supply challenges include climatic changes, the imminent compliance with the Colorado River 4.4 plan, successive and extended periods of drought, and the growing need for environmental and ecosystem restoration.

Water conservation, water recycling, and most recently desalination are gaining considerable attention from scientists, resource planners, policy-makers, and other stakeholders in addressing supply reliability in California. The main driving force for the renewed interest in water desalination is the remarkable technological advancement in desalination processes particularly membrane technology and energy recovery equipment, which has recently led to a much lower cost of desalinated water than 15 years ago. Figure 2 shows the trend in seawater desalination cost over the past 30 years. Desalination has the potential to offer an alternative water supply that is more reliable and drought proof, bringing about a diversified and more secure water resources portfolio for many local areas of the state.

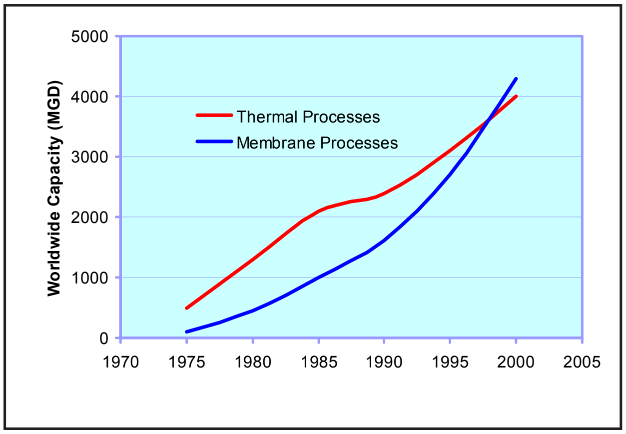

Figure 1. Trend in Worldwide Desalination

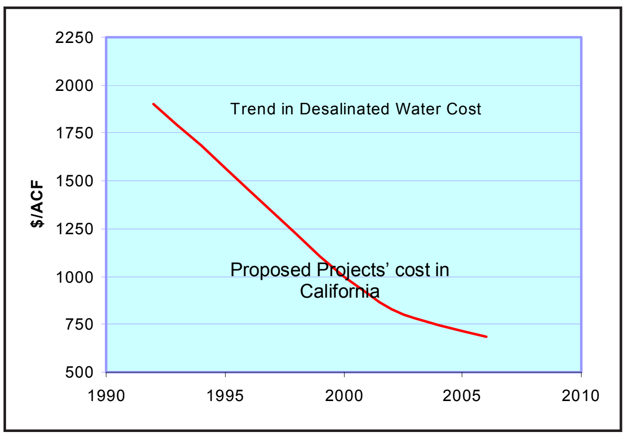

Figure 2. Trend in Desalinated Seawater Cost

The State Legislature recognized the future importance of seawater and brackish water desalination through legislation. In 2002, the Legislature approved Assembly Bill 2717 (Robert Hertzberg). The bill asked the Department of Water Resources (DWR) to convene the California Water Desalination Task Force to look into potential opportunities and impediments for using ocean water and brackish water desalination, and to examine what role, if any, the State should play in furthering the use of desalination technology. The report containing the Task Force findings and recommendations was prepared with significant input from its members comprised of representatives from twenty-seven organizations. The Task Force outlined key findings that provide context for evaluating desalination. The findings included some facts and figures about brackish and seawater desalination in general and highlights of several environmental issues as well as cost, energy, and permitting issues related to desalination.

One of the primary findings of the Desalination Task Force is that economically and environmentally acceptable desalination should be considered as part of a balanced water portfolio to help meet local areas existing and future water supply and environmental needs. The Task Force forecasted that the potential for the increased use of desalination in California is significant and that the opportunities are great for providing water supply from seawater and brackish water desalination as well as recovering contaminated groundwater.

Current and Potential Desalinated Water Use in California

Californians have used desalinated water since 1965. Desalinated water use is expected to dramatically increase in the near future as water agencies need to supplement their water supplies. Today, California's water agencies and industry desalinate annually about 50,000 acre-feet and most of this is brackish water desalination.

Although most estimate that desalination will contribute less than 10 percent of the total water supply needs in California, this still represents a significant portion of the State's water supply portfolio. There is a potential of about 0.5 million acre-feet of additional desalinated water by the year 2030. Of that amount, about 0.2 million acre-feet would be ocean water desalination. This potential of new water could meet the household water demands of about 20 percent of the additional 12 million Californians projected by 2030. However, such potential is contingent upon a capital investment of 0.9 to 1.9 billion dollars. Figure 3 shows the range of water supply benefits presented in the draft California Water Update Plan, which is being finalized.

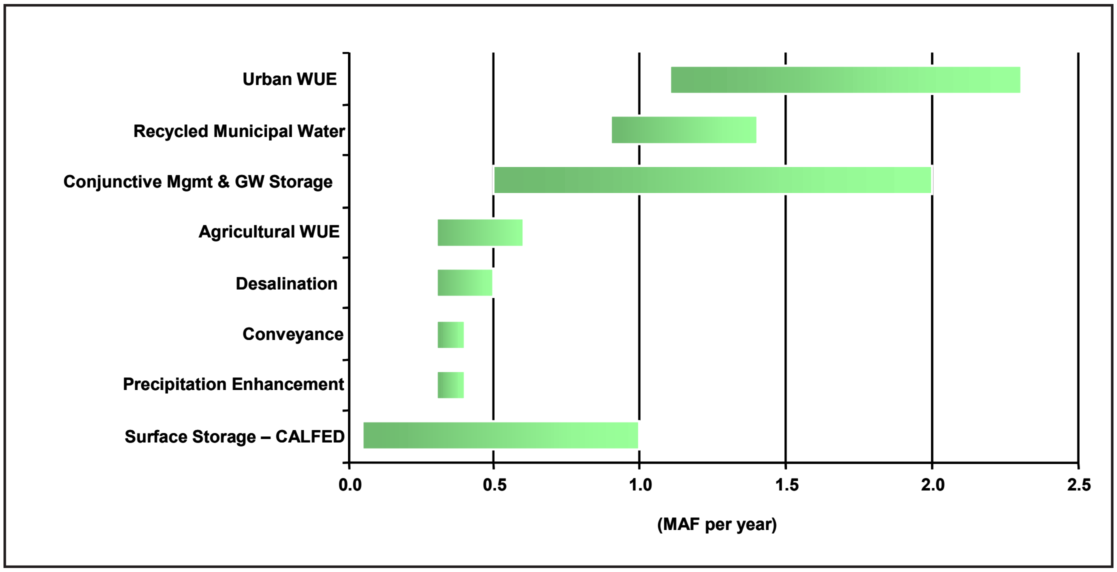

Figure 3. Range of Water Supply Benefits

Major Issues in Desalination

Cost – Desalination has historically been prohibitively expensive. The improvements in technology and the rising cost of conventional water supplies have made desalination competitive with importing water and recycled municipal wastewater in a number of cases. However, cost is still an issue to consumers. The cost will be influenced by the type of feedwater, the available concentrate disposal options, the proximity to distribution systems, and the availability and cost of power. In some cases, the higher costs of desalting may be offset by the benefits of increased water supply reliability and/or the environmental benefits from using desalination for a water supply instead of other sources that could place further stress on fresh water environmental reserves.

Environmental impact & permitting – Brackish water desalination plants have fairly routine environmental and permitting requirements. Coastal desalination plants, however, face much closer scrutiny. With a location within the coastal zone, and with the need for water intake and outfall structures, there will be considerable reviews by numerous agencies and organizations.

Seawater intakes – Existing seawater intake systems for power plant cooling are proposed as the source of supply for almost all of the currently proposed desalination plants. These existing intake systems can have impacts on the coastal zone. Addressing these issues may limit the potential capacity of seawater desalting on the coast.

Concentrate discharge - Desalination plants of any type produce a salt concentrate that must be discharged. Brackish water plants in California discharge their concentrate to municipal wastewater treatment systems where they are treated and blended with effluent prior to discharge. Seawater desalination produces a concentrate approximately twice as salty as seawater. In addition, residuals of other treatment chemicals may also be present in the brine. The plants currently being planned would utilize existing power plant outfall systems to take advantage of dilution and mixing prior to discharge. Studies have been conducted for a number of proposed coastal desalination plants and others are currently underway. The availability of power plant cooling systems to dilute the concentrate prior to discharge to the ocean will also be affected by the future of coastal power plants as discussed in the prior section.

Energy use – Desalination's primary operation cost is for power. A 50 mgd seawater plant (approximately 50,000 acre-feet per year assuming operating 90% of the time) would require about 33 MW of power. The reduction in unit energy use has been among the most dramatic improvements in recent years due to improvement in energy recovery systems. For comparison, the current energy costs of desalination along the southern coastal areas of California is about 30% greater than the energy required to import water from northern California.

Growth-inducing impacts – In a number of locations, primarily coastal communities, the availability of water has been a substantial limitation on development. Desalination on the coast is now a much more affordable option in comparison to the past. The lack of water may no longer be as strong a constraint on coastal development as it once was. Population growth along the coast would lead to increasing pressure on coastal zone resources. These are local issues that need to be addressed by the local communities.

Water rights – Proposed private desalination operations raised concerns among some public officials and advocacy groups, who worry that ocean water as a public resource will be exploited for private profit and sold to the highest bidder. In addition, multinational companies could try to use international trade agreements to get around local and state environmental regulation. This raises the issue of water rights. Under the Porter-Cologne Water Quality Control Act, the State Water Resources Control Board (SWRCB) has the ultimate authority over water rights and water quality policy of the State. In accordance with its water rights responsibilities, the SWRCB has the authority to amend water rights. Water rights are likely not needed for proposed desalination facilities using water from the open ocean, but may be needed by facilities proposing to use water from enclosed or semi-enclosed areas, such as bays or estuaries, or saline groundwater. Applicant and lead agencies should contact the SWRCB to determine whether a specific desalination project will require a water right (California Coastal Commission, March 2004 Seawater Desalination and the California Coastal Act report, page 92).

Proposition 50 Water Desalination Grants

In November 2002, California voters passed Proposition 50, the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002. Chapter 6 of Proposition 50, entitled Contaminant and Salt Removal Technologies, allocates the sum of $100 million to be available for grants for seawater and brackish water desalination projects as well as projects for treatment or removal of contaminants such as MTBE, NDMA, perchlorate, and other emerging contaminants. The California Department of Water Resources administers a $50 million desalination program for seawater and brackish water desalination projects under Chapter 6(a). The program provides grants for construction projects as well as research and development, feasibility studies, pilot and demonstration projects. This grant program aims to assist local public agencies with the development of local water supplies through brackish water and ocean water desalination. A Proposal Solicitation Package and application submittal guidelines was released for the first cycle of this program on 10-25-04. It is posted on the Department's website at: http://www.owue.water.ca.gov/finance/index.cfm.

Fifty million dollars in grants under Sections 6(b) and 6(c) covering the treatment and removal of contaminants and disinfection technologies will be administered by the California Department of Health Services.

Summary

Water conservation, water recycling, and most recently desalination are gaining considerable attention from scientists, resource planners, policy-makers, and other stakeholders to address water supply reliability issues in California. The main driving force for the renewed interest in water desalination is the remarkable technological advancement in desalination processes which has recently led to a much lower cost of desalinated water than fifteen years ago.

Desalination has the potential to offer an alternative water supply as part of a balanced water portfolio for many areas of the State. In California, it is reported by the California Water Plan update, that desalination has a potential to generate about 0.5 million acre-feet of additional desalinated water by the year 2030. Of that amount, about 0.2 million acre-feet would be ocean water desalination. This potential of new water could meet the household water demands of about 20 percent of the additional twelve million Californians projected by 2030.

The California Desalination Task Force identified the potential water supply benefits associated with the increased use of desalinated water as well as the challenges facing California in regard to it. The Department of Water Resources will continue its efforts to provide technical and financial assistance to pursue desalination as an important water supply strategy for California's diversified water portfolio.

Michael D. Norris *is the technical manager for the Bureau of Reclamation's Yuma Desalting Plant and the plant's Salinity Control Research program. He is the director of the Water Quality Improvement Center (WQIC), Reclamation's field test lab on the lower Colorado River. Mike has worked for Reclamation since 1991 in the area of plant engineering and water research. He earned a bachelor's degree in electronic engineering in 1984 from DeVry University.*

RESEARCHING WAYS TO STRETCH WESTERN WATER SUPPLIES

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HISTORY OF THE YUMA DESALTING PLANT AND WATER QUALITY IMPROVEMENT CENTER

In 1961, Wellton-Mohawk Irrigation and Drainage District (WMIDD) started discharging saline water from drainage wells (average salinity of 6,000 parts per million [p/m]) to the Gila River, which in turn drains into the Colorado River upstream of the Northerly International Boundary (NIB) with Mexico. Also at this time Reclamation was filling Lake Mead in anticipation of the completion of Glen Canyon Dam, so excess deliveries to Mexico were reduced and less water flowed down the Colorado River to dilute the WMIDD return flows. As a result of these actions, the salinity levels in water delivered to Mexico at the NIB increased to, at times, more than 2000 p/m. Mexico's objections to these high salinity levels led to negotiations and resulted in the Colorado River Basin Salinity Control Act. The Act contains two divisions: Title I, for measures taken below Imperial Dam; and Title II, for measures taken above Imperial Dam.

The Act intended to provide measures to ensure the salinity requirements of Minute No. 242 would be met without adversely impacting the seven Colorado River basin states, either in terms of dollars or water resources. The Act authorized, among other things, construction of the Yuma Desalting Plant (YDP) and a research program into reducing the costs of operating and maintaining the YDP. Reclamation constructed the YDP between 1974 and 1992; salinity control research began at the YDP's test plant in 1989. In 1997, Reclamation expanded the test plant and renamed it the Water Quality Improvement Center (WQIC).

WHAT IS THE WATER QUALITY IMPROVEMENT CENTER?

The WQIC serves as a field site to investigate new and improved technologies, including pretreatment associated with desalination. The intent is to make pilot water research and field-testing more cost effective and practical for entities such as the U.S. Government, desalting researchers, universities, water treatment companies, municipalities, private industries, and foreign governments. The facility's mission is to advance the development and transfer of water purification technologies at its state-of-the-art facility through field tests, hands-on training, and implementation.

WQIC research pilot systems are designed to treat brackish water using both chemical and physical processes. In addition, the Center is configured to supply a variety of feed-waters dissolved-solids range to the pilot systems. These include Colorado surface water, brackish well water, and agricultural drainage water. Focus areas include suspended-solid gravity settling, lime-softening and coagulation, depth filtration, microfiltration, nanofiltration, ultrafiltration, reverse osmosis, and natural organic material precipitation.

WQIC RESEARCH GOALS

The three main goals of the WQIC are to reduce the costs of operating the Yuma Desalting Plant, to support the intention of the Technology Transfer Act, and to support the accomplishment of Reclamation's mission. Deliverables associated with those goals are the following:

- Operate a research and education program that conducts/supports activities that result in reduced YDP operating costs. Results of research are described in project reports published by Reclamation. Successful research is also incorporated into YDP's operations (i.e., high recovery testing identified a process that allows YDP to operate successfully at 80 percent recovery rather than the design-specified 70 percent; this means that for every 100 gallons of feed water, the YDP can recover 80 gallons rather than the original design specification of 70 gallons. This translates to a lower unit cost of production and more "wet" water available to users).
- Partner with other federal agencies, academia, municipalities, and private parties to conduct water quality research that reduces the cost of water treatment, encourages the adoption of desalination or other advanced water treatment technology developed using taxpayer dollars. This benefits the government by creating revenues that flow back to the government, and benefits the public by providing a return on their investment in the form of successfully developed technology put to good purpose.
- Support other federal and non-federal water research and planning activities that will result in a wider-spread adoption of advanced water treatment technologies, since these technologies are a tool of conservation and allow otherwise unusable waters to be recovered and put to beneficial use. By supporting desalination and water quality research and planning activities, the WQIC actively helps Reclamation meet its commitments to deliver water to contracted users.

PUBLICALLY FUNDED LABS WORKING WITH PRIVATE INDUSTRY

The WQIC is a National Center for Water Treatment Technology, initiated by the Bureau of Reclamation, the National Water Research Institute (NWRI), and the U.S. Army. Through the National Centers affiliation, the WQIC opened its doors to the public to conduct water treatment research. Through this public research, Reclamation leverages the WQIC to accelerate improvements in water treatment technology and decreases the federal investment required to conduct research that will benefit the YDP and other reverse osmosis desalination plants.

The essence of the national centers program is the establishment of a network of facilities across the United States accessible to researchers who need a place to test their projects at the demonstration or a pilot-scale level. So far the program has inaugurated seven national centers.

The National Centers' program seeks to advance knowledge about water treatment through more unified research efforts in the public and private sector. To that end, the program provides financial support to academia, municipalities, federal agencies, and private entities to accomplish water research projects that contribute to improved knowledge about water and wastewater treatment. Researchers can apply for grants of up to $10,000 at any time of the year – NWRI will fund eligible research projects until money for a particular year runs out. Projects should have an environmental, municipal, or industrial application. Researchers must conduct their tests at one of the seven designated national centers across the United States.

CRADAS MAKE PARTNERING EASY

WQIC uses Cooperative Research and Development Agreements (CRADA) to facilitate work with non-federal parties and the government to stretch their research budgets. A CRADA is a relatively simple vehicle and has a streamlined government review process.

A CRADA enables the government and the collaborating partner to share patent and patent rights. This would result in royalties being paid to the collaborating partner, the government, and any federal inventor(s). The partner will retain all rights to the invention if the government is not involved with the development of the invention (i.e., the government only tests the invention).

CRADAs also provide a means for sharing technical expertise, ideas, and information in a protected environment. The federal government will protect from disclosure any information brought into the CRADA by the partner that is identified as proprietary. A CRADA permits the federal government to protect information emerging from the CRADA from disclosure for up to five years, if this is desired by the collaborating partner.

Entering into a CRADA with the government can enable the government to cost-share individual projects. Collaborating partners agree to provide resources that may consist of funds, personnel, services, facilities, equipment, funds, or other resources needed to conduct a specific research or development activity. The federal government agrees to provide similar resources but no funds can be transferred directly to the partner. However, grants, contracts, and other types of cooperative agreements can be entered into with the federal government in which the government can provide funds to the partner. Research and development activities at the WQIC are also offered on a cost reimbursement basis in which the partner agrees to reimburse the government for services, facilities, or other resources provided by the government.

WQIC LABORATORY FACILITIES

The Yuma Desalting Plant Laboratory (YDP Laboratory) operates an onsite, fully staffed and state licensed water laboratory. The lab can conduct drinking water and waste water analyses, bacteriological analyses, and analyses of major inorganic constituents of water. The laboratory is licensed by the Arizona Department of Health Services for drinking water and wastewater inorganic analyses. The laboratory is also EPA certified in Arizona. The lab has the capacity to process more than 10,000 water samples per year. The YDP Laboratory participates in the U.S. Geological Survey, the U.S. Environmental Protection Agency, and Environmental Resource Associates quality control programs.

IN-HOUSE AND PARTNERED PROJECTS

YDP Aluminum-Bronze Life Analysis - High-pressure, low pH flows appear to be corroding YDP equipment fabricated from aluminum-bronze. This equipment includes process piping, pumps, and valves. This project evaluates the ability of various high-carbide stainless steels, high-nickel alloys, and aluminum-bronze to stand up to conditions that occur at the YDP and other brackish water desalting plants. The findings from this study will be used to calculate the expected life of aluminum-bronze fluid-handling equipment at YDP, and will provide information about suitable replacement materials.

Nontoxic Storage of YDP RO Elements - RO membranes stored for use at the YDP are subject to damage by microbiological agents such as bacteria, fungi, and chemicals, cutting short their useful life and increasing plant operating costs. One method of arresting this damage is to store membranes in a biocide. However, this method of storage has problems at all stages – from prep for storage to post-storage handling. This project evaluates the effectiveness of gamma irradiation in providing non-damaging sterilization of Fluid Systems 12-inch membranes. Results have been promising enough that staff are planning to patent the process.

Maintaining YDP Pretreatment and RO Technologies - When the YDP was designed in the 1970s, the design was based on the most reliable water treatment and desalting technologies available. YDP uses RO desalting and "conventional" pretreatment: partial-lime softening-clarification and gravity filtration. Over the past 20 years, an array of advances in RO pretreatment and RO systems has occurred. These technologies need to be evaluated to determine how suitable they would be for use at the YDP. This research enables YDP not only to comply with legislation on finding ways to run the plant cost-efficiently, but in satisfying that legislation, YDP satisfies its responsibility to taxpayers to protect their investment in the plant.

Chlorine Resistant PA Membrane Study - PA membranes have the disadvantage that chlorine and other oxidizing biocides used in the feedwater can result in irreversible oxidation damage. Chlorine, the most common biocide for water and very effective, must be neutralized to safe levels before contacting such membranes. Commercial PA membranes use 1,3,5 -benzenetricarboxylic acid chloride and m-phenylenediamine with interfacial polymerization to make membranes. By building PA membranes using other acid chlorides and/or amines, chlorine resistance can be designed into membranes on a molecular level resulting in a superior product. The overall goals of the project are:

- Learn how to make acid chloride reproducibly and practically.
- Design supercritical equipment for the *in situ* production of above.

High Purity High Rejection CA membranes (Title I & S&T) - Cellulose acetate membranes continue to hold promise, if certain shortcomings can be overcome, as the preferred polymer for the next generation of reverse osmosis membranes. First of all, the superiority of CA must be recognized over other polymer systems due to its hydrophilic nature and smooth surfaces, which minimize bio-attachment. Also, the polymer is more chlorine resistant than PA membranes and is a less-expensive commercial product. CA membranes are in use with operational pressures of 200 psi. The shortcomings with current CA membranes are due to salt passage that result from irregularities with the polymer.

Data generated thus far clearly demonstrates that a superior CA film can be produced that we believe will have the needed properties to make a higher-rejection membrane. Additional support that our approach is correct can be found in the fact that multiple layers of CA thin films overlaid on each other improved salt rejection from the low values of 94.4 percent to improved values of 99.0 percent. Indeed, this paper reports a salt rejection on one membrane sample tested of 99.81 percent compared with 99.83 percent calculated from Eq. 4 (see paper: Riley, R.L., H.K. Lonsdale, C.R. Lyons, and U. Merten, *J. Appl.Polym. Sci*., 11:2143-2158 (1967).

Desalination Research with Metropolitan Water District (MWD) - MWD's mission is to provide its service area (17+ million consumers in Southern California) with adequate and reliable supplies of high quality water to meet present and future needs in an environmentally and economically responsible way. The Colorado River is a major source of water for MWD. A planning goal at MWD is to meet or exceed the 500 mg/L total dissolved solids secondary USEPA non-health standard. One way to accomplish this goal is through desalination. Since the district is planning to use desalination equipment similar to that used at the Yuma Desalting Plant, Reclamation benefits by partnering with them.

MWD is conducting research associated with various aspects of membrane water treatment. These aspects consist of:

- Evaluation of new, high-performance reverse osmosis (RO) membranes;
- Investigation of hybrid-membrane processes (i.e., combining RO and nanofiltration (NF) membranes) to achieve 90 percent total water recovery;
- Evaluation of high-voltage, capacitor-based technology to prevent colloidal, biological, and precipitative fouling;
- Develop a pilot-scale, membrane crystallizer to minimize brine residuals.

The research project is expected to last for one year. MWD will also be supplying supplemental equipment. Burns & Roe Services Corporation will provide operations and maintenance services.

Somerton Surface and Groundwater Blending Study - In some locations such as Tucson and the Yuma County Foothills area, corrosion problems have been reported when Colorado River water has been blended with existing well water sources. The City of Somerton is planning to blend Colorado River water with Somerton well water in the near future. This study investigates corrosion issues of the blended water in order to anticipate possible problem areas. The corrosion properties of various materials of construction in the water treatment, distribution, and customer piping areas will be studied. City of Somerton well water, Colorado River water, and blended water will be used to investigate corrosion rates under static and dynamic conditions. The goal of this project is to evaluate the corrosion characteristics of typical materials of construction with City of Somerton water supplies and blends. The effectiveness of water treatment with the addition of corrosion inhibitors and other chemicals will be determined.

***Frank Leitz** has 42 years of experience in the field of desalination and water treatment. This comprises performance, supervision and monitoring of research; proposal evaluation and selection of research projects; equipment and component design; field testing; economic application studies; procurement; and equipment shakedown. It includes specialized experience with the processes of reverse osmosis and electrodialysis. Frank's experience includes 13 years in private industry with a major manufacturer of desalination equipment; 29 years with the federal government working on all aspects of desalination plants, and treatment of acid mine drainage; three years in Saudi Arabia working with the US-Saudi Joint Commission, located in Riyadh, as Research Coordinator and as Team Leader working primarily on establishment of the desalination Research, Development and Training Center in Al Jubail; and 10 years as member of the Editorial Board of Desalination Journal. Frank received B.S., M.S., and The Chemical Engineer degrees from M.I.T. He has more than 60 publications in desalination, water treatment, mass transfer, electrochemical processes, and computer simulations. Frank also has four patents on membranes and electrochemical cells.*

NATIONAL DESALINATION EFFORTS

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Thank you, Bobby, for that introduction. The title of my presentation is a little grander than my talk. The talk really is about the national desalination effort viewed from a Reclamation perspective. There are other agencies in the government that work on different aspects of desalination and I am not going to cover their efforts. On a biographical note, I spent a number of years working for a desalination company before I came to the government and I suspect that I was working on desalination before some of the members of this audience were born.

To begin, I'll give you an outline of my talk: I will start with a few comments on national needs, provide the status of the desalination effort as we see it, describe some of Reclamation's current activities and, finally, list some places where you can get information.

National Needs

A number of people at this meeting have already mentioned drought. Figure 1 shows drought conditions as of January this year. The darker colors, the red and the browns, represent the really bad areas and they seem to cover most of New Mexico. Personally, I had not appreciated how bad things were until I drove down here and noticed by the side of the road a couple of yellow and black diamond shaped signs that said

"Watch for water." Now, I did not see any but I presume that if I had I was supposed to dial 911 or something.

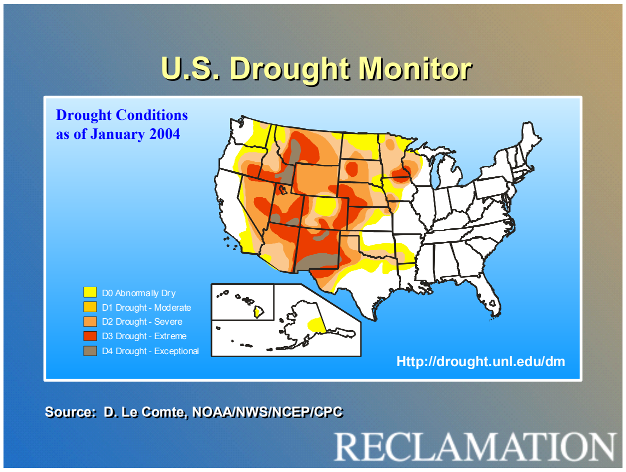

Figure 1.

Along with the drought, which hopefully will be over one of these days, we have long-term trends. One of those is population growth and the resulting increased need for water. The population of the 17 western states in 1902 was 11 million. I am not sure why someone picked 1902 except that that was the year that the U.S. Reclamation Service was founded. The 17 western states are basically Reclamation's area of concern. In 1990, those states had a population of 76 million, and in 2000, 91 million. It's no surprise that in the future, it is going to get more crowded here.

Between the years 2000 and 2025, the population of this area is expected to increase from 91 million to 126 million persons. Water withdrawals are predicted to increase from 91 million acre-feet to 284 million acre-feet. This represents an increase of 89 million acre-feet that must come from somewhere.

Where is this water going to come from? We have identified five possibilities that we are looking at, one of which, desalination, is what I will talk about today. The other possibilities are reuse, transfers, water conservation, and other new sources of water.

Status of Desalination

If I could only get two points across to you today, the first one would be that desalination is here and now. Figure 2 is a picture of the worldwide growth of the use of desalination, both curves of which are at about 3,000 million gallons per day. Don't ask why desalination plant capacities are expressed in millions of gallons instead of acre-feet; it's just that way. Water people generate this state of confusion to keep everyone on their toes.

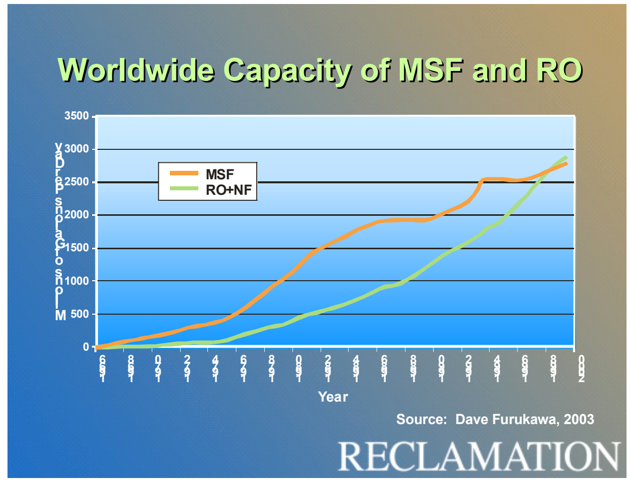

Figure 2.

Both thermal processes and membrane processes in the year 2000 were running about 3,000 millions of gallons a day cumulative capacity. This is probably divided among something like 10,000 different desalination facilities of one sort or another.

For those of you who have not seen a picture of a big desalination plant, Figure 3 is a shot of the Tampa Bay, Florida plant. To give you some scale, note the ordinary-sized automobiles toward the bottom left; you'll get the idea that this is a fairly large facility.

Figure 3.

Figure 4 shows where desalination plants are located in the United States. According to the IDA 2002 Worldwide Desalination Plants Inventory Report No. 17, about 2000 plants with a product capacity of over 150,000 gallons per day were scattered around the U.S., representing municipal, industrial, and pure water plants. Notice that the states with the largest accumulation are California, Texas, and Florida with over 100 plants per state. Only a couple of states in the U.S. do not have an identified desalination plant in this list. This report lists 20 plants in New Mexico.

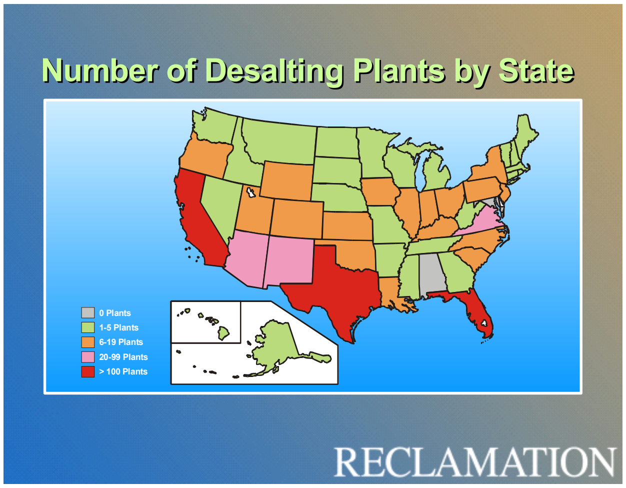

Figure 4.

Figure 5 shows locations for proposed desalination plants in the United States. One cannot miss the fact that the largest single cluster is around Los Angeles.

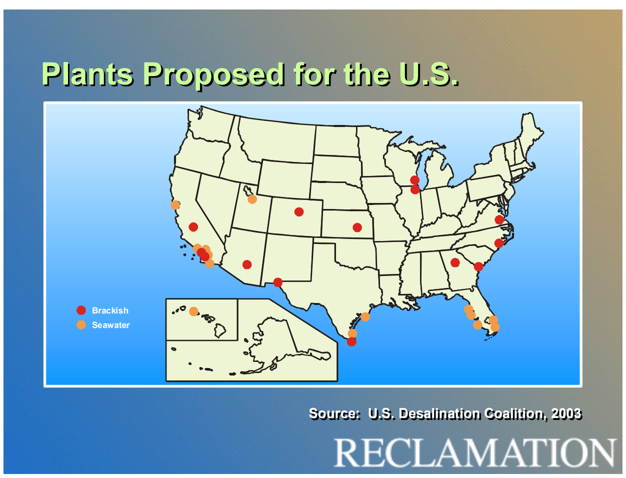

Figure 5.

The second point I want to get across is that desalination prices have gotten to the point where they are reasonable – not cheap, but reasonable. On Figure 6, I have used figures for seawater desalination although I recognize that New Mexico is not going to benefit from that in a big hurry, but these are a good representation of the cost trend. Please notice these are specific plants. They are fairly large seawater plants starting with the 1991 Santa Barbara plant. At that time, the cost of desalinating 1,000 gallons of seawater was almost $6.00. Over the next decade, cost has gone down to about $2.00 per 1000 gallons in Ashkelon, Israel. In case you wondering about the validity of these costs, most of these are plants built, owned, and operated not by a municipality, but by a private entity that runs the plant. These figures represent transfer costs to the water utility. So these are very definite, real costs. Whether the company makes money on the deal or not is something else again. At any rate, these are probably the best values we have for real costs and they show a very significant decrease over time. The source of these data is "Desalination Market Analysis 2001 – Today and Tomorrow" by Aqua Resources International, prepared for the Bureau of Reclamation, October 2001.

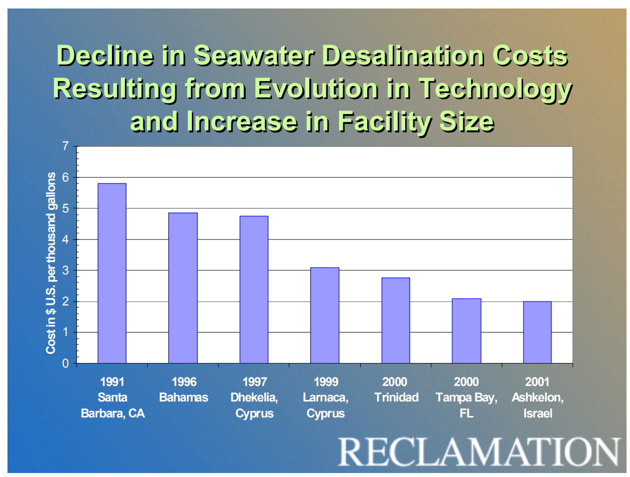

Figure 6.

With this in mind, let's look at a comparison of water costs. Sea water desalination costs $2.00 to 3.00/ 1000 gallons. This represents desalination costs and does not include distribution costs. Characteristically, brackish water desalination costs $1.00 to 2.00/1000 gallons, keeping in mind that costs are highly dependent on the chemical makeup of the brackish water. These again represent production costs.

Now what does water sell for? I looked up my local water utility in Evergreen, Colorado, and I am paying (in addition to connect charges) $2.50/1000 gallons for the first 9000 gallons used. Our water comes from a mountain lake. It is put through a microfiltration plant, stabilized and delivered. The cost increases with the next 5000 gallons used to $3.00/1000 gallons, and above 14,000 gallons, we pay $7.00/1000 gallons. A surtax in added when we are in a drought period. Thus, the production costs associated with desalination are not to far off from what some people currently are paying.

As for bottled water, I did a survey at my neighborhood market. The highest cost water I saw at the Kroger store near where I live was $8.56/gallon—note this is per gallon, not per 1000 gallons. The cheapest bottled water they had sold for just under a dollar per gallon.

Current Reclamation Activities

The Bureau of Reclamation partners with many other entities and organizations including the WaterReuse Foundation, American Water Works Association Research Foundation, National Water Research Institute, Membrane Applied Science & Technology Center, Center for Biofilm Engineering, Middle East Desalination Research Center, Sandia National Laboratories, and the Interagency Consortium for Desalination and Membrane Separation Research. You can see that many folks are working on different aspects related to water desalination and we try to bring groups together to share problems and to avoid duplication of effort. Our research program at this point is largely guided by the desalination roadmap that you will hear about in the next presentation by Tom Hinkebein of Sandia National Laboratories.

One of our major efforts right now is getting the Tularosa Basin National Desalination Research Facility started. Your program cover has an architect's rendering of the facility.

It is reasonable to ask why we do research in desalination. We want to create options for water planners and water supply agencies. It seems appropriate for the government to share in the risk in some of the R&D investments. You heard Professor Tarquin talk earlier about the work he is doing on lime treatment. Some of the avenues he's gone up make sense and some efforts work very well. We are willing to share some of the risk inherent in research. We want to show how new technologies and practices can be made sustainable. We need to provide information on how these things work. And we want to create confidence so that a design engineer can go in, design a plan, and expect it to work reasonably well.

Our Desalination and Water Purification R&D Program is authorized by Public Law 104-298. You can look it up on the internet. It is the so-called "Simon Act." Senator Simon was a fairly far-sighted person whom, unfortunately, we no longer have with us. The Program's primary goals are to increase the nation's usable water supply; to develop and demonstrate the effective desalination and water treatment technologies; and to lower the costs of desalination technologies and related systems. We do not make any water with desalination, we make water that was unusable into usable water.

This Program is national in scope, unlike Reclamation's other efforts that are limited to the 17 western states. This is a national program with a strong nationwide constituency and we do applied research. The "applied" probably should be underlined. We are not really into basic research that somebody might use 20 years from now. We want to support research that somebody can take out into the street in a few years. The projects are cost shared, they are competitive, merit reviewed, and we constantly look at the "value" of the project.

I want to go quickly through some of the programs on which we are currently working. A gentleman earlier asked about oil fouling. Yale University is studying cleaning of fouled membranes. A foulant is a material that collects on a membrane surface and slows down passage of water through the membrane. Colloidal material is very finely divided particles that make water turbid or cloudy. Organic foulants come from decay of vegetative matter and frequently give color to natural waters. Scaling results from exceeding the solubility of salts like calcium carbonate and calcium sulfate. Biofouling results when bacteria settle on a surface and make themselves at home. All of these have affected membrane plants at one time or another and each may require a different method of removal.

Montgomery-Watson-Harza is a company working on removing perchlorate. This is a relatively new contaminant that people have started to worry about. It presumably has some undesirable health effects.

The Dow Chemical Company is looking at the possibility of using large diameter membranes. The standard conventional size for big plants is an 8-inch diameter element that is 40 inches long. A consortium under the leadership of Dow is looking at much larger membranes, 16-18 inches. They are looking ahead at what process simplification we have if we go to much bigger elements instead of the relatively small ones.

The Texas Water Development Board is just completing a study on using oil fields for concentrate disposal. A number of non-technical, institutional and permitting problems will need to be resolved.

Finally, a Professor at the University of Colorado is looking at taking pilot plant information or smaller bench-scale information and conducting plant-scale engineering with it. It will be interesting to see his results.

Our FY-03 pilot projects include dewvaporation, a process we are testing in Phoenix. It is a distillation process but it is a low temperature process and hopefully it will be able to use waste heat to further concentrate and come up with possibly either dry or solid material. Corollo Engineers is investigating river bank filtration as a pretreatment process. Another pilot project is being conducted by Novaflux Technologies. In the Novaflux process of cleaning membranes, a spray of fine water droplets shoots through a membrane element. The droplets may contain a detergent to aid cleaning. By dispersing water in air, a much higher shear force can be applied to the membrane surface than can be obtained with the conventional flowing of a stream of water through the element. They use a spray containing very small amounts of cleaning solution and the technique gets much higher shear force right at the membrane where you want to do your cleaning. Their preliminary investigations have been very successful.

FY-04 new research studies are in the process of being approved and are being processed through our acquisitions department so I can’t name any names. However, the projects will include: membrane process work on produced waters; adding thermal processes to water treatment cost model; a study of the presence and removal of boron from water; a study of biofilm attachment to membranes; and a study to increase water recovery from high silica waters.

Produced waters are the great flushes of saline water that come out of gas wells when they are first developed. It is very expensive to get rid of this water because it usually contains a lot of salt and other contaminants. Right now the technique is to re-inject it. If we could treat this water at a reasonable cost, there is a chance of being able to put some of this water to useful purposes and to limit the amount of water we have to reinject.

We have a cost model that has been published. It is quite effective, however, it does not include thermal processes and that is something that we are working on right now.

The latest contaminant to come down the pike that people are worried about is boron. We have a group that will study not only the current distribution of boron in potential source waters but how effective some of our desalination processes are in removal of boron.

I mentioned biofilms earlier in terms of foulants. We are funding a study where we look at how biofilms attach themselves onto membranes with the intent of determining possible prevention and removal.

Finally, we are looking at increasing the water recovery from high silica waters. I am sure nobody who was here this morning could possibly guess when we would be doing that.

Figure 7 shows one of the new processes, Direct Contact Membrane Distillation (DCMD). This is a real quirky process, but it may turn out to be very useful. The diagram depicts the sides of a very narrow plastic tube; brine is put on one side and cold water on the other side. The water distills through the pores of the membrane. The appealing part of this process is that the path the water has to move along is in the order of a few microns.

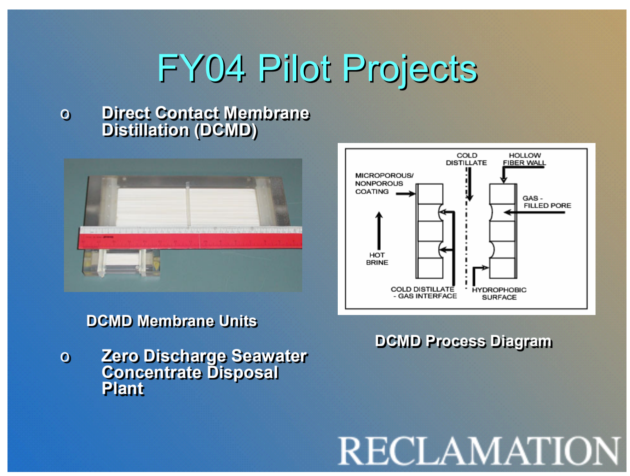

Figure 7.

We are also going to have a pilot plant on a zero discharge seawater concentrate disposal system. I always have reservations about “zero discharge” because zero is never quite zero. This project looks at how we can recover useful materials. A chemical engineering professor is working on the project and has come as close as I know of anybody to what really is important or possible from this sort of standard.

Available Information

Technology transfer is an important part of our program. It does not do us any good to have information and final reports if we cannot get them out to those who need the information. We have an active group that has developed and published a handbook for planners, Desalination Handbook for Planners. Our cost model, WTCost©, is a water treatment cost estimation program sponsored by AMTA. Desalnet is being marketed through the American Water Works Association and contains 50 years of a full-text desalination literature database. This represents some 1200 reports that were originally generated by the Office of Saline Water and are very difficult to find now. We have the databases on CD and they are all word searchable. Anybody who is trying to look through a bunch of reports for information can appreciate the virtue of the keyword search.

Finally, here are three websites that will give you access to our information:

- Program Homepage – www.usbr.gov/pmts/water/ desal.html
- Newsletter – www.usbr.gov/pmts/water/wfw.html
- Research Reports – www.usbr.gov/pmts/water/reports.html

My parting thought for today comes from Senator Simon: “If we spent five percent as much each year on desalination research as we spend on weapons research, we could enrich the lives of all humanity far beyond anything anyone has conceived.”

To which I say, Amen.

***Tom Hinkebein** manages the Geochemistry Department at Sandia National Labs, which is responsible for a number of fundamental science studies as well as the development of novel water treatment processes. Tom received his Ph.D. in chemical engineering from the University of Washington, Seattle, and has worked at Sandia for 25 years. In the water treatment program, Tom is responsible for novel arsenic removal and perchlorate removal technologies. He is also currently managing several lab-directed research and development programs that explore novel concepts in water supply enhancement and desalination. Tom is also responsible for coordinating the development of a technology roadmap for future research in desalination technology.*

ROADMAP FOR NATIONAL AND INTERNATIONAL DESALINATION RESEARCH

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The idea of this conference is to consider the problems and challenges facing the desert southwest concerning its water resources and how we are going to plan for the future. We have heard about the Tularosa Basin National Desalination Facility and some of the research efforts the Bureau of Reclamation has been working on the past couple of years. I think these efforts are incredibly important, but I want to underscore how critical the problem really is.

In 1990, there were 20 percent more New Mexicans than there were in 1980. In 2000, that number was 20 percent again. I think we can expect this increase to occur for another couple of decades. So by the year 2020, there will be 45 percent more New Mexicans than there are right now.

When you think about that population growth, you start to wonder if the technologies that we are putting on the table adequately address our future growth needs. My concern is that we may not have stretched far enough to really meet our future needs. When we wrote our planning document to develop a roadmap, we did it with the knowledge that two paths need to be followed.

The first path is the one that looks at our current technology, reverse osmosis, and looks for ways to improve it, that is, to incorporate what we already know into reverse osmosis to make it more efficient and better in all ways. But I think we would be remiss if we did not consider alternate paths; things we might do that are beyond what reverse osmosis may be able to do for us. In particular, we are looking at how we can develop novel ways of looking at things. How can we plan a process that engineers creativity into the process itself? That is what a roadmap is all about; it is a planning document to engineer creativity into what we do.

Right now the City of Albuquerque is using about 170 gallons of water per person per day. They are hoping to knock that number down by 15 percent. Meanwhile we are going to experience a 45 percent growth in the number of people in Albuquerque. Quite clearly, conservation is not going to get us all the way to where we need to be. We will have to obtain additional water supplies.

Let's kick in one more factor. The 150 gallons per person per day is the water that is used for municipal and some light industrial applications. Last night we all sat down and had a really wonderful meal. How much water was involved in the making of that meal? I can give you an idea: the total water usage for each human in the United States is about 1,500 gallons per person per day - ten times larger than the numbers for which we are planning. The increase in population that we are looking at is something that definitely requires planning. And it definitely requires that we stretch beyond the current technology and start to look for next generation improvements that can address the concerns that are in front of us.

I want to point out a couple of things: our roadmap effort has produced a real document (http://www.usbr.gov/pmts/water/media/pdfs/rroadmapreport.pdf). We have worked together with the Bureau of Reclamation to produce a document that is real; the ideas embodied in it are planning scenarios. The question we all have is whether this document 20 years from now will be looked at as a work of fiction or a work of facts. If it is a work of facts, you will all forget my name and we will be trying to figure out how to solve our water problems. If it is a work of fiction—all efforts in the library that are works of fiction are filed by the author's name. So I hope I am not associated with this document 20 years from now.

When you prepare a road map, you must being with a vision and that vision must lead to quantifiable goals and workable components. This vision has four workable components: 1) we must be able to produce water that meets our need for safety; 2) we must produce water that meets our need to have sustainable supplies; 3) we must produce water that it is affordable (and that is the one component everybody pays the most attention to); and 4) what we produce must be adequate to assure local and regional availability during periods of drought or shortages.

When we started this process to develop new ideas, we started with a vision. The vision lead to the idea of having water that is safe, sustainable, affordable, and adequate. Figure 1 shows the architecture of the roadmap process. We had to define high level needs and the way we did that was through the observation or examination of many case studies. We looked at case studies from particular regions of the country and considered the problems that existed in those regions. We then would excerpt and generalize those needs to come up with some high level defined needs. The next step was to define critical objectives or measurable milestones that allow us to determine how we are progressing. And lastly, we identified the technology areas and specific research areas that need attention. Those technology areas will have a set of milestones associated with them and will have a set of measurable quantities that will tell us how good we are doing. That way we can eliminate the ones that are not working and put more effort into those that are.

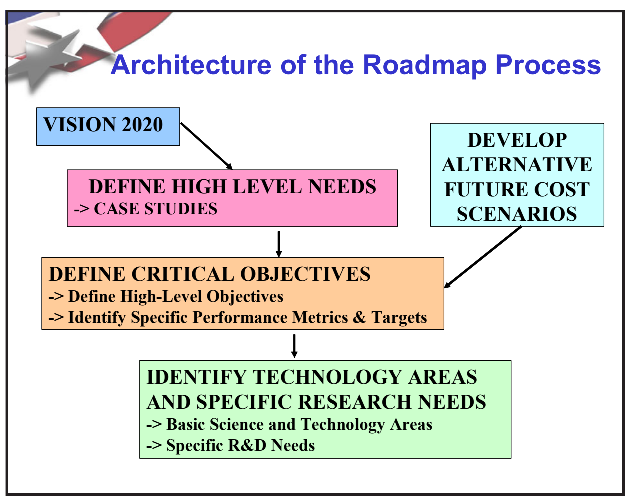

Figure 1.

Developing a roadmap is a people process. Many people are involved. Figure 2 summarizes the people involved in our effort. We broke into four main areas: membrane technologies; alternative/thermal technologies; reclamation/reuse technologies; and concentrate disposal technologies. The themes for those four areas will be continued in the future. We did not have enough experts in thermal technologies to do an adequate job so we combined them with alternative technologies, which I think will be very important in the future.

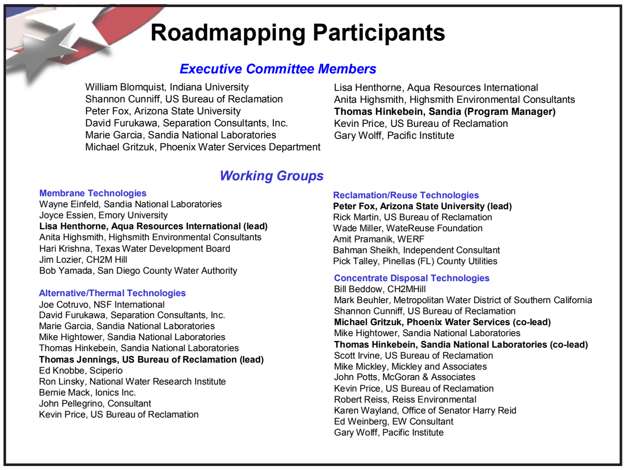

Figure 2.

One of the main area categories was reclamation and reuse. We seldom consider reclamation and reuse as being a desalination activity, but, in general, the technologies are so similar that the benefits derived from studies in reclamation and reuse are usually directly applicable to desalination, at least partly applicable.

Lastly we considered concentrate disposal. In the Southwest and other inland environments, concentrate disposal is one of the more costly aspects of the problem. As a matter of fact, concentrate disposal usually runs between one-third and one-half of the total cost of the process when applied to an inland environment.

As an example of one of the case studies, consider the study we did looking at inland urban and rural areas where a number of challenges were identified (Fig. 3). These areas are all grappling with sustainability and adequacy concerns resulting from the persistent drought. An additional major concern is concentrate disposal. We summarized the needs that derive from these challenges in terms of broad-based statements about the kinds of improvements that needed to be made—reducing cost and enabling the disposal of concentrate.

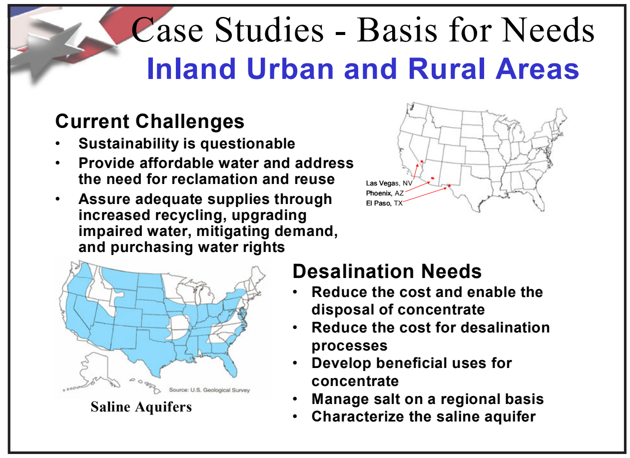

Figure 3.

Reducing the cost of the desalination processes is also important (Fig. 4). In 1965, Gordon Moore made the observation that exponential growth was occurring in the semiconductor industry. For semiconductors, the growth rate is 37 percent and double every two years. Another industry that began in the 1960s was membrane separation. In this case, the improvement is 4 percent per year. If we want larger improvements, we must adopt a better growth process. The exponential growth noted in the graphs in Figure 4 is based on the premise that future gains are based on past successes. (We can all be tall when we stand on the shoulders of giants.)

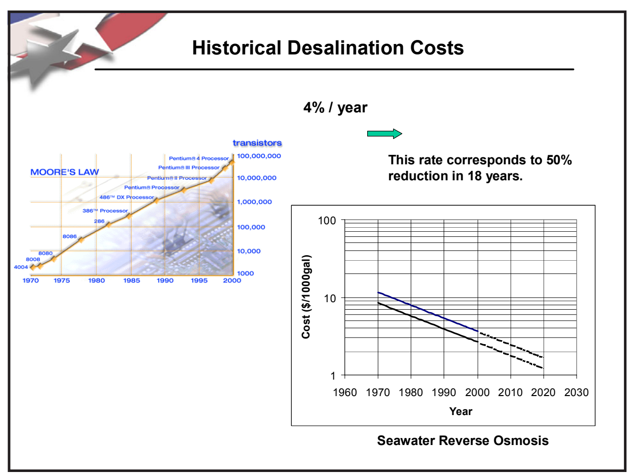

Figure 4.

Think about concentrate disposal as being able to turn a sow's ear into a silk purse, which is one of our goals. Can we develop beneficial uses of concentrate that will improve the way that we look at this process and actually enable us to pay for the processes? In the Phoenix area, they have so much salt in the valley that being able to deal with that salt represents a long-term problem for them.

Lastly, and probably one of the most important areas, is being able to characterize the saline aquifers so that we know what our source terms are.

How do you tell what good will happen with any improvements that you might make? Consider the ideas embodied in Moore's Law in Figure 4. How does the number of transistors on a chip relate to anything? If you plot the number of improvements that can be made (in any technology as a function of time) on a semi-log plot, and as long as you don't start to run into barriers, those improvements end up plotting on a straight line (Figure 5). The idea behind these plots is that, as embodied here, we can make improvements that are so much greater than anyone can imagine because we are standing on the shoulders of all of those improvements that came before and we can see a lot further as a consequence. If we apply the same kind of curves to the cost of sea water desalination between 1970 and 2000, we find a band of improvement that results from plotting the data that actually is linear. And if we do not run up against constraints, we could continue to have improvements well into the year 2020. However, I think there will be constraints. It was the overall opinion of everybody participating in developing the desalination road map that the 4 percent per year improvement is going to eventually start to run into trouble as we get closer and closer to thermodynamic minimums. Currently we are functioning at about three times the thermodynamic minimum and there is still room for improvement. But at what point do we cease being able to make these improvements? We will be looking for improvements that some people refer to as "and now a miracle occurs."

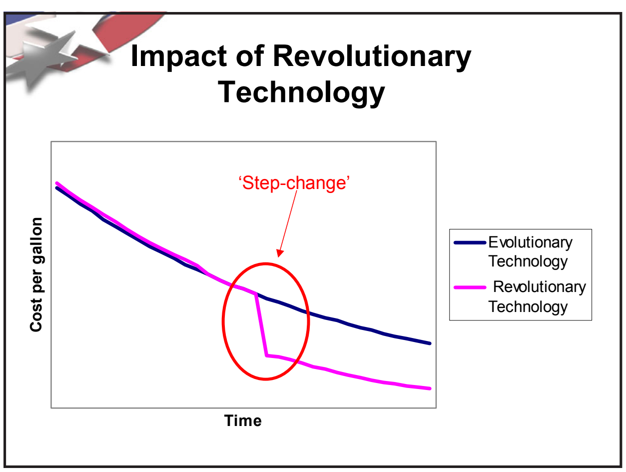

Figure 5.

Concerning our critical objectives as they apply to concentrate removal or the concentrate disposal process — our near-term (between now and six years from now) critical objectives are to reduce capital costs by 20 percent; increase energy efficiency by 20 percent; reduce operating costs by 20 percent; and reduce the cost of zero liquid discharge processes by 20 percent. You can see the constant theme of 20% improvements over the next 6 years or so. That is consistent with the 4 percent improvements that have been observed historically. Thus the kinds of improvements we hope to achieve are consistent with the steady-as-you-go incremental improvements to the existing processes.

Our long-term objectives are regulated by the fact that the population is growing at a very high rate and we need to make substantial improvements in our ability to deliver water to major population areas as well as small population areas. We must deliver water in such a way as to match population growth in order to keep costs at a reasonable level based on today's standards.

I excerpted a study from efforts that were done in Phoenix Arizona by Mike Mickley on disposal options (Figure 6). The Phoenix group was talking about a large pipe-lining project to deliver all of the concentrate to the Gulf of Mexico. That pipeline project was very expensive and had geopolitical problems associated with crossing six state boundaries plus an international boundary, which were going to be monumental. We proceed anyway and figured the cost of the project. The Pipeline bar in the Figure 6 graph has a white area (above the capital cost and operating cost) that includes the cost of the lost resource. All the water that is delivered to the Gulf of California is water that is no longer in the system and thus a lost resource and it does represent a cost. You can do the same kind of analysis for evaporation ponds and for thermal evaporation over the top of evaporation ponds. What you come up with when you evaluate the comparison of disposal alternatives is that the cost of concentrate disposal, if all of the costs are factored in, are, in fact, pretty high. When a true accounting of all costs are considered, concentrate disposal results in increasing the cost of the desalination process by a lot. Further, it gives us added pause when we start to consider the cost of lost water and looking at ways to recover that lost water.

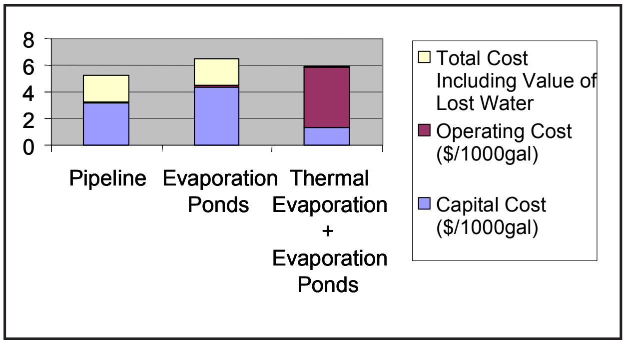

Figure 6.

Let's look at the current costs associated with a couple of options as shown on Figure 6. These are not all of the options; only a couple of options. You will note that currently, evaporation ponds in the Phoenix area are out of sight because the land costs are so great. And even efforts like enhancing evaporation or spraying water into the air really does not change the economics substantially. But you can begin to look at each of these processes and say, "If we did the best that we could, how might we decrease the cost of each alternative by 2008 and by 2020?" We can then start to compare these alternatives with other processes that we might dream up. We have seen some of those processes presented in the last couple of days. We want to take those ideas and evaluate them using the same yardstick indicating how well the economics and other factors compare with the current technologies.

Zero liquid discharge is likely to be one of the most important driving factors when we consider concentrate disposal, especially in the arid West where we need all of the water we can get. Environmental concerns are one driver for concentrator facilities (zero liquid discharge). Another driver is lost water. Uses and markets for individual salts are emerging and processing companies are beginning to develop.

When we created the roadmap, we developed near-term and long-term thrust areas (Fig. 7). These were determined by a "people-process" where you ask people, "What do you think is the best way to move forward?" One idea put forward for a long-term thrust area was the idea of developing solidified residuals and a recapture of 100 percent of the water, again recognizing the value of a lost resource.

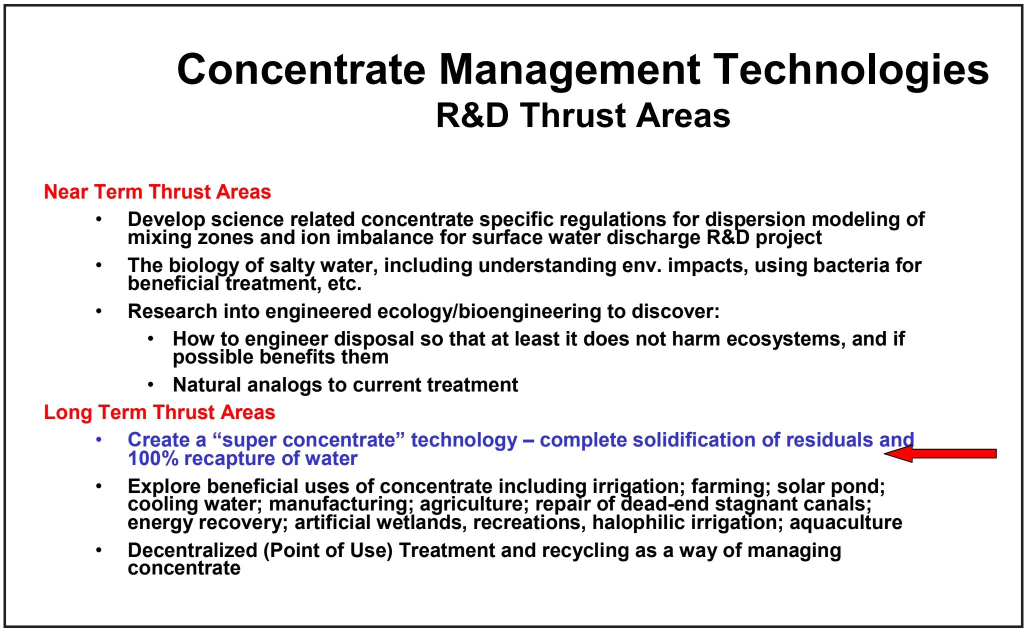

Figure 7.

A couple of ideas have been advanced to deal with those issues; you heard earlier a bit about the dewvaporation process that James Beckman of Arizona State University is developing. In this process, air evaporates water from saline feeds and forms pure condensate at atmospheric pressure with humidification-dehumidification. The process naturally transfers heat released by dew condensation to assist evaporation on opposite sides of a heat transfer wall. The process is highly energy efficient and shows minimal fouling. The external heat source can come from waste heat, solar collectors, or fuel combustion. Figure 8 depicts the equipment involved in the process.

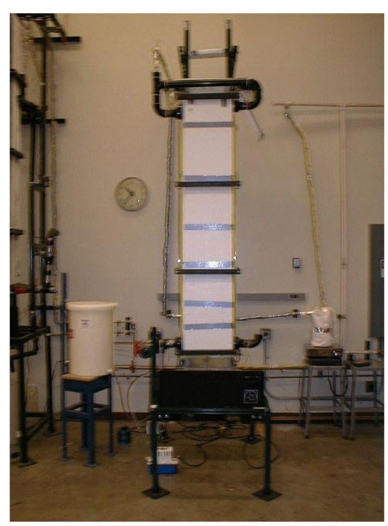

Figure 8.

Another process that deserves an honorable mention in terms of how one might deal with water loss is a wind-aided intensified evaporator (Figure 9). E. Leshman, J. Gilron, Y. Folkman and O. Kedem from Lesico Ltd. and Ben Gurion University are investigating this method. The process allows water to drip down plastic sheets that wave back and forth in the wind allowing the boundary layer to break up and eventually a solid material is formed out of the discharge from the test facility. The process shows minimal fouling. The costs associated with the wind-aided evaporator vary between \$3.2 to \$3.8/1000 gallons, which is substantially less than the costs associated with straight evaporation ponds. This may potentially be a technology that will prove efficient and cost-effective and I am sure there are others to consider.

Figure 9.

Sandia's National Desalination Program consists of three main activities. The first is the work on the National Desalination Research Implementation Plan that is part of the roadmap. That effort is a joint activity with the Bureau of Reclamation, Water Reuse Foundation, American Waterworks Association, and the National Water Research Institute. We will be doing follow-on activities to develop ideas for conducting research in all the main research areas that we talked about plus at least one other that relates to some of the non-technical factors associated with the development of desalination technologies.

The second main activity is the idea of developing demonstration-scale desalination processes, along the same lines as those pursued by the Bureau of Reclamation. It is our goal to make sure that we coordinate with the Bureau in selecting the "right" processes to be tested so we know we are putting our resources into the right places. Our third main activity concerns the development of advanced concept desalination processes. In the future, we will be spending more effort in attempting to go way outside the traditional technologies that are being pursued. Again, we want to examine technologies that can really break through a lot of the cost barriers that are associated with reverse osmosis.

Thank you for your attention today.

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