New Mexico
EARTH
MATTERS

SUMMER 2015

Brackish and Saline Groundwater in New Mexico

New Mexico meets its ever-growing need for water through both surface and groundwater resources. The supply of surface water is largely dependent upon precipitation, and its availability is therefore subject to periods of drought. Shallow, fresh groundwater resources supplement the state's water needs, but many of these resources are being used far faster than they are being replenished, and are therefore finite. We know that there are deeper, largely untapped groundwater resources, but generally these are too salty to drink or to use for irrigation without treatment. Nonetheless, they provide a potential alternative source of groundwater, and are of increasing interest to the state, particularly as our evolving technologies are providing ways for us to use them.

Groundwater is water that is found in pore spaces of rock and sediment below the land surface. We know that much of our shallow groundwater in New Mexico is fresh in quality, and is a good source of drinking water and water for irrigation. However, in many places we encounter saltier water when we drill wells into groundwater basins. How much salty water is there, and where can we find it? Can we use it during times of drought, or in remote locations that do not have rivers or lakes? Or in applications where fresh water is not required? Will we damage the environment, especially our existing fresh water resources, if we try to use it?

In New Mexico, the Office of the State Engineer (NMOSE) characterizes water as being "deep non-potable water" when TDS is greater than 1,000 mg/L *and* the water is located more than 2,500 feet below ground surface. This deep water is characterized differently because shallower water is considered to be "righted," and has potential for beneficial use, regardless of salinity. This rule is used to protect known fresh water supplies, so that they can be defined in a basin and protected. Even though a water right *per se* is not assigned to this deeper, saltier water, the NMOSE must be notified when someone plans to drill a well into these zones, in order to manage the basin water supplies and to prevent impingement on nearby fresh water.

WATER TYPE	TOTAL DISSOLVED SOLIDS (TDS) IN MILLIGRAMS/LITER)	COMMENT
Fresh	Less than 500	Typical fresh range
Brackish	1,000 to 10,000	As defined by USGS
Saline	10,000 to 35,000	Seawater is ~35,000
Brine	35,000 to 200,000	
Oil and gas co-produced waters	~500 to over 200,000	Derived from oil and gas production
Fully salt saturated	Greater than 250,000	Found in some oil and gas produced waters and deep saline reservoirs

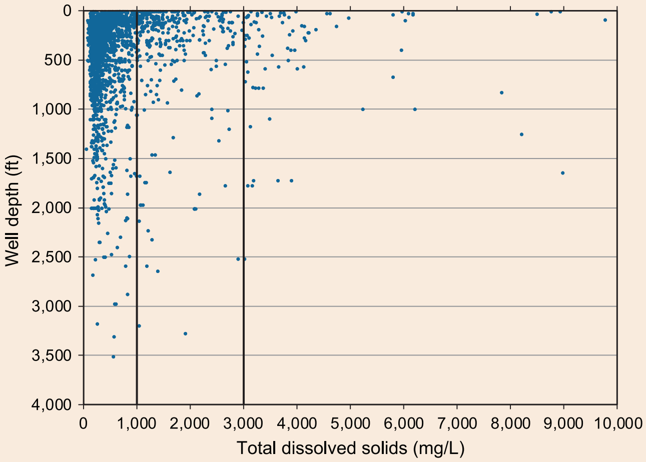
Types of water classified by salinity range as defined by total dissolved solids (TDS) in milligrams/liter (mg/L).

Status of New Mexico's Brackish Water Resources

Some of the first national-scale studies on brackish water resources were performed in the late 1950s and early 1960s by the U.S. Geological Survey (USGS). These studies have been cited repeatedly since then, because most subsequent water exploration has been focused primarily on fresh water, not salty water. Records were often not kept of the fresh water/salt water interface when water-supply wells were drilled; the drillers seeking fresh water would plug the hole if the water became too salty. The oil and gas industry also drilled through both fresh and brackish aquifers—however, the fresh and brackish water aquifers did not usually contain economically viable oil and gas deposits, so records of the brackish water occurrence, depth, and quality were not kept or were not publicly available.

Recently, the USGS began to update the national inventory of brackish water resources, focusing efforts on the groundwater within 3,000 feet below land surface, with total dissolved solids less than 10,000 mg/L and with the potential for "useable" water yield. This work is projected to take about 4 years, and it will be most useful to address brackish water availability at regional or basin scales.

In New Mexico, there are multiple datasets describing fresh, brackish, and saline water resources, however, they are not compiled together to help address the state's current water needs. Much of the pertinent data for New Mexico's brackish and saline water resources are held within historic water reports, geologic research reports, or with oil and gas producer's records. In 2003–2004, a brackish water task force was formed, aiming to characterize all of New Mexico's brackish water resources. However, work quickly ended due to the lack of funding. Currently, the New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech's



Graph of salinity and depth in New Mexico wells. More data exist for freshwater and shallow locations. (Sources: NMBGMR, USGS, NMED).

Petroleum Recovery Research Center, and the New Mexico Water Resources Research Institute, along with other institutions in New Mexico, are gathering information to create a database of all water resources in New Mexico, including fresh, brackish, and saline inventories, as well as produced water quality, quantities, and locations. Work recently completed by the New Mexico Bureau of Geology and Mineral Resources describes the fresh and brackish water aquifers in the San Juan Basin region (Kelley et al., 2014). The most recently compiled estimates of the quantity of brackish groundwater in New Mexico come from sources such as Feth (1970), Huff (2004), and Hale et al., (1965). Currently, there is no reference that gives adequate or complete volume estimations of brackish water for the state.

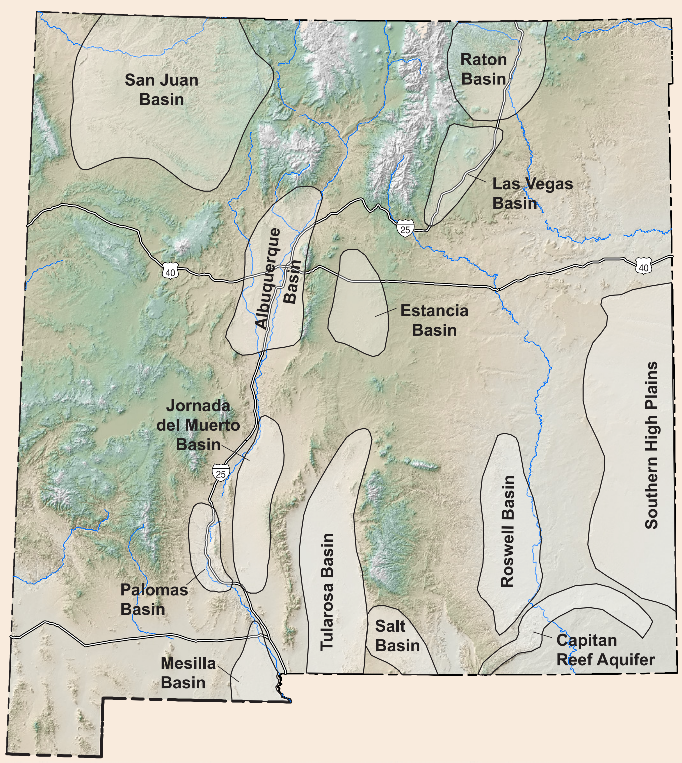
Locations of Brackish Water Resources in New Mexico

Extensive work over the last 50 years has cataloged basins in the state containing fresh and brackish water. Significant basins include the Albuquerque Basin, San Juan Basin, Roswell Basin, Capitan Reef Aquifer, Estancia Basin, Mesilla Basin, and Tularosa Basin. In addition, some rivers, streams, and springs or seeps in the state are salty, such as stretches of the Pecos River and the Rio Grande. This is mostly the result of saline or brackish groundwater discharging to the surface, surface water interaction with the underlying geologic units, or sometimes it is the result of evaporation.

Brackish Water as a Drought Solution

With advanced planning and the necessary funding, we can use brackish water as a supplement to fresh water in times of drought or other shortage situations. This use can improve the lifetime of our fresh water supplies.

Because brackish water will usually need to be desalinated, this means we need to invest in ways to extract (via pumping), transport (via pipelines or trucks), and treat the water (e.g., using membrane methods like reverse osmosis, or thermal methods like distillation). In 2010, of the 314 desalination plants in the U.S., 95% were inland. Municipal plants were 67% of the total desalination plant capacity, followed by industrial plants (18% of total) (Mickley, 2010). Common municipal applications of desalination include the production of water for drinking, reuse, and recharge. We also need to dispose of the resulting salty waste stream (known as brine concentrate), and to transport the treated water to the point of use. The extraction of deep brackish waters is much more expensive than extraction of shallower fresh water. Pumping costs are much higher, and aquifer permeability is much lower in deep aquifers. Multiple wells may be needed to extract the water.



Approximate locations of brackish water basins of interest.

Capital costs to install a brackish water treatment facility can be between $10 million and $95 million, depending upon system size. Operations and maintenance can cost $4 million to $6 million per year. Financing, permitting, and energy sources must be acquired. This adds up to about $500 per acre-foot of water delivered *above* the costs for fresh water delivery. In contrast, the cost for water from a municipal drinking water treatment facility is about $300 per acre-foot delivered from a fresh surface source. The electricity requirement for reverse-osmosis desalination ranges from 3–12 kWh/m^3 with electricity costs reaching 50% or more of the total cost to desalinate. In sum, desalination is effective but not necessarily the least expensive or most energy-efficient method to improve water supply reliability.

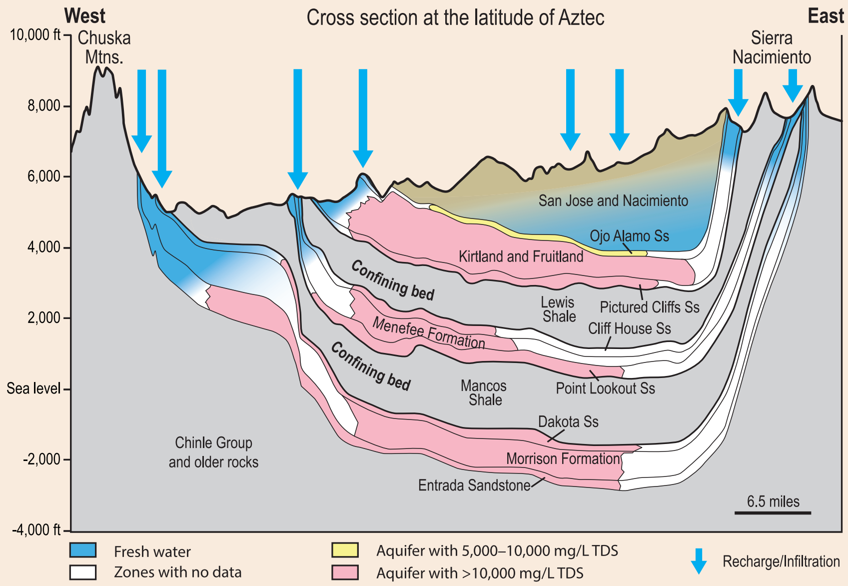
Environmental Impacts of Brackish Water Use

Brackish water in deep, confined aquifers is, in most cases, not a renewable resource. If we extract this water, eventually the supply will be depleted. Land surface subsidence from groundwater extraction in the Central Valley of California has reached up to 30 feet. That water cannot be replaced in aquifer storage because of permanent collapse in the aquifer pore spaces.

Water extraction from shallow brackish aquifers should not deplete or contaminate fresh water that may be interconnected. Impingement can occur if we withdraw brackish groundwater that is interconnected to fresh water by geologic faults or other means. Pumping can entrain and mix the two waters if there is not a sufficient barrier between the aquifers. Barriers are composed of low-permeability rocks or sediments that prevent water flow. Permitting by the NMOSE is implemented to help examine and prevent this mixing and impingement. Sufficient hydrologic studies of the boundaries of a brackish groundwater source are necessary prior to extraction; a clear understanding of nearby fresh water resources also is important. This means that appropriate advance planning and hydrogeological surveys are needed prior to accessing brackish water aquifers, in order to quantify the risks and benefits of use.

Another critical environmental issue is the proper handling of brackish water from the well field to the point of treatment, so as to prevent spills. Pipelines are the most cost-effective means of moving large volumes of water; trucks are used for lower-volume applications. Pipeline leaks, or spills must be remediated to prevent soil contamination and impacts to vegetation. Pipeline monitoring and leak detection systems for transport vehicles and storage tanks will be needed to prevent environmental damage.

Concentrate disposal also is an important environmental concern. Because the treatment process is a separations process, we usually can only recover about 40–90% of the water that we treat, depending on the source salinity and the technique of treatment. Disposal of the remaining brine concentrate requires special handling and permitting. Near the ocean, less expensive disposal is possible because the concentrate is discharged back to the ocean away from land. In inland regions such as in west Texas or New Mexico, disposal is typically performed by using wells classified by the United States Environmental Protection Agency Underground Injection Control program for this purpose (Class I or Class V wells). Strict disposal-well construction rules are imposed to prevent leakage in the well bore, so as to prevent contamination to fresh aquifers. The Kay Bailey Hutchison Brackish water desalination facility in El Paso uses wells for disposal of their concentrate. Interestingly, they were able to find a relatively shallow formation for disposal, which has a salinity level higher than the concentrate itself. Extensive hydrologic studies were done to define the location and capacity of the disposal formation; the formation also is in a more remote area where future development is less likely. Currently, researchers are working on ways to separate useful salts as salable products. However, this also is costly and is not yet in general use.



One example of a basin containing both fresh and brackish water is the San Juan Basin. Recent data compilation has identified zones of saline water that exist below fresh water aquifers (Kelley et al., 2014). Typical of many basins, salinity and age of the water increases with depth. Recharge to the basin occurs from rainfall and snowmelt at the basin margins and the land surface across the basin. The deepest saline zones are very old, connate water that is not actively recharged. The shallower, younger brackish water zones are the most likely sources for future supplies in this basin. *Modified from Kelley et al., 2014.*

Uses for Brackish Water

Some uses of brackish water do not require desalination. Sometimes the water can be blended directly with fresh water, resulting in slightly saltier water that can be applied for agriculture, usually when the plants are salt-tolerant. Brackish water has been used successfully to grow algae for biofuels. Brackish and saline waters also are used in the mining industry. There are large potash (fertilizer) solution mines in southeastern New Mexico and in Utah that use salty groundwater to dissolve the potassium-containing minerals. The salt solution is better for recovering the valuable minerals than are physical excavation processes. Brackish and saline water also is useful for oil and gas production.

All of these uses require planning and sometimes additional permitting. A clear understanding of the use, the quality of the water to be used, and the potential impacts of use is crucial.

The Special Case of Oil and Gas Produced Water

Oil and gas operations extract saline and brackish water (called "produced" or "co-produced" water by regulatory definition) at approximately 7 to 10 times the volume of extracted product. Some oil and gas producers are recycling a portion of the water that comes up with the oil and gas. The water is reused for enhanced oil recovery, water flooding of oil reservoirs, and drilling and completion operations including hydraulic fracturing. Producers also are finding that treatment of the water can be minimal prior to reuse. Some operators utilize simple filtration processes to remove mineral scale, fine particles, and bacteria. Desalination is not always needed, thus reducing the cost of reuse considerably. Liquid wastes from treatment can be disposed via permitted injection wells, while solid wastes from filtration are sent to permitted landfills, both common and well-understood processes in the oil and gas industry. Reuse replaces valuable fresh water, another way that saline and brackish waters can substitute for fresh water withdrawals, especially during drought.

Innovative Brackish Water Treatment Technologies

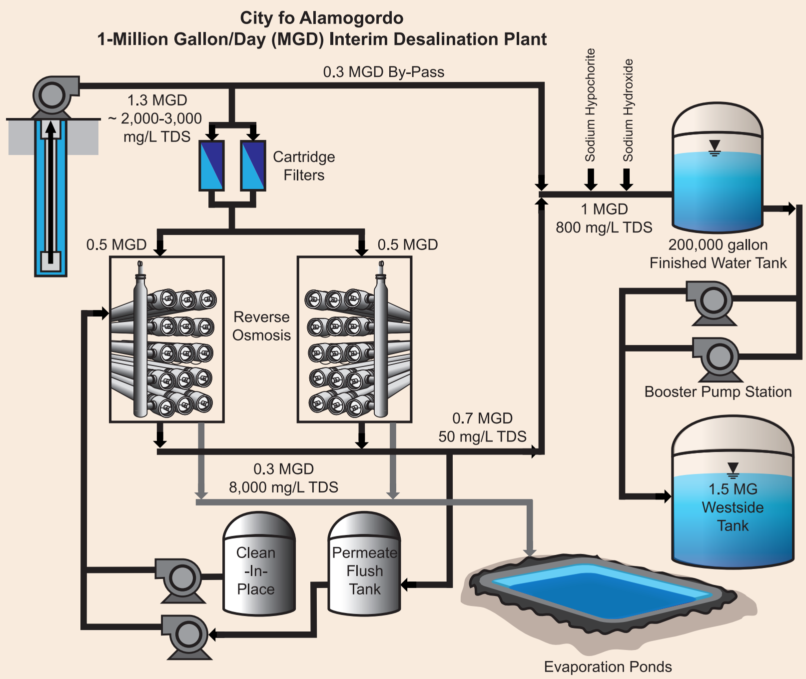
Solar-based desalination systems are being installed more frequently as the technology has advanced in the last 10 years. Typical locations utilize seawater and can use solar thermal or solar electric energy sources for treatment. The largest plant to date is being installed in Saudi Arabia. The Al-Khafiji solar desalination plant will use solar-generated electricity to drive a reverse-osmosis system with a capacity of up to 30,000 m^3 per day, supplying up to 100,000 people. Smaller plants can utilize solar thermal methods, such as those on the Canary Islands and in demonstration units in Hawaii and California. Growth of this technology is rapid and promising for the right locations, particularly because of its ability to reduce energy costs and to reduce the need for importation of fossil fuels to islands or remote areas.

Researchers are developing more ways to utilize various heat sources for desalination, to reduce the energy costs involved and to reduce the use of fossil fuels. Virtually any source of heat can be used for desalination. Traditional distillation methods, such as *multistage flash distillation* or *multiple-effect distillation* utilize waste heat from electricity generation plants. This is frequently done in the Middle East and is being developed in China. Typical operating temperatures for these systems are from 70 to 120°C. However, geothermal heat, solar heat, and other waste heat sources can be used in "combined cycle" systems that facilitate evaporation and distillation processes at lower temperature ranges (e.g., from 50 to 90°C). One example is *adsorption desalination*, where vapor distilled from saline water is concentrated on a silica adsorbent material and then released using waste heat. This is one of several new methods that use the physics of heat transfer in a controlled system for producing high-quality distillate, with the aim of reducing energy demands and costs.

Likewise, wind-generated electricity could be used to treat saline water during off-grid hours. By pairing wind electricity with natural gas resources—which are plentiful in New Mexico—to provide a steady stream of energy, we could provide a reliable supply of desalinated water at lower cost. The U.S. Bureau of Reclamation recently studied the integration of wind power with desalination technology (Swift et al., 2009). A key benefit is the reduction of overall energy costs for desalination, although higher energy costs are predicted for pumping the water to be desalinated from a deeper aquifer. System integration and the intermittent power from wind sources still require careful system design and demand analysis.

Desalination in New Mexico

New Mexico is home to the Brackish Groundwater National Desalination Research Facility in Alamogordo. This research facility, managed by the U.S. Bureau of Reclamation, hosts researchers from around the world, enabling testing of new desalination technologies. Factors that contributed to the optimal siting of the research facility included abundant, relatively shallow brackish water and the availability of injection formations for waste disposal.



Schematic diagram for the interim desalination plant under construction for the City of Alamogordo. The source well field depicted in the upper left corner of the diagram is intended to pump 1.3 million gallons per day (MGD) for approximately 4 months per year. As shown in this schematic, some brackish water will be blended with fresh water to meet the volume needs for the community. Evaporation ponds will be used for waste concentrate waste disposal, depicted in lower right. *Diagram modified from CDM Smith.*

While there is widespread interest in implementation of brackish water desalination in New Mexico, currently there is only one facility under construction in the City of Alamogordo, nearby the research facility. There is a dire need for new fresh water to supply the city. The plan is to have Phase I of a modular facility that can be expanded if needed, installed by 2018. The initial method for concentrate disposal will be evaporation ponds, made feasible by the high evaporation rates in the region. The facility is expected to create 1 million gallons of treated water per day and was funded by multiple grants, loans, and severance tax allocations.

Summary

Here in New Mexico, we are working to better understand the alternative water resource options available. With improved data access and aquifer characterization related our brackish water resources, this can enable us to make well-informed decisions about the potential use of alternative water resources. Applications of some of the most innovative water reuse and desalination processes is within our reach with enough time, proper planning and financial investment. Ultimately, brackish water desalination, managed along with conservation and reuse, can contribute to a resilient, sustainable supply of fresh water. (For more resources see back panel of this issue).

—Jeri Sullivan Graham

Dr. Sullivan Graham is a senior scientist in the Chemistry Division at Los Alamos National Laboratory. She is a hydrogeologist and geochemist with 30 years of experience in environmental chemistry, ground-water hydrology, water treatment, systems modeling, and field studies. She has developed considerable expertise in produced water and brackish water chemistry and treatment over the last 15 years of her research. Dr. Sullivan Graham currently is a science advisor to Secretary David Martin of the New Mexico Energy, Minerals, and Natural Resources Department and is the coordinator for the Brackish Water working group under the Governor's Drought Task Force. She is a certified professional geologist, and holds a Bachelor's degree in Chemistry from the University of Virginia, a Master's degree in Geochemistry from the University of North Carolina at Chapel Hill, and earned her PhD in Earth and Environmental Science from New Mexico Tech. She lives in Los Alamos, New Mexico with her husband Paul and cat Miss Lucy Belle.

Bureau News

New Director and State Geologist, Matthew Rhoades, arrives at the Bureau of Geology

Matthew has a BS and MS in Geology and an MBA with emphasis in Project Management. He brings to the bureau 30+ years of experience as a consulting geologist and environmental program manager, and is licensed in six states as a professional geologist. His research and management experiences include exploration programs, site investigations, aquifer characterizations, environmental remediation, mining, and environmental permitting. Matt has extensive experience with groundwater, surface water, soil, leachate, mine waste, and mine tailings. He has considerable project experience throughout Mexico and South America and is a capable Spanish speaker.

Rockin' Around New Mexico—Socorro and Magdalena, New Mexico, July 15, 2015

Rockin'Around New Mexico, a geology workshop for K-12 teachers, was held in Socorro on July 8–10, 2015. The 26 participants received instruction on the hydrogeology of the Magdalena area and its role in the 2013 water shortage. Several field trip stops included discussions about precipitation, surface runoff, and infiltration as it impacts aquifer recharge. Teachers also learned that the extensive faulting

A field lecture by Dave Love on the left, and Bruce Harrison on the right.

and fracturing in Magdalena and the surrounding area complicates groundwater flow and plays a role in rapid groundwater depletion in high water demand situations, which was the case during the 2013 Magdalena water shortage. On the campus of New Mexico Tech, teachers visited a watershed study site where surface water runoff, infiltration, and erosion rates are being measured. A presentation on the structural significance of the rift-bounding La Jencia fault near Magdalena included information on recent earthquakes that were felt in the Socorro (2014) and Magdalena (2013) areas. After an update on the recovery following the 2011 Christ Church, New Zealand earthquake, teachers practiced the Drop, Cover, and Hold On! earthquake safety drill.

This workshop was sponsored by New Mexico Bureau of Geology, New Mexico Department of Homeland Security Emergency Management, and New Mexico Mining Association.

New Building Dedication

On Friday, May 8th, the new Bureau of Geology building was dedicated to Jessie and Chuck Headen, longtime supporters of New Mexico Tech. The Headen Center is named for former residents of Socorro, Chuck and Jessie Headen, who bequeathed the bulk of their estate to New Mexico Tech. Tech received the first annual payment from the Trust earlier this year for more than $500,000, all of which supports the university's scholarship fund.

Jerry Armijo, NMT regent, cuts the ribbon for the new Bureau of Geology building. Greer Price, former Director of the Bureau on the left, and Dr. Daniel Lopez, President of NMT, on the right.

We've settled into our new building since our move across campus to the corner of Bullock and Leroy Streets during the month of May. The Mineral Museum and Bureau Bookstore are now open. Visit our website at http://geoinfo.nmt.edu for hours and further details.

New Mexico
EARTH
MATTERS

Volume 15, Number 2
Published twice annually by the
New Mexico Bureau of Geology and Mineral Resources

Matthew J. Rhoades, CPG, RG
Director and *State Geologist*
a division of

New Mexico Institute of Mining and Technology

Daniel H. López
President
801 Leroy Place
Socorro, New Mexico 87801-4750
(575) 835-5420

Bureau Albuquerque office
2808 Central SE
Albuquerque, New Mexico 87106
(505) 366-2530
Visit our website at:
geoinfo.nmt.edu

Editors
Stacy Timmons, Gina D'Ambrosio, and Richard Arthur

Layout, Design, Production:
Gina D'Ambrosio
Graphics: **Leo Gabaldon and Brigitte Felix**

Earth Matters is a free publication.
For subscription information please call (575) 835-5490, or e-mail us at publications@nmbg.nmt.edu

Cover photo of Ship Rock, New Mexico
© Gary Rasmussen

New Mexico Bureau of Geology & Mineral Resources
New Mexico Institute of Mining & Technology
801 Leroy Place
Socorro, New Mexico 87801-4750
Return service requested

NONPROFIT ORGANIZATION
U.S. Postage
PAID
PERMIT NO. 1888
ALBUQUERQUE, NM

For More Information

http://water.usgs.gov/ogw/gwrp/brackishgw

http://water.epa.gov/type/groundwater/uic/

An Overview of the Hydrogeology of Saline Ground Water in New Mexico, by G. F. Huff, 2004, New Mexico Water Resources Research Institute, Las Cruces, New Mexico, 14 pp.

Hydrologic Assessment of Oil and Gas Resource Development of the Mancos Shale in the San Juan Basin, New Mexico, by S. A. Kelley, et al., 2014. New Mexico Bureau of Geology and Mineral Resources, Open-file Report.

Wind Power and Water Desalination Technology Integration by Andy Swift, et al., 2009. US Department of the Interior, Bureau of Reclamation, Denver, CO., 400 pp.

Inland Desalination: Current Status and Challenges, by M. Mickley, 2010. 25th annual Water Re-use Symposium, Washington, DC.

Guidance Manual for Brackish Groundwater Desalination in Texas, 2008, NRS Consulting Engineers, Texas Water Development Board, Austin, Texas, 96 pp.

Desalting Handbook for Planners, 2003, US Department of the Interior, Bureau of Reclamation, Water Treatment Engineering and Research Group, 3rd Edition, Report No. 72, 233 pp.

State-of-the-art of reverse osmosis desalination, 2006, by C. Fritzman et al., Institue fur Verfahrenstechnik, RWTH Aachen, Germany, 76 pp. Access through **www.sciencedirect.com.**

For More Information About the Bureau and its Publications:

Visit our website at **http://geoinfo.nmt.edu**
Write or visit our Publications Office at our **NEW LOCATION**
across campus (on Bullock Blvd.) at New Mexico Tech, 801 Leroy Place, Socorro, New Mexico 87801
Call (575) 835-5490 or e-mail us at **publications@nmbg.nmt.edu**