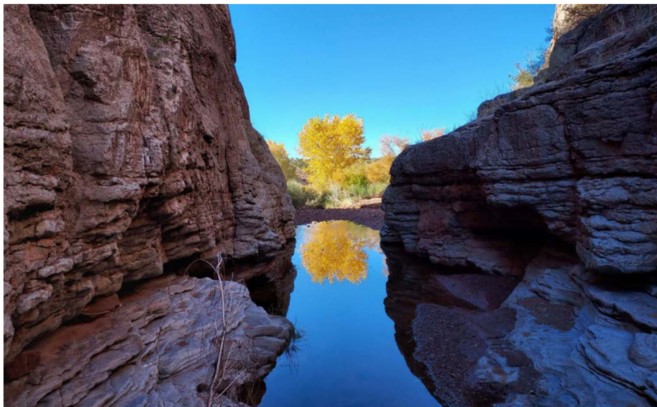

SUMMER 2025

New Mexico EARTH MATTERS

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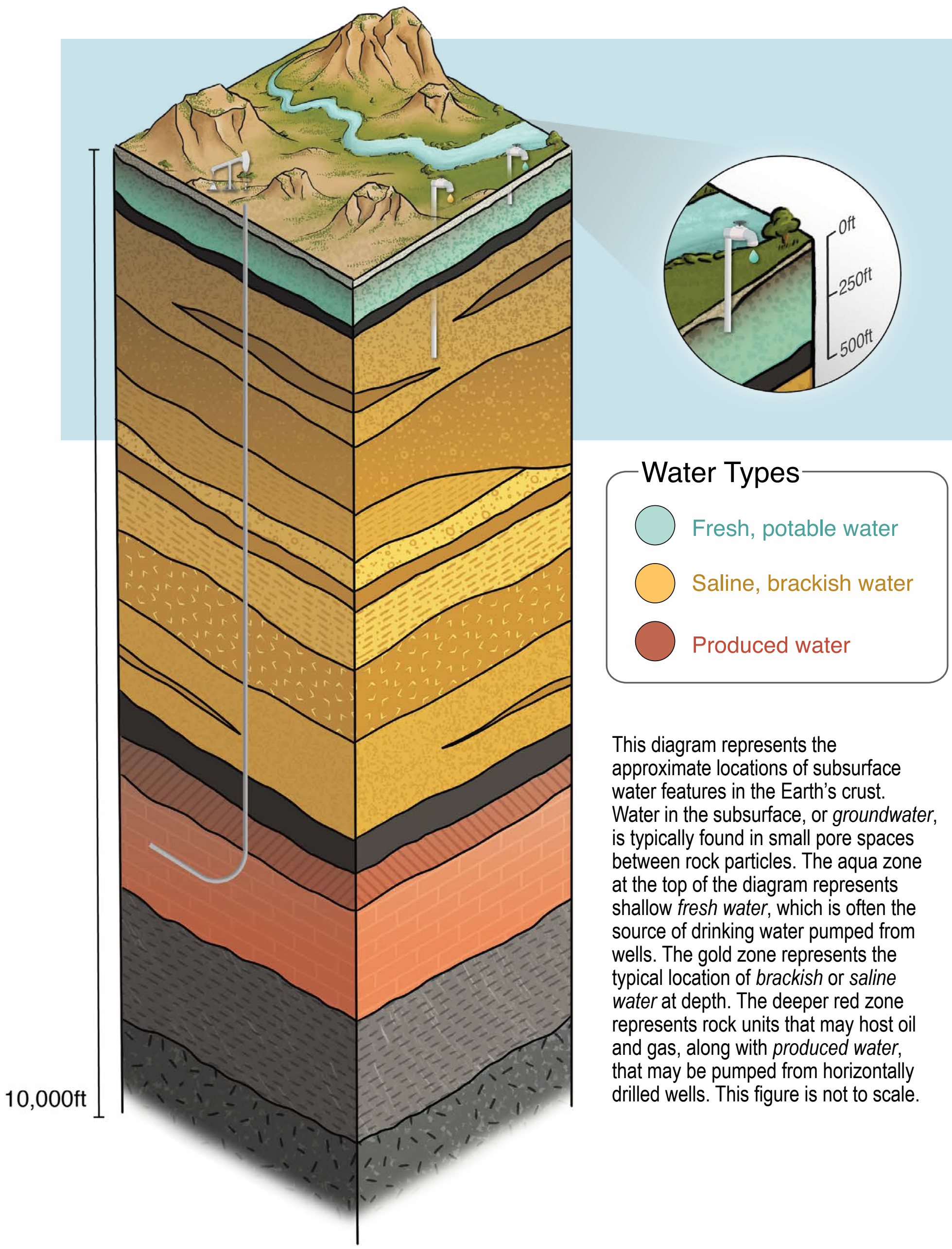
Brackish, Saline, and Produced Water— Understanding New Mexico's Alternative Water Resources

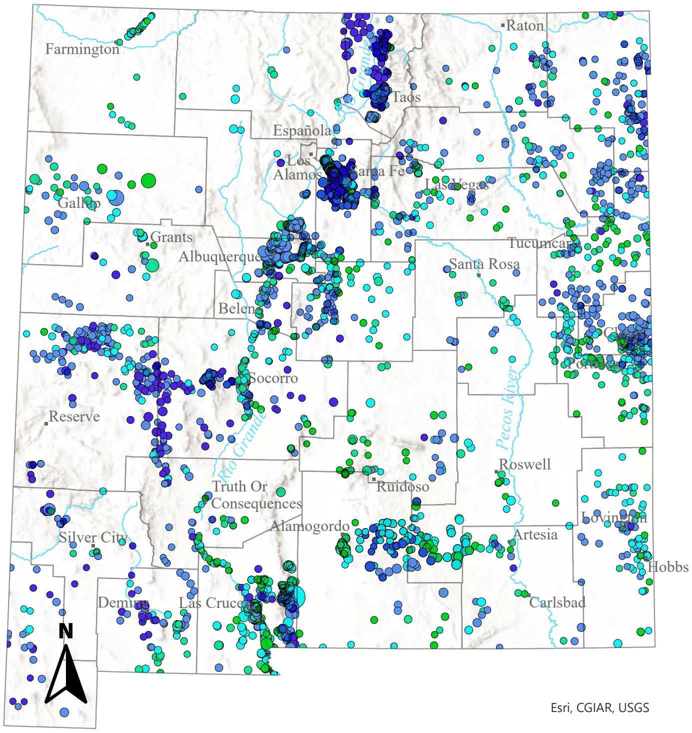


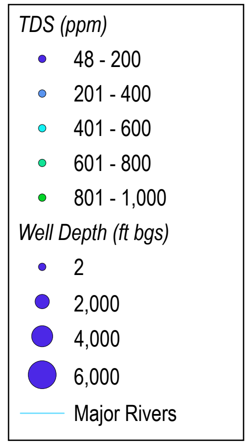
This diagram represents the approximate locations of subsurface water features in the Earth's crust. Water in the subsurface, or *groundwater*, is typically found in small pore spaces between rock particles. The aqua zone at the top of the diagram represents shallow *fresh water*, which is often the source of drinking water pumped from wells. The gold zone represents the typical location of *brackish* or *saline water* at depth. The deeper red zone represents rock units that may host oil and gas, along with *produced water*, that may be pumped from horizontally drilled wells. This figure is not to scale.

THE MOST VISIBLE AND WELL-UNDERSTOOD WATER RESOURCE IN NEW MEXICO is the *surface water* that flows through our rivers and streams. Another very important but less visible resource is our *groundwater*, which is found in pore spaces and fractures in rocks and sediments below the land surface. Understanding our groundwater resources is critical in New Mexico, especially as our climate becomes warmer and drier, leading to decreases in available surface water.

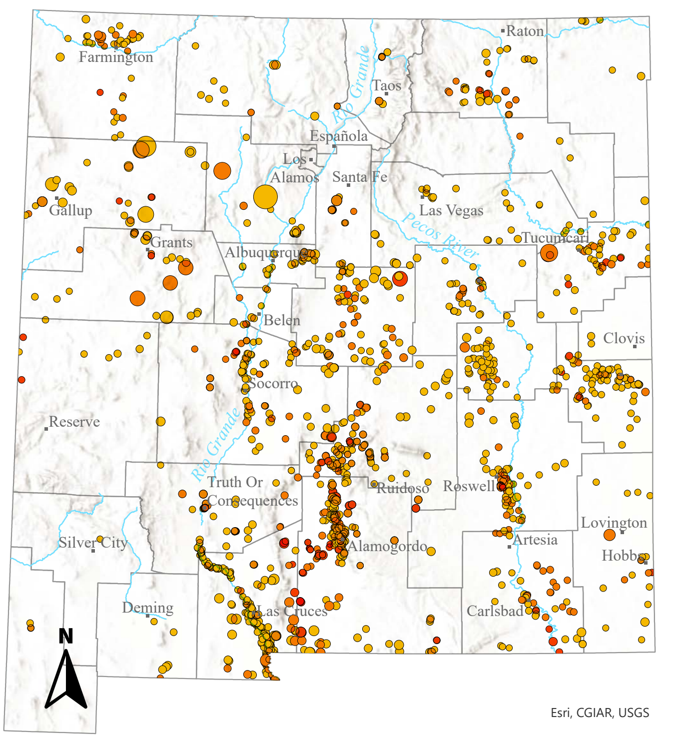
Much of the groundwater currently used is of overall good quality and is the source for approximately 95% of drinking water systems in New Mexico. However, some groundwater from subsurface geologic formations is not potable and can contain naturally occurring elements and chemical compounds, such as arsenic, uranium, fluoride, or salts, some of which can be harmful in high concentrations.

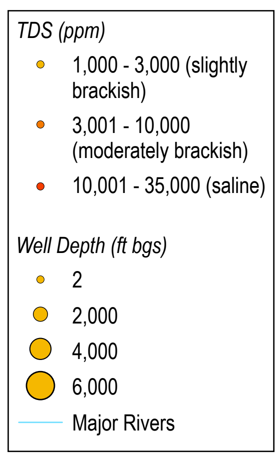
For centuries, humans in New Mexico have relied on readily available freshwater resources. Today, a warming climate means that our state is facing a challenging future, including prolonged drought, increasing average temperatures, and more aridity, all of which lead to declining availability of fresh water. In this issue of *Earth Matters*, we'll look at some of the "not-so-fresh" water alternatives that we have in New Mexico, which we may need to turn to as freshwater options become less available. We'll provide some context for the different ways we describe groundwater in particular, including where it is found, its chemical composition, and its source. We are not advocating for how we should or should not use these alternative waters, but are providing simple explanations of the different types of water that exist in New Mexico.





Location of freshwater wells in New Mexico with known chemical composition showing the range of well depth and water quality based on total dissolved solids (TDS, in parts per million, ppm). ft bgs = feet below ground surface





Location of brackish and saline water wells in New Mexico showing well depth and water quality based on total dissolved solids (TDS, in parts per million, ppm). ft bgs = feet below ground surface

Water type	Total dissolved solids (TDS) in parts per million or milligrams/liter	Comment
Fresh	up to 1,000	Typical range
Brackish	1,000–10,000	As defined by U.S. Geological Survey
Saline	10,000–35,000	Seawater is ~35,000
Oil and gas produced waters	~500–250,000	Natural formation waters associated with oil and gas production

Fresh Water

Fresh water in New Mexico is typically limited to the waterways that cover a very small amount of our land surface (only 0.2%) or to shallow groundwater. Fresh groundwater is commonly found less than 500 ft below the land surface. In certain places, where geologic conditions are favorable, fresh groundwater can be found at greater depths (more than 1,000 ft). As surface water flows through waterways or as groundwater moves through sediments and rocks in the subsurface, it may dissolve minerals within the local rocks, such as calcite ($CaCO_3$), gypsum ($CaSO_4{\cdot}2H_2O$), and halite (NaCl). As water moves through porous rocks and dissolves minerals, it accumulates dissolved ions that make up these minerals, such as calcium (Ca^{2+}), sulfate (SO_4^{2-}), sodium (Na^+), and chloride (Cl^-). This "dissolved rock" in water is measured as total dissolved solids (TDS), which is the sum of the concentrations of ions in solution. TDS is a simple and widely used measure of water quality. Potable water typically contains TDS less than 1,000 parts per million (ppm, which is equivalent to milligrams per liter, mg/L).

Groundwater occupies the tiny open spaces (pores) in rocks or sediments made up of sand and gravel, or in cracks (fractures) in seemingly impervious rocks like granite or limestone. In some rocks, particularly those that are sandy and gravelly with ample interconnected pore space, groundwater can move relatively easily and quickly. In less-permeable rocks, such as dense siltstone or clay, groundwater moves very slowly. When groundwater moves slowly through rocks, the water and minerals in the rock interact for longer time periods, allowing more opportunity for minerals to dissolve and leading to higher TDS.

Shallow, fresh groundwater is commonly found along rivers and arroyos and is *recharged*, or replenished, by runoff of snowmelt, rain, and from rivers, streams, and acequias. These areas of shallow fresh water provided water to develop our state and supported early agricultural production because premodern civilizations could reliably find water along drainages.

Surface water and shallow groundwater may be interconnected, meaning that shallow groundwater can be recharged by surface water. Therefore, shallow groundwater is vulnerable to changes in land use and potential contamination. This can occur if leakage from septic systems or accidental releases of chemicals, such as PFAS or contaminated wastewater, are transferred to shallow groundwater through recharge.

The age of fresh groundwater in New Mexico is typically **younger than 100 years** (but it can be mixed with older water, too). Such young ages indicate that shallow groundwater depends on rapid recharge from streams, rivers, or acequias. If land use practices, such as significant groundwater pumping, or increased aridity

A view along the middle Rio Grande. *Photo by Christi Bode/Moxiecran Media*

reduce surface water flows, serious groundwater level declines can occur, potentially leading to wells going dry.

Brackish and Saline Water

Groundwater that has dissolved a significant quantity of minerals is called *brackish* or *saline*. Brackish or saline water is typically not safe to drink without special treatment. Across the spectrum of water quality, brackish and saline waters contain higher TDS than fresh water. In other words, the water tastes saltier. Water is considered brackish if the TDS concentration is between 1,000 and 10,000 ppm and saline if TDS is between 10,000 and 35,000 ppm. For reference, seawater contains about 35,000 ppm TDS. Water becomes fully saturated with salt, meaning that solid mineral grains will precipitate from the water, above 250,000 ppm TDS.

Brackish groundwater can be found at shallow depths (0–50 ft below the surface) in several areas of the state, including the Estancia Basin, Tularosa Basin, and Salt Basin. These large basins are considered *closed basins* with respect to surface water because they are not associated with a through-flowing river that can remove saline water and shallow groundwater from the basin. Over millions of years, the groundwater and recharge from the streams that drain the surrounding highlands moves slowly toward the lowest point in the basin. Ponding of water, creating *playas*, can occur where groundwater discharges naturally at this lowest point, and/or where stream and groundwater inflow match evaporative outflow. As water evaporates from these playas, the remaining water becomes increasingly salty.

Salinity and brackishness tend to increase where water moves slowly through the subsurface. Certain geologic formations contain more abundant soluble minerals than others, and this can contribute to poorer-quality groundwater. Additionally, at depth, geologic formations tend to have less available pore space between grains or narrower fractures due to the weight of the overlying rock column, which slows the movement of groundwater and gives water more time to interact with the rocks, thereby further increasing TDS concentrations. Deep-seated water is typically warmer, which also increases the rates of mineral dissolution. Thus, over long periods of time and with higher temperatures, even less-soluble minerals can dissolve, which worsens the water quality over time (as shown by higher TDS concentrations). Older water, which has spent more time in contact with rock, typically has a higher TDS than it did when it started its journey as surface water in stream headwaters and recharge areas hundreds or thousands of years ago.

Brackish and saline groundwater is typically tens of thousands of years old and commonly has very high TDS concentrations. Brackish water is also found in localized areas at relatively shallow depths in aquifers composed of loose, river-laid sediments within the Rio Grande Valley, mostly due to geologically controlled zones of upwelling of deep saline waters that mingle with fresher shallow groundwater.

The observation that deep brackish and saline groundwater is typically thousands to tens of thousands of years old is an important consideration when pumping this water for use. While advanced filtration technologies can remove many impurities, much of this deep brackish and saline water in New Mexico is not being actively recharged or replenished, and in most cases, these water sources are effectively nonrenewable resources. However, rock formations that host brackish and saline groundwater are extensive and contain very large volumes of salty water. In some regions, such water sources may be the only option available for reliable water supplies.

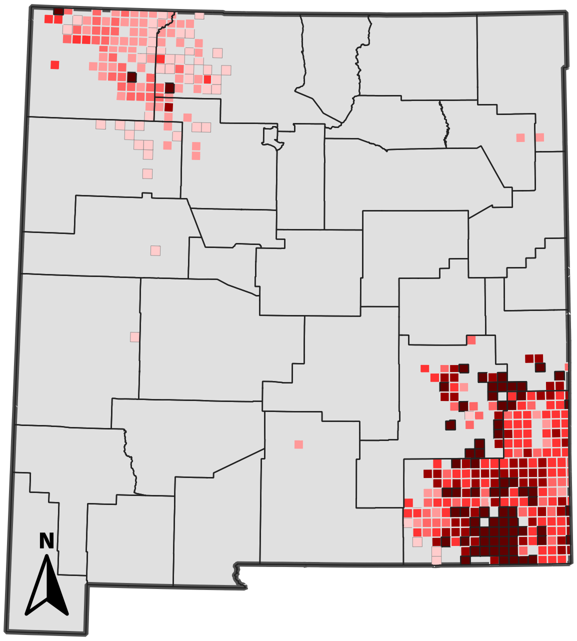
Very large reserves of brackish groundwater, perhaps somewhere around 2 to 4 billion acre-feet (over 650 trillion gallons), may exist in New Mexico. These estimates have been made using available information about the expected TDS of major geologic units in the subsurface. Knowledge of the occurrence, quality, and volume of brackish and saline water varies significantly across the state depending on the availability of subsurface data.

Produced Water

Produced water is a byproduct of oil and gas extraction, originating from rock formations deep underground. Most of this water, known as formation water, is ancient and has been trapped in the rock for millions of years. In some cases, produced water may also include fluids that were previously injected into the formation to help extract the oil and gas.

Most oil- and gas-bearing rocks were once soft and unconsolidated sediments that were deposited in ancient seas, river systems, and inland basins. Over many millions of years, these sediments were buried, compacted, and transformed into rock in a process called *lithification*. Under the right conditions, the associated organic material within the sediments slowly turned into oil and gas. As sediments are compacted, the volume of porosity gets smaller, and much of the original water is expelled. The water that remains interacts with the minerals in the rocks, dissolving some soluble minerals and precipitating less-soluble minerals. Burial also causes rocks to heat up—temperatures within the Earth increase roughly 1.4–1.6°F per 100 ft of depth, depending on the location and rock type. This heating can increase the speed at which minerals dissolve into water, and with sufficient time and heat, even minerals that don't dissolve easily may also contribute to the chemical composition of the formation water.

In New Mexico, we have oil and gas in rock formations ranging in age from the Devonian Period, about 419 million years ago, to as young as the early Eocene, roughly 50 million years ago. Some of the most prolific hydrocarbon reservoirs are Permian in age, around 300 to 270 million years old.



Average quality of produced water generated by New Mexico townships based on total dissolved solids (TDS, in parts per million, ppm).

Although the water that was trapped within these ancient rocks may move from one formation to another, we can assume that all formation water is very old, and because of this, it usually has a complex chemical composition as compared with, for example, rainwater. Today, when these rocks are tapped for oil and gas, the ancient formation water is brought to the surface with the oil and gas resources—and is then known as produced water.

When a well is drilled into an oil or gas reservoir and pumped, it drains the pore spaces in the rock that hold both hydrocarbons and formation water. Depending on the reservoir, water may occupy anywhere from 15 to 50% of the pore space. As hydrocarbons are extracted, the water is brought to the surface as well.

In addition to this naturally occurring formation water, oil field activities often introduce a mixture of fresh and recycled water into deep geologic formations to enhance oil recovery from these reservoirs. Most modern wells are hydraulically fractured—fractured by high-pressure fluid injection—to improve the flow of oil or gas, a process also known as *fracking*. Water is the main component of this fluid; however, other proprietary chemical compounds and a propping agent (like sand) are included. A portion of the water mixture remains in the reservoir, mixing with the formation water, before eventually returning to the surface as produced water. Over time, many fields also rely on water injection to maintain reservoir pressure and to enhance oil recovery.

As hydrocarbons are extracted, void space is created in the reservoir, causing reservoir pressure to drop and making production increasingly difficult. To help maintain reservoir pressure, producers may inject large amounts of water back into the reservoir. Eventually, both the natural and injected water cycle back up the well along with the hydrocarbons.

Produced water has an uneven distribution in terms of geology, volume, and quality. In New Mexico, the Permian Basin in the southeast and the San Juan Basin in the northwest generate the vast majority, while the Raton Basin in the northeast contributes only a small fraction of the state's total produced water volume. Over the past five years, more than 95% of the state's produced water has come from the Permian Basin, which also accounts for about 98% of oil and 80% of gas production in the state. Just like the oil and gas it accompanies, produced water is found at different depths depending on the geology of the region. In some parts of the Permian Basin, producing formations lie well more than 12,000 ft below the surface, while in areas like the San Juan Basin, formations may be as shallow as 1,500 ft. In New Mexico, state regulations define produced water as water from underground sources 3,000 ft or more in depth that is a result of oil or gas production. Water produced from shallower formations may be classified as "underground water" and fall under different regulatory jurisdiction, particularly if it has a salinity less than or equal to 10,000 ppm TDS.

In New Mexico, produced water typically has very high salinity. Because the water has been in contact with rock for millions of years, it has dissolved a wide range of minerals and elements from the surrounding formation. This leads to TDS levels far exceeding those of seawater (~35,000 ppm).

In the Permian Basin, average TDS levels in produced water exceed 100,000 ppm, and some samples have measured more than 300,000 ppm—about nine times saltier than seawater. By contrast, produced water from the San Juan Basin tends to be significantly less saline, typically around 30,000 to 50,000 ppm. Water quality can vary for several reasons, including the type of environment where the rock originally formed, the kinds of minerals it contains, how deeply it was buried, how long it has been underground, and how water has moved through it over time.

The scale of produced water volumes in New Mexico is staggering. In 2023 alone, the Oil Conservation Division of the New Mexico Energy, Minerals and Natural Resources Department reported that the Permian Basin generated more

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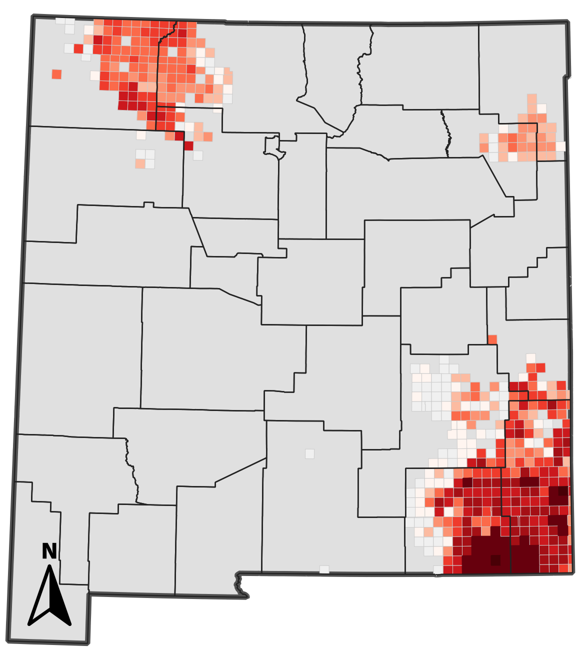

Volume of produced water generated by New Mexico townships in 2023. Volume is shown in barrels (bbls), and each barrel is equivalent to 42 gallons.

continued from page 4

than 96 billion gallons of produced water. As oil fields age, the proportion of water to oil—called the water-to-oil ratio—tends to increase. In some mature fields, especially in the Permian Basin, the produced fluid can consist of up to 98% water and only 2% oil, although a more typical ratio would be between 4:1 and 6:1 (water:oil).

Because of the large volumes involved, produced water has gained attention as a possible alternative water resource—especially as a way to conserve higher-quality groundwater and surface water. But there are still major challenges, including the high costs of managing the water and concerns about its safety and suitability for reuse.

Produced water has traditionally been treated as waste in the oil field. Managing it is expensive: there are costs associated with production, separating the water from oil and gas, transporting it to disposal sites, and injecting it into deep wells built specifically for disposal. The water itself can contain a mix of potentially harmful substances, including salts, heavy metals like lead and nickel, naturally occurring radioactive materials from underground rock, and a variety of hydrocarbons and organic compounds. Some of these contaminants are relatively easy to remove, but others are toxic, persistent, and require costly treatment processes that may not be practical.

Despite these challenges, growing economic, environmental, and regulatory pressures have led the oil and gas industry to begin viewing produced water as a potential resource instead of just a liability. FracFocus reported data that show New Mexico's oil and gas industry used approximately 14.5 billion gallons of water for drilling and well completions in 2020, consisting of 25% fresh water and 75% recycled produced water. Reusing produced water can reduce the need for fresh water in drilling and completion, improve operational efficiency, and help address concerns about groundwater protection and induced seismicity (earthquakes generated by injecting water deep underground).

Currently, state regulations limit produced water use to within the oil and gas industry. In New Mexico, only about 10% of produced water is reused or recycled, and nearly all of that is for operations like hydraulic fracturing. Still, research is underway to explore broader reuse options. Efforts are focused on developing more affordable and effective treatment methods, using lightly treated water in industrial processes like cooling or road construction, and even recovering valuable minerals from the water. These studies, led by universities, industry, and national labs, are making great advances in purification technologies for both brackish and produced water and could open the door to using at least some fraction of these vast water sources at a scale and price point that would help supplement New Mexico's overall water supply.

Where Do We Go from Here?

When thinking about the future of water in New Mexico, we want to consider all options for supplying water to the numerous and varied water users across our state while also conserving our limited fresh water. In some cases, we lack sufficient information, the regulatory framework, deep geologic and hydrologic data, or basic geochemical understanding to assess and use these alternative water resources. Presently, brackish and saline groundwater is being mapped through state-funded programs by the New Mexico Bureau of Geology and Mineral Resources, along with other regional efforts to build a strategic water supply that follows House Bill 137, which was passed in 2025.

Produced water is currently available in large volumes and faces increased challenges for disposal. Although a small portion of produced water is recycled or reused by oil and gas producers, it could be an attractive alternative supply of water for certain uses by implementing advanced treatment options. What kinds of uses depend greatly on the available technologies to treat the water sufficiently for new applications.

With fresh water becoming scarcer, we need to evaluate alternative sources of water. Doing so requires addressing a host of challenges, including identifying potential sources and testing innovative treatment options. As we look ahead to our changing water supply portfolio in New Mexico, staying informed on the science, new treatment technologies, energy costs, and waste disposal considerations while maintaining a vision for how to develop reliable water supplies is an important aspect of planning for the future.

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Bureau News

Geothermal energy in New Mexico highlighted

Bureau scientists Dr. Shari Kelley and Luke Martin have spotlighted geothermal resources in New Mexico through a recent conference and publication. The Advancing Geothermal Development Workshop was held May 1 at New Mexico Tech (NMT) and was attended by 105 people. Workshop speakers and panelists discussed geothermal energy opportunities and future growth in New Mexico's geothermal industry, engagement with the petroleum and mining industries, involvement of tribes and pueblos, partnerships with utilities in geothermal development, and opportunities to improve policies and regulations. The final session focused on workforce development, including the exciting launch of the Graduate Certificate in Geothermal Energy that will be offered this fall at NMT. Workshop participants spanned academia, state government, the private sector, and national laboratories, and all had ample opportunity for exchanging technical knowledge and networking.

Recently, Project InnerSpace, a nonprofit initiative focused on geothermal energy development, released a report entitled "The Future of Geothermal in New Mexico," produced in conjunction with the New Mexico Bureau of Geology and Mineral Resources and NMT. This report details New Mexico's unique advantages, including subsurface heat, well-developed expertise in the oil and gas sector and geothermal industries, and support from political leadership that may soon drive a

Dr. Shari Kelley at the Advancing Geothermal Development Workshop. *Photo by Frank Sholedice*

"geothermal boom." The report identifies 15 policies that, if enacted, would spur the development of more geothermal resources by establishing additional legal and regulatory certainty for the geothermal industry, creating conditions to accelerate geothermal production, expanding incentives, encouraging the development of geothermal heating and cooling, and preparing the workforce for new geothermal jobs, as is already being done at NMT.

State Forester Laura McCarthy receives Earth Science Achievement Award

The 2025 Earth Science Achievement Award for Public Service and Public Policy was awarded to New Mexico State Forester Laura McCarthy at the New Mexico State Capitol in February. As State Forester, McCarthy is responsible for forest management on 43 million acres of state and private lands, including wildfire prevention and response, forest health improvement, reforestation, watershed health, and climate change adaptation. Under her leadership, the State Forestry Division has doubled in size, modernized its business systems, and taken on the challenges of postfire recovery and reforestation of burned areas with the year 2100 climate in mind. She is committed to an ecosystem-based approach to forest health, drawing on her decades of experience as a forester, wildland firefighter, and policy advisor.

Before being appointed State Forester in 2019, McCarthy worked for over two decades in advocacy and policy development in New Mexico. As associate state director of The Nature Conservancy's New Mexico Field Office, she led the Rio Grande Water Fund, a public-private partnership to restore 600,000 acres of at-risk forests to protect watersheds that supply water for one million New Mexicans. She also advocated for federal fire and forest restoration policies, working closely with Senators Jeff Bingaman and Pete Domenici to create the Collaborative Forest Landscape Conservation Program in 2009.

Over her years of service to the state of New Mexico, both as a private citizen and State Forester, she has earned numerous awards, including New Mexico Environmental Leader of the Year in 2015, the Yale School of Forestry and Environmental Studies Distinguished Alumna Award in 2017, and the Outstanding Service Award from the Society of American Foresters Southwest Division in 2018.