HOW AN "OCEAN' UNDER ARIZONA AND OIL COMPANIES WATER COULD REDUCE ARIZONA'S WATER CRISIS

In 2018 the United States Geological Survey reported it estimated there was 680,000,000 acre feet of brackish water under Arizona. That represents what Arizona uses in for 100 years. This water was left between 500 and 1500 feet under the surface of the state millions of years ago when an ocean covered what is now Arizona. Brackish water is not as salty as seawater, but it is more so than fresh water. It is found in geological layers lower than fresh water and does not mix with it. Brackish water cost about 50 percent less to desalinate than seawater. The state has a giant desalinization plant in Yuma that is hardly used and a huge atomic reactor outside of Phoenix that can make it potable/drinkable. The state could choose to make more desalinization plants.

Untreated brackish water can be used for industrial and non-industrial uses. Such as fire control, power generation, cleaning, and even some kinds of irrigation. Brackish water can be used to supplement water needs to help endangered species that require brackish water to survive in coastal regions. It is critical to help maintain ecological balance of these coastal ecosystems. Other uses include aquaculture, mining, cooling (e.g., nuclear power plant, etc.), ground water recharge, and to help industries use less freshwater and reduce wastewater production. Brackish water can contain minerals and rare earths that can be used to create solar panels, hydrogen fuel cells, and wind turbines as well as other technologies.

Brackish water also comes out of the ground when oil and/or gas is extracted from the ground. This water again was deposited millions of years ago when the region well is now was covered by ancient oceans.

Currently there is about 1,000,000 petroleum wells in the country that produce around 58,000,000 barrels of brackish water every day (7800 acre feet/2,236,000,498 gallons). The brackish water and oil/and or gas reach the surface mixed and must be separated through a process often conducted by tanks close to the well.

Petroleum companies view brackish water as a burden. They have no use for it and must find ways to dispose of it. The brackish water is extracted and is eventually trucked to a "disposal well." A well that has been pumped dry of its oil and gas. The brackish water extracted from other wells is pumped down the disposal well to "dispose" of it.

Arizona could decide to provide petroleum companies another way do get rid of their unwanted brackish water. They could use the gigantic national underground national pipeline system that is connected to every state in the continental US to send brackish water to Arizona. The petroleum companies could even use their current pipeline easements to construct dedicated brackish water pipelines to Arizona. It would be a win-win. The

petroleum companies could get rid of a burdensome byproduct and Arizona could access an almost unlimited source of water.

There are many potential uses of untreated brackish water. However, there is a serious need for potable drinking water in the state. How could we desalinate this water in an efficient cost efficient way? Currently, there are four methods of desalinating brackish water:

- **Reverse Osmosis –Using a membrane to remove salt.**
- **Electrodialysis- Using electrified membranes to remove salt.**
- **Ion Exchange-- Using an electrified resin to remove salt.**
- **Distillation-Boiling brackish water to remove salt and collect the fresh water condensate.**

Salt recovered from the desalination of brackish water could be sold on the international salt market, which represents a $34,000,000,000 yearly business. These funds could help the state overcome budget shortfalls, and fund public infrastructure projects among other things.

The Arizona state legislature is about to vote to determine if the state should fund serious study of the potential of using brackish water for solving at least part of our water crisis. It is my sincere hope it makes a wise informed decision that includes brackish water as part of the solution.

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HOW TO CONVINCE OIL COMPANIES TO SEND WATER TO ARIZONA TO REDUCE THE STATE'S WATER CRISIS

Yes, you read that right. It may be possible to entice oil companies to send water they find a worthless burden via the country's huge pipeline system to Arizona that could be used to relieve the state's water shortage. Brackish water is the name of the type of water oil companies cannot use and want to get rid of.

Brackish water is a combination of saltwater and fresh water. The salinity of the water is determined by the exact location of where it was obtained (Redford, 2023). The brackish

water that comes out of the ground when oil and/or gas is taken out of the ground is called "produced water" (Dalrymple, November 13, 2023). This water was deposited millions of years ago when of the region was covered by ancient seas and oceans (Dalrymple, November 13, 2023; Wallace, January 8, 2018).

Currently there is approaching 1,000,000 oil and/or gas wells in the country that produce around 58,000,000 barrels of brackish water every day (7800 acre feet/2,236,000,498 gallons) (Andrews, 2024). The produced water and oil/and or gas reach the surface mixed and must be separated through a process often conducted by tanks close to the well (Andrews, 2024).

Produced water can be used for industrial and non-industrial uses. Such as fire control, power generation, cleaning, and even some kinds of irrigation. It can be desalinated and used as potable/drinkable water. Produced water can be used to supplement water needs to help endangered species that require brackish water to survive as in coastal regions. It is critical to help maintain ecological balance of these coastal ecosystems. Other uses include aquaculture, mining, cooling (e.g., nuclear power plant, etc.), ground water recharge, and can be used to help industries use less freshwater and reduce wastewater production (Redford, October 6, 2023). Produced water can contain minerals and rare earths that can be used to create solar panels, hydrogen fuel cells, and wind turbines as well as other technologies (U.S. Department of Energy, June 2024).

Produced, or brackish water is often seen as a burden to oil and gas companies. Since they often have no use for it they must find ways to dispose of it. It is often highly corrosive to metal tanks and machinery. As a result, companies see it as a useless burden to get rid of. This water often finds itself in huge tanks close to the well where it was extracted and is eventually trucked to a "disposal well." This is an oil well that has been pumped dry of its oil and gas. The produced/brackish water that has been pumped up from other wells is pumped down the disposal to "dispose" of the unwanted water (Andrews, 2024; Redford, October 6, 2023).

The process of disposing of produced/brackish water is a time consuming and costly process for oil and gas companies with little upside. How does the above have anything to do with the water crisis in Arizona? As was mentioned, the United States produces 2,236,000,498 gallons per day of produced/brackish water that can be used to lessen the burden on Arizona's fresh water supply. When added to the 600,000,000 acre feet/19,551,0857,142,859 gallons of brackish water a recent University of Arizona study estimated are under Arizona's surface this represents much that can reduce our state's water crisis (Quinn Tariqi, November 30, 2023). Since Arizona uses 7,000,000 acre feet of water per year (Pullen, August 2, 2023) just the brackish water under Arizona's surface represents several decades of potential water to draw on. When that is added to even a fraction of the water that can be recovered from "produced water" over 100 years of additional water is available for Arizona.

How could Arizona take advantage of the bonanza of brackish water produced in oil producing states? Easily, there are hundreds of miles of natural gas and crude product (gasoline, etc.) pipelines across the state that are connected by a national pipeline system to every oil producing state (Author, No Date, Map, EIA, US Energy Atlas; Author, No Date, www.caliper.com). The product/brackish water can be sent to Arizona via the same pipeline system that petroleum products are delivered to the state currently. However, the corrosive properties of the salt contained in the water may preclude using the same pipelines. Additionally, the brackish water may need to be separated from the petroleum products again. The oil companies could probably use the same easements to lay brackish water pipelines next to their petroleum product pipelines. The water could also be trucked to the state.

Having a market for their "worthless" product/brackish water could be enough incentive to encourage petroleum companies to make this water available to the state.

As has been mentioned above, there are many potential uses of untreated brackish water. However, there is a serious need for potable drinking water in the state. How could we desalinate this water in an efficient cost efficient way? Currently, there are four methods of desalinating brackish water:

- **One way is by reverse osmosis. A semi-permeable membrane is use to filter out salt and other unwanted minerals.**
- **Electrodialysis is another method of desalinization often used. The brackish water passes through a series of electrified membranes. The membranes attract the unwanted salt and other minerals to them, purifying the water.**
- **Ion exchange is a desalinization process similar to electrodialysis, except it uses a resin to attract the salt and unwanted minerals instead of membranes.**
- **Distillation, another desalinization process involving boiling the brackish water, which leaves behind the salt and unwanted minerals, while the steam produced condenses into clean water. Nuclear reactors can use brackish water to cool their cores and as a byproduct the brackish water is turned into steam to condenses into purified water (Redford, October 6, 2023). Please note, the brackish water that cools the core is not exposed to radiation (Crownhart, January 17, 2024).**

What would Arizona do with all the salt it would produce from what it collected from the above. Sell it! The international salt market is estimated as a 34 billion dollar a year business. Arizona could sell it's salt on the international market for all the uses mentioned above (Author (October 21, 2024).

How would Arizona begin to work toward developing this massive water resource? Fortunately, the state of New Mexico has developed a great method of developing the

beginning ground work of using its brackish water (Grover, July 1, 2024). There are even several oil wells that have been pumped dry of their oil and are now pumping produce/brackish water. This is being desalinated in the eastern part of that state (Grover, July 1, 2024). For more details of this effort please refer to the following article:

Grover, H. (July 1, 2024). Searching for Solutions: In New Mexico, Researchers Seek to Make Brackish Water a Viable Supply. NM Political Report. From website: https://nmpoliticalreport.com/news/searching-for-solutions-in-new-mexico-researchers-seek-to-make-brackish-water-a-viable-supply/.

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How Arizona's Underground "Ocean", Carbon Dioxide Sequestration, and Petroleum Companies Can Reduce Our Water Shortage

Every day there is twice the amount of brackish water pumped up from oil and gas wells in the continental United States than goes over Niagara Fall in one day (Andrews, 2024). That is 7800 acre feet/2,236,000,498 gallons per day. This water was left between 500 and 1500 feet under the surface of parts of the nation millions of years ago when an ocean covered those areas. Brackish water is not as salty as seawater, but it is more so than fresh water. It is found

in geological layers deeper than fresh water and does not mix with it. Brackish water costs about 50 percent less to desalinate than seawater.

Besides the 600,000,000 acre feet of brackish water under Arizona, which represents what Arizona uses in 100 years, the brackish water from other states can be used to add an almost unlimited source of water to the state (Quinn Tariqi, November 30, 2023; Pullen, August 2, 2023).

The US Department of Transportation's Pipeline and Hazardous Materials Safety Administration published that there are 2.6 million miles of pipelines in the continental US (Author, November 6, 2018). Only 50 percent, or 1.3 million miles of those pipelines are being used (Kelly, December 15, 2021).

Perhaps Arizona could take advantage of some of that unused pipeline to have brackish water transported from petroleum producing states to our state. Imagine adding all the water from the "ocean under Arizona" and under all the states that produce brackish water. This could add many more years to the state's water supply.

The Three Types of Well Production

When Edwin Drake struck oil after drilling the first oil well in Titusville, Pennsylvania on August 27, 1859 at a depth of 69 and 1/2 feet he started the petroleum era. The well produced 1,000 barrels of oil a day for three years (Author, November 25, 2024). What Drake did was what is currently called "primary production."

Primary production is the first way oil is recovered from an oil well using natural pressure of the reservoir, or artificial pumps. Secondary production is used when primary production no longer works. Water or gas is injected into an adjoining well to force the oil up and out of the well. Eventually, tertiary production is needed to retrieve the last of the oil. Superheated water steam or a gas like carbon dioxide is injected into to the well to force the oil out (Author, No Date).

Drake had no way to know what techniques would be developed to remove oil from the ground over the last 160 years. The same can be said of those extracting brackish water from under Arizona. Over the next 100 years new, better and more efficient technologies will be developed to gain access to "Arizona's Ocean." One new idea to gain access to Arizona's brackish water would be by "carbon dioxide sequestration."

Carbon dioxide is a greenhouse gas that is the second biggest contributor to global warming (water vapor is first). Although it occurs naturally in the atmosphere burning fossil fuels has increased its atmospheric concentration many fold (Helmenstine, January 9, 2020). Carbon dioxide can be injected in the ground to force brackish water to the surface. Measures can be taken to ensure the carbon dioxide does not leak from the well as the brackish water is recovered. The well can be sealed leaving the greenhouse producing gas underground. With

this technique Arizona could gain access to much needed water and reduce its carbon footprint at the same time.

A recent literature review from the United Arab Emirates (Mustafa, J. et al., June 1, 2020) found that simultaneous treatment of brackish water and carbon sequestration is possible. A 2022 study conducted by Seoul National University in South Korea (Thanh, 2022) also indicated using carbon dioxide to force brackish water to the surface is a safe, efficient, and cost-effective method of sequestering the greenhouse gas and obtaining water.

Land Subsidence

"Land subsidence in the basins of Arizona is generally due to compaction of alluvium caused by lowering of the water table. As the water table declines, pores in the alluvium once held open by water pressure are no longer supported and collapse" (Author, No Date 2). Alluvium is soil that is eroded from higher altitudes (eg., mountains) and deposited in valleys. Occasionally, the amount of water pumped out of shallow freshwater wells in Arizona can leave enough of a void underground without enough structural integrity to support the soil on top and this causes the surface ground to collapse, or create fissures. This can be a serious concern (Author, No Date 2; Author, June, 27, 2018). Although most brackish water in Arizona is found in zones that are deeper than freshwater aquifers removing brackish water could cause some subsidence issues.

Water resource managers became concerned about the possibilities of aquifer subsidence in the 1970's. In 1980 the Groundwater Management Act was passed in Arizona. This was the first time issues related to ground water extraction were seriously considered in the state. By 1980 the state freshwater aquifers had been significantly depleted and subsidence was a problem. Up to then not many had concerned themselves about subsidence issues. Over forty years have passed since the Groundwater Management Act became law and significant updates need to be made to it to reflect changes in scientific knowledge and our new appreciation of subsidence issues, and the utility of brackish water.

Today with the help of the US Geological Survey and the Arizona Geological Survey we can more responsibly remove groundwater with less risk of subsidence. Both agencies can monitor subsidence issues using the Global Positioning System (GPS) and Synthetic Aperture Radar (SAR) (Author, No Date 2). When there is a potential subsistence issue observed these agencies can take actions to mitigate the situation.

Fortunately, Arizonan's do not need to drain all the reserves of brackish water in the state because of the one million plus miles of unused pipelines in the continental United States. While pumping some of our brackish water we can have more pumped to us from out of state. Part of the brackish water we have sent to us from elsewhere can be injected into partially produced brackish water reserves to help reduce the risk of subsidence. Additionally,

we can decide not to use some currently produced freshwater aquifers for a few decades to allow them to be recharged from rainfall and other natural processes. In addition, we can avoid pumping brackish water in locations in which subsidence would endanger infrastructure or residences. By using the brackish water resources of Arizona and other states wisely the state could have enough water for hundreds of years.

Cheap Brackish Water for Phoenix?

Recently scientists from Arizona State University (ASU) (Weisman, November 6, 2024) discussed a new type of brackish water purification for cities like Phoenix they have developed. This new technique uses reverse osmosis with a fiber-based crystallizer and high efficiency heat pump. No water will be lost using this technique and it's power source is the Sun. Hence, the system has no carbon footprint! Although this project remains in the prototype stages it can offer huge metropolitan areas hope of having abundant freshwater in the future.

Perhaps, these new developments could help the state's leaders be more positive about the possibility of using brackish water as part of solving the state's water crisis.

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