Barriers Preventing the City of Phoenix from Implementing Direct Potable Reuse

by

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Table of Contents

Abstract

In arid environments, water is often considered the most precious resource. Not only does water support human life and allow for population numbers to flourish; but it is also one of the core aspects of sustainable development. When water supplies decrease at alarming rates in these arid environments, it can cause panic amongst the public while also forcing city officials to contemplate the future of their city's water. Phoenix, a large city in the state of Arizona, is situated within a desert landscape that, due to extended drought, is experiencing yearly decreases in water supplies. The Colorado River supplies water to Phoenix, but with dwindling water levels, it is crucial that this bustling desert city explore other available water sources in geographical proximity. Direct potable reuse, the treatment of wastewater to potable water standards distributed within a water system and consumed by the public, is an option the City of Phoenix should pursue. The barriers to implementing such technology, in order to access a new water source, will be explored in this paper using a comparative case study analysis.

Introduction

For millions living in the United States and other developed countries, the simple act of turning on the faucet and water dispensing has become an expectation. Not only is there an expectation that water will be delivered upon turning the faucet, but also that the water is safe to consume and use, also known as potable water. Potable water sustains human consumption needs, as well as large sectors, like power generation, agriculture, mining, and other industries. Potable water that is delivered through municipal or private utility distribution systems is sourced from either surface water or groundwater. To ensure that water is safe for public use, these municipal and private water systems are monitored and must abide by regulations set forth by local, state, and federal agencies. Across the United States, 269 million people are connected to a public water system, with 107 million receiving groundwater and 162 million receiving surface water (Johnson et al., 2022). Surface water resources typically contain more contaminants than groundwater, but are easier to access. Groundwater resources typically have fewer contaminants but have a higher mineral content and are more difficult to access. Groundwater use varies widely across the United States, with most groundwater use occurring in the West, where surface water supplies are not as accessible. Less groundwater use occurs on the East Coast, where surface water supplies are plentiful (Megdal et al., 2015). The difference in groundwater versus surface water use in various regions of the country is especially true in Arizona, where in-state rivers supply 18% of the state's water resources, reclaimed water supplies 5%, the Colorado River supplies 36%, and groundwater supplies 41% (Faller, 2022).

Water resources, whether from surface water or groundwater supplies, are critical to the state of Arizona and particularly to the city of Phoenix, Arizona's largest city with the largest population. The City of Phoenix supplies water to 1.7 million people, with 95% of water sourced from surface water and 5% from groundwater (City of Phoenix, n.d.-a). The city sits on top of a large fossil aquifer, which contains water from past geological and climatic conditions, but this aquifer is not connected to the current water cycle, meaning that any water that is pumped out is not replenished or renewed. Given that this aquifer cannot be replenished, the city views it as a non-renewable resource and strictly prioritizes and monitors how much water is removed from it. The City of Phoenix prioritizes water conservation by actively engaging with and educating its communities on measures to decrease water usage inside and outside of their homes, as seen in Appendix A (COP, 2021), with advances in household toilets being a prime example. Further, the city recycles 97% of its wastewater by supplying reclaimed water to golf courses, parks, recharge fields, and as cooling water for the Palo Verde Generating Station (City of Phoenix, n.d.-b).

The City of Phoenix, through its water conservation measures, efficient management of supplies, and diverse water supply portfolio, has managed to sustain one of the fastest-growing cities in the country. To sustain this growth with water into the future, without pumping water from hundreds of miles away, Phoenix must look at what barriers currently prevent it from increasing its potable water supply. Due to the severity of the impending water shortage, it is imperative that Phoenix considers all available water resources. A resource that should be considered is recycled wastewater treated to meet national and state drinking water standards in a process known as Direct Potable Reuse (DPR). All types of water and wastewater treatment processes experience some form of questioning and debate. Still, DPR is a process that is not widely known or used and, therefore, faces especially strong criticism given that it involves both potable water and wastewater. If the barriers to DPR could be identified, Phoenix can then determine whether DPR is a viable and continuously available water resource for the City of Phoenix.

Allocation of Colorado River Water in the Southwest

The Colorado River begins in the Southern Rocky Mountains in Colorado and stretches 1450 miles until it reaches the Gulf of California and supplies water to roughly 40 million people (Rivera-Torres et al., 2021). In 1922, the Colorado River Compact established two basins known as the Upper Basin and the Lower Basin, as seen in Figure 1, which apportioned Colorado River water supplies between the two basins. The Lower Basin, consisting of Arizona, California, and

Nevada, and the Upper Basin of New Mexico, Utah, Wyoming, and Colorado, were allocated 7.5 million acre-feet (MAF) of Colorado River Water.

Figure 1. *Colorado River Compact Established Two Basins* (Bureau of Reclamation, 2021)

In 1994, a treaty between the U.S. and Mexico allocated 1.5 million acre-feet of Colorado River water to Mexico (Stern et al., 2024). After the signing of the Colorado River Compact, arguments quickly arose between states within both basins about how the 7.5 million acre-feet should be divvied up. In 1948, the Upper Basin states signed a Colorado River water contract, assigning 11.25 percent to New Mexico, 14 percent to Wyoming, 23 percent to Utah, and 51.75

percent to Colorado (Gelt, 1997). Disputes over Colorado River water between the Lower Basin states continued long after the Upper Basin states agreed and signed their water contract, especially between California and Arizona. The most recent dispute led Arizona to request the U.S. Supreme Court engage in judicial apportionment in 1952. After eleven years of intense court disputes, the U.S. Supreme Court approved Colorado River water's apportionment by assigning Nevada 300,000 AF., Arizona 2.8 MAF, and 4.4 MAF for California (Gelt, 1997). Arizona was only able utilize 1.5 MAF of its Colorado River water allocation until the completion of the Central Arizona Project in 1985, allowing the state to take its full allocation.

Several states in the US, as well as Mexico, depend upon the Colorado River's water. In addition, 30 federally recognized Native American Tribes in the area also rely on the Colorado River water, as seen in Figure 2 (Bureau of Reclamation, 2024). The total available water in the Colorado River Basin is 16.5 MAF, with all 30 federally recognized Native American tribes collectively holding water rights to 20%, or 3.3 MAF (Kwon & Gimbel, 2021) of that water. All 30 tribes' water rights are known as federal Indian reserved water rights. Such rights can never be lost due to nonuse and displace other water rights that began or were acquired after the initial establishment date of the tribal reservations. The amount of water allocated to each tribe, via water rights, is dictated by the size of the reservation.

Despite the tribes having higher priority, known as senior water rights, over U.S. states in the Basin, the Bureau of Reclamation is the governing authority over the Colorado River and determines water allocations and apportionments. The 30 federally recognized Native American tribes must work with the states in which their reservations reside to manage allocated water. When the Bureau of Reclamation declares shortages for the Colorado River, the tribes are significantly impacted, due to their lack of infrastructure to access Colorado River water and, oftentimes, exclusion from water management discussions. Most of the tribes do not have water treatment plants or the necessary piping to transport water efficiently from the Colorado River to their reservation. Because the tribes are often excluded from water allocation discussions, they are often left to litigate with their overarching state to get their designated portion of the allocated water. Water shortages result in less water for agriculture and less drinking water access for communities to sustain themselves. It also disrupts cultural practices, including traditional fishing and water-associated ceremonies.

Mexico, with its 1.5 MAF Colorado River allocation, is also allocated 200,000 AF of water when the Bureau of Reclamation declares a surplus in the supply of water within the Southwest's water reservoirs according to the 1944 Water Treat between the US and Mexico (Kwon & Gimbel, 2021). The last 100-miles of the Colorado River journeys through the Colorado River Delta, in Mexico, until it reaches the Gulf of California. Within the Delta, 8.2 million acres of farmland are irrigated, drinking water is supplied to cities like Tijuana, which is home to millions of people, and the Ciénega de Santa Clara wetlands, a critical migration point for millions of birds, as seen in Figure 3 (Kwon & Gimbel, 2021). When the Colorado River experiences a shortage, less water reaches the Gulf of California, which has a devastating impact on the region's ecosystem and threatens the livelihoods and access to clean water for millions of people.

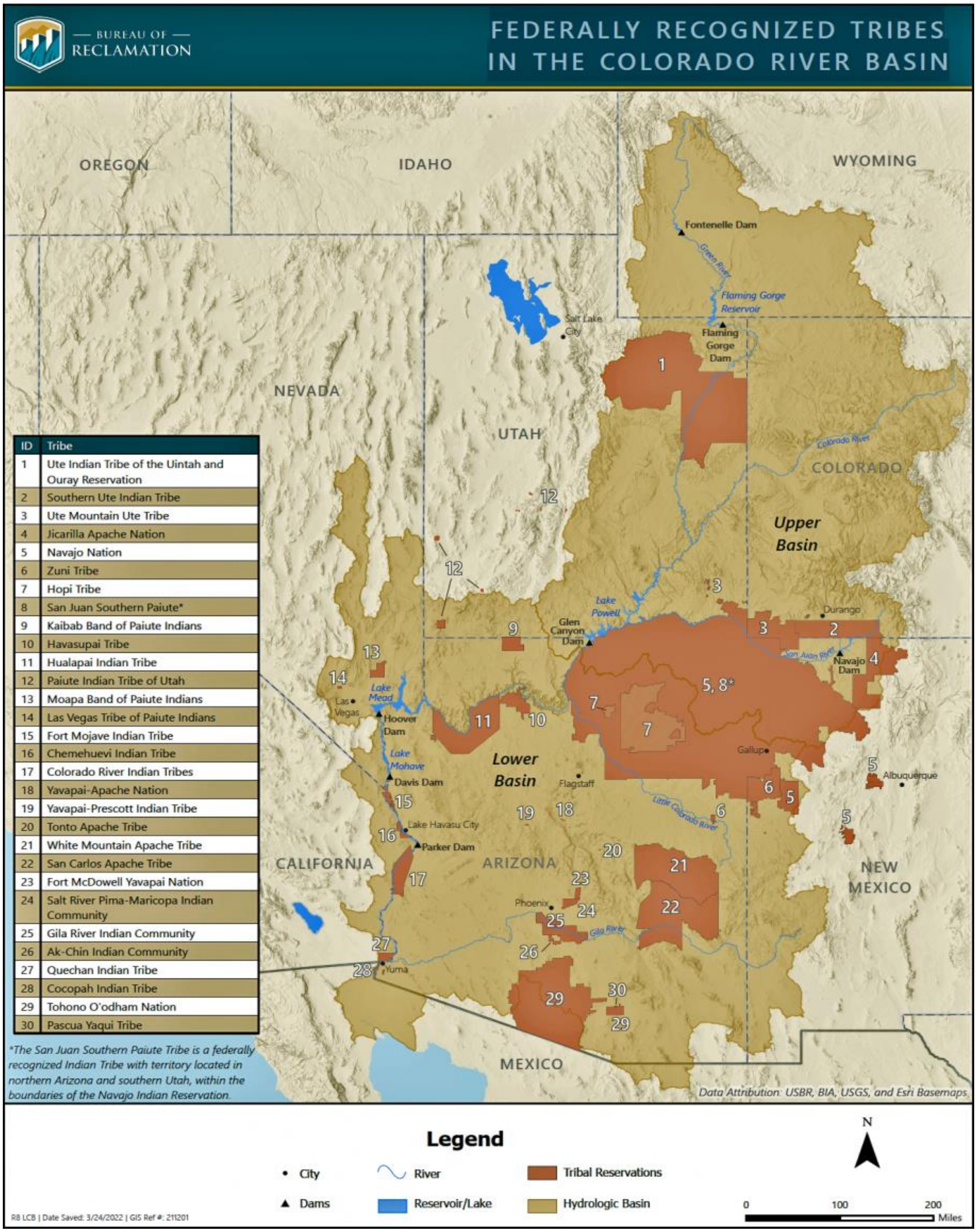

Figure 2. Colorado River Basin's 30 federally recognized Native American Tribes (Water Politics LLC, 2023)

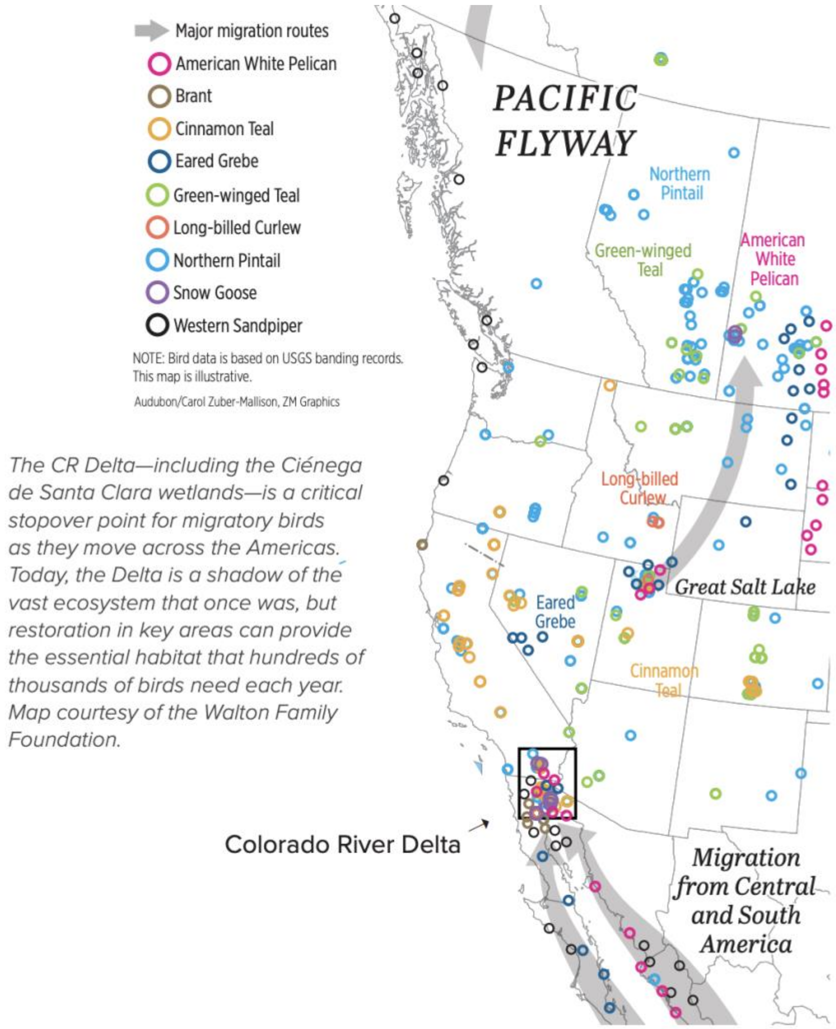

Figure 3. *Bird Migration and the Colorado River Delta (Kwon & Gimbel, 2021)*

Status of Water Resources in the Southwest

Since 2000, the Southwest has been in an active drought, which has evolved into a megadrought due to its length of time and intensity (Krajick, 2023). According to Reinhart (2024), the current megadrought is the driest period the Southwest has experienced in the last 1,200 years. This megadrought has put immense stress on the region's water resources, especially the Colorado River. In May 2019, all seven basin states signed the Drought Contingency Plans. The signing of the Upper Basin Drought Contingency Plan established a target setpoint of 3,525 feet in water elevation for Lake Powell, with the goal to keep water elevation within the lake above 3,490 feet (Stern, 2019). The signing of the Lower Basin Drought Contingency Plan established an agreement that if Lake Mead dropped below a water elevation of 1,075 feet, all water deliveries beyond the previously agreed upon water allocations would be foregone while at the same time establishing an elevation of 1,020 feet being the minimum setpoint for Lake Mead and allowing the voluntary commitment of lower basin states to store 100,000 acre-feet of water in Lake Mead (Stern, 2019). The signing of the DCPs was intended for the basin states to recognize the status of the Colorado River and its two main reservoirs and put forth their best efforts to reduce the risk of future power and water shortages. Shortly after the signings of the DCPs, Lake Mead and Powell continued to gradually decrease in water elevations. In 2021, Lake Mead's water elevation dipped below 1,090 feet, prompting Arizona to operate in a tier zero status, which required Arizona to commit 192,000 acre-feet of its 2.8-million-acre-foot Colorado River water allocation to Lake Mead (Swette Center, 2022).

Later in 2021, after calculating water levels in comparison of Figure 4, the U.S. Bureau of Reclamation declared a Tier 1 shortage that would take place in 2022, which resulted in Arizona decreasing its yearly water allotment by 512,000 acre-feet in Central Arizona Project (CAP). Further, deliveries and agricultural water decreased by 65% with a 100% reduction in all excess water users (ADWR, 2022). In 2022, the U.S. Bureau of Reclamation forecasted water elevation levels in Lake Mead to drop below 1,036 feet before the end of the year and declared a Tier 2a shortage for 2023, which resulted in Arizona's annual water allotment to be reduced by another 80,000 acre-feet of water to equal an annual water allotment of 592,000 acre-feet in CAP water deliveries (The University of Arizona, 2022).

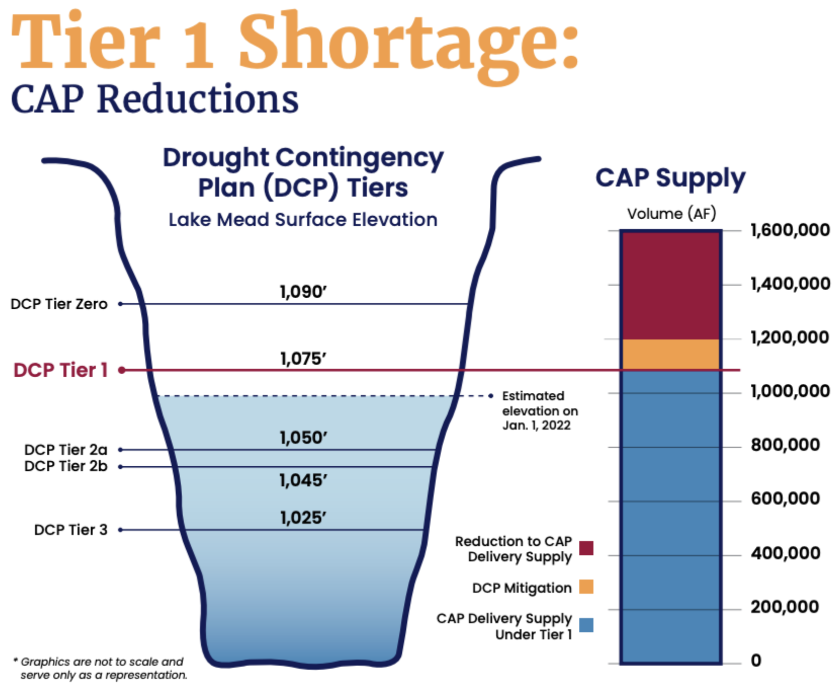

Figure 4. *Bureau of Reclamation Tier Shortages* (ADWR, 2022)

In 2023, with hopes of avoiding mandatory water cuts by the Bureau of Reclamation, Arizona, California, and Nevada submitted a plan or agreement that would see voluntary cuts in water allocations totaling close to 3 MAF from 2023 to 2026 in exchange for federal payments with Nevada conserving 0.29 MAF, California conserving 1.6 MAF and Arizona conserving 1.1 MAF (Womble, 2023). The winter of 2023 to 2024 brought above-normal snowpack to the Southwestern states such as Colorado, Utah, and northern New Mexico, which resulted in an increase in water elevation levels in Lake Mead and Powell, which reduced Arizona's Tier 2a shortage to a Tier 1 Shortage (NIDIS, 2024). To date, the Southwest has experienced drier than normal conditions for 2024, and with Lake Mead currently at 37% full capacity, the Tier 1 Shortage status is expected to continue moving into 2025. Officials have made it clear that if Lake Mead's water elevation levels fall below 37%, there is a high probability that water will not be delivered downstream from this lake, which would halt all hydropower production. This decrease in water elevation for Lake Mead would spark a regional water shortage, resulting in the Lower Basin states experiencing decreases in water allocation not experienced before. Future climate simulations have indicated that the Southwest region is to experience an increase in both temperature stress and depletions in soil moisture, which results in a high probability that Lake Mead and Lake Powell will not reach full-capacity levels with the current demand placed on them (Wahl et al., 2022).

Increased water demands due to population growth, changes in land use, recreational uses, Native American tribal allocations, mandated instream flows for ecosystems, and endangered species preservation are further stressing overallocated water resources in the region (Woodhouse et al., 2010). Arizona faces increased pressure to fulfill all of its water allocations and maintain its water portfolio, with state officials looking into options to increase water supply.

The City of Phoenix's Reliance on the Colorado River

The Central Arizona Project (CAP) delivers Colorado River water to the City of Phoenix. The Central Arizona Project is a 336-mile-long aqueduct system that pumps Colorado River water from Lake Havasu to just south of Tucson, as seen in Figure 5 (Witcher, 2022). Authorization for the Bureau of Reclamation to construct the CAP was initiated in 1968 when President Lyndon B. Johnson signed the Colorado River Basin Project Act, allowing Arizona's 1.5 MAF of Colorado River Water allocation to be delivered to central and southern Arizona (CAP, n.d.). According to the City of Phoenix's Water Resources Management Advisor Cynthia Campbell (personal communication, August 27, 2024), "Colorado River water accounts for 40% of the entire water resource portfolio for the City of Phoenix, with the Colorado River being the second largest supplier of water to the City."

Figure 5. *The Central Arizona Project on a Map of Arizona* (Lindroth, 2019)

"If the City were to lose all or even half of our Colorado River water allocation, we would have to withdraw water from our underground water reserves, putting us in a bad situation regarding water resources" (C. Campbell, personal communication, August 27, 2024). Phoenix does not have a plan for countering or remedying the loss of its CAP allocation. If the Central Arizona Project were to significantly decrease the volume of water it distributes through its canal, or if its canal could not operate due to low flow in the Colorado River, Phoenix would not have another way to access Colorado River water. Should a 40% reduction in water supply occur, City officials would immediately declare water curtailment. Still, the amount of water that could be saved from implementing a water curtailment would not be enough to make up for the loss.

Unconventional Water Resources – Direct Potable Reuse

When they flush the toilet, most people consider it a waste product with no other benefit but to be discarded from a residence or business. Until recently, plumbers and those working in the water and wastewater treatment industry only knew that the waste flushed from a toilet travels to a local sewer system, where it is labeled as wastewater. This wastewater often travels miles to a wastewater treatment plant, where it is treated to the highest standards. This treated wastewater could be released back into the environment or saved underground as groundwater for later use. Direct Potable Reuse (DPR) is treated wastewater distributed directly into the potable water system without an environmental buffer (EPA, 2024a). The concept of DPR has been around for decades, but only in the last fifteen years have research and pilot programs been carried out to bring the concept to fruition.

The typical conventional wastewater treatment process, as seen in Figure 6, involves raw wastewater from the sewer system traveling through a screening and grit removal process where large solids and non-biodegradables are removed. From there, the wastewater will either flow into an equalization basin or primary clarifier where even more solids within the treatment process settle out, the wastewater then flows into an aeration chamber where the denitrification process takes place to remove nitrates from the wastewater so that they are not discharged into the environment later in the treatment process. Once the wastewater completes the denitrification process, it travels into the secondary clarifier, where any remaining solids are removed, leaving the liquid to remain and possibly travel through some filtration before being disinfected with an ultraviolet light or chlorine. The treated effluent or reclaimed water that is discharged from a conventional wastewater plant can be discharged to lakes or ponds utilized for irrigation purposes, or depending on the treatment plant's permit and continuous monitoring of constituents, it could be discharged directly into waterways such as a river or stream or underground into an aquifer.

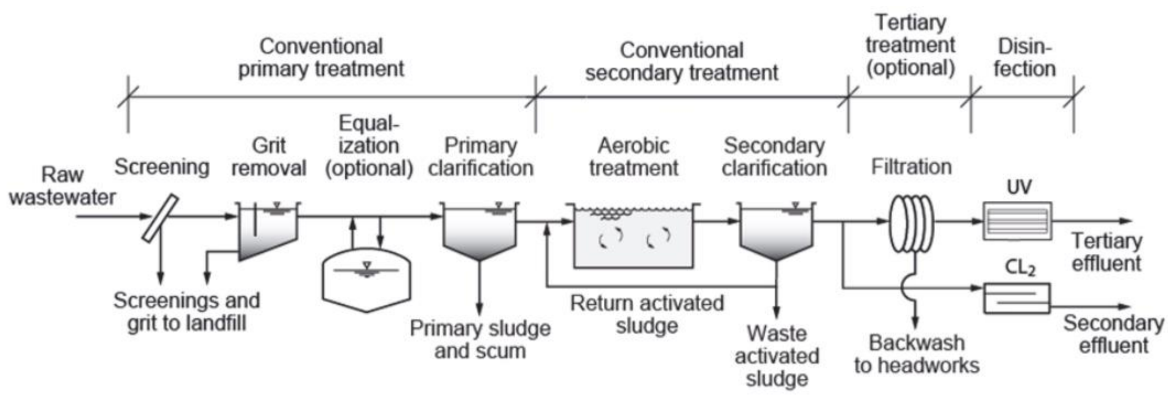

Figure 6. *Conventional Wastewater Treatment Process* (Tchobanoglous, 2015)

A minimal amount of water is lost during the extended treatment process that prepares reclaimed water to become water suitable for consumption. However, a large amount of water is returned after entering the distribution system and returned to the wastewater treatment plant, which creates a cycle that minimizes losses in the overall amount of water in the entire system. Direct potable reuse has the potential to significantly replace the demand for freshwater resources depending on the scale of the process implemented, as seen in Figure 7. Researchers of DPR state that once an acre-foot of water enters the potable system, DPR can take that one acre-foot of water supply and meet two acre-feet of municipal demands (WRA, 2023).

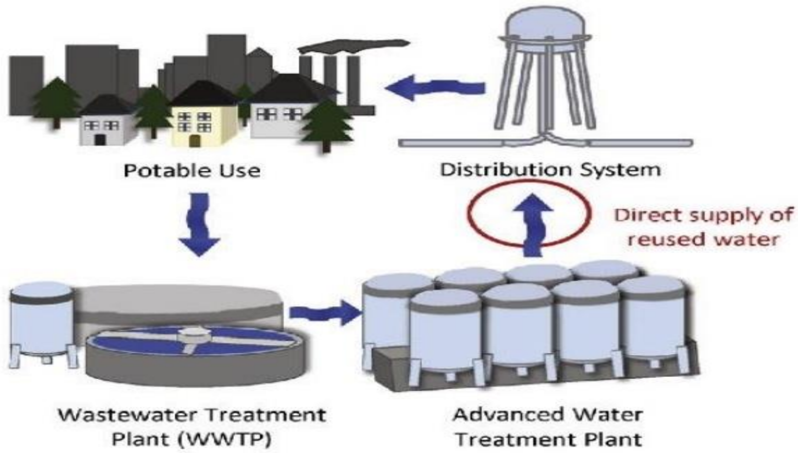

Figure 7. *Cycle of Direct Potable Reuse* (Pour Fakhar & Janmohammadi, 2020)

The process for direct potable reuse has the primary objective of targeting pathogens and harmful chemical contaminants by utilizing certain technologies such as ozone or reverse osmosis, advanced oxidation, biologically active carbon filtration, micro or ultrafiltration membranes, ultraviolet light, and chlorine (ADEQ, 2024). The order in which these technologies are implemented can differ, and utilities will often add more or different steps to the treatment train, as seen in Figure 8, to ensure that their treatment process is invulnerable and as a safety net in case one of the technologies were to fault out or stop altogether. Once the water has passed through all stages within the advanced water purification process, it is directly discharged into the potable water system, where customers are able to consume or utilize it.

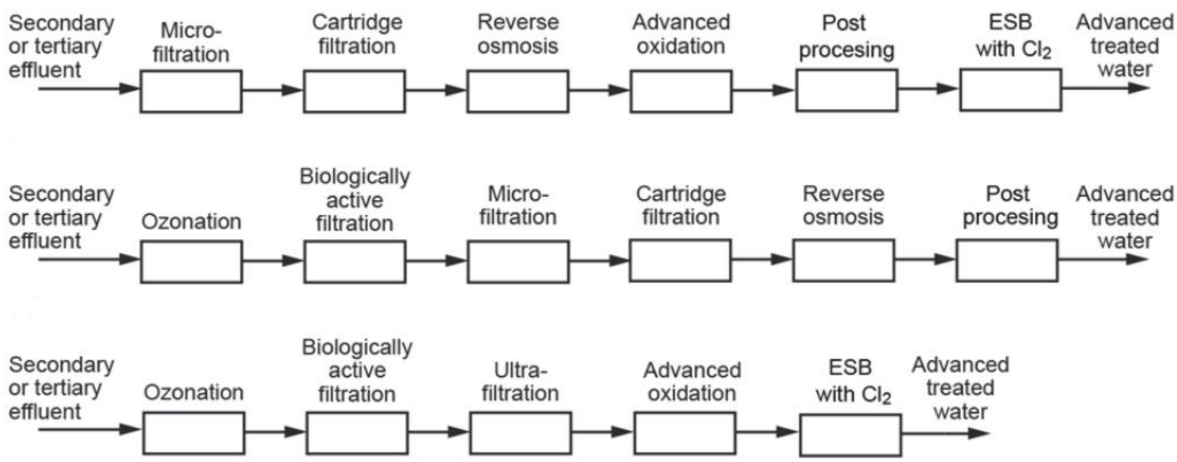

Figure 8. *Advanced Water Treatment Processes* (Tchobanoglous, 2015)

Parameters are continuously monitored for each stage of the DPR process, just like in the conventional wastewater treatment process. The difference with DPR is that continuous monitoring also occurs for each stage to measure the performance in pathogen reduction to ensure that no trace of pathogens enters the potable system. Given the complexity and length of the DPR process, hourly, daily, and weekly grab and composite samples of each process would be taken and analyzed in the DPR facility and verified by a third-party laboratory.

Direct potable reuse mimics the natural water cycle by forcing effluent through a series of filtration methods that result in water containing no contaminants or pollutants. In a natural environment, water passes through soil, gravel, silt, and sand, which act as filters before reaching an aquifer.

City of Phoenix Site Information and Background

The City of Phoenix has a long history of transporting water over great distances. For 1,500 hundred years, the prehistoric North American Hohokam people inhabited the area where the city of Phoenix is now situated until A.D. 1450 when their society vanished due to unknown reasons (NAU, 2011). The Hohokam people left a lasting impression on the land by constructing irrigation canals that diverted water from the two largest rivers crisscrossing the Phoenix area, the Gila and Salt Rivers, and delivered this water hundreds of miles away to irrigate their crops. The Hohokam are believed to be the only North American culture that has relied on irrigation canals to supply water to their crops and sustain their way of life for thousands of people. The hundreds of miles of ancient canals are still being used today, albeit they have been expanded and lined with concrete, since their original construction. Phoenix's primary canal system is recognized as utilizing the same ancient routes and canals to deliver millions of gallons of water to irrigate crops and water to treatment plants to later serve as a potable water source. To this day, the ancient canals' ability to deliver water for such distances provides an excellent example and framework for modern engineers when constructing modern water delivery systems.

Geography

Arizona is a landlocked state located in the Southwestern region of the United States. The City of Phoenix is in the south-central part of Arizona and the Sonoran Desert's northeastern region. The city is often called the Valley of the Sun as it sits rather level and is surrounded by mountains, including the White Tank Mountains to the west, South Mountain to the south, the Superstition Mountains to the east, and the McDowell Mountains to the northeast. The city's topography is generally flat, with small rivers and streams running across the desert landscape and the smallest waterways periodically running dry. The city takes up a large landmass of 500 sq miles, which is larger than the City of Los Angeles (COP, 2024b). Although the city already takes up a significantly large amount of land, there is still room for the city to expand for new residential, commercial, and industrial development, and it is expected that the city will grow in size for decades to come. The City of Phoenix has been known for having a low population density and allowing for development, through its zoning code, to occur far from the city's downtown area, making the city the perfect example of urban sprawl. Instead of the city of Phoenix growing vertically, it has grown horizontally, and large commercial, industrial, and residential development occurring on the city's outskirts is a common occurrence.

Population and Development

The city of Phoenix is the largest city in Arizona and the fifth largest in the United States (COP, 2024b). The city has been experiencing rapid growth since the 1950s when air conditioning became readily available, making the summer heat more tolerable. In the 1950s, Phoenix had a population of just over 100,000 (COP, 2013). The city recorded a population of just under 1.7 million in 2020 and is expected to grow to two million by 2040 (COP, 2022b). With this type of growth, 200 to 300 people are moving to Phoenix daily. The city has experienced a much higher population growth than the national average of one percent. Phoenix is currently leading the nation at the number one spot for active industrial projects and is second in the country for the highest number of industrial real estate projects under construction. The City of Phoenix's strategic location, favorable business climate, and extensive infrastructure networks have allowed it to grow substantially both in population and business development. Phoenix is located within one out of five of Arizona's Active Management Areas (AMAs). An active management area is one in which groundwater has been significantly depleted historically, and the State of Arizona has decided these areas need aggressive management to preserve groundwater to sustain the area's economy better. The Assured Water Supply Program, monitored and implemented by the Arizona Department of Water Resources, requires all industrial, commercial, and residential developers to obtain a Certificate of Assured Water

Supply (CAWS). A Certificate of Assured Water Supply signifies that the applicant or the applicant's customers will have adequate storage, treatment, and water delivery for 100 years (ADWR, n.d.). The 100 years of water supply is based on scientific modeling that utilizes computerized representations of aquifers to predict how much groundwater is available.

Climate

The City of Phoenix is considered to have a hot desert climate, with long summers that often experience durations of extremely hot temperatures and mild winters that will experience freezing temperatures for very short durations. The city experiences relatively low humidity and low annual rainfall, with most rain falling during the monsoon season from June through September (Arizona State Climate Office, n.d.). The city is known to be in one of the world's sunniest regions, with comparisons extending to being similarly as sunny as the Sahara region in Africa. Phoenix has the hottest average high temperatures of all major cities, making it the hottest city in the United States. Phoenix is the only major city to record temperatures over 100 degrees Fahrenheit for more than 100 days and more than 90 degrees Fahrenheit for more than 160 days (Osborn, n.d.). For 2023, Phoenix recorded having one of its driest monsoon seasons with little annual precipitation. Just 0.15 inches of rain was recorded at Sky Harbor International Airport, the major airport near Phoenix's downtown area (COP, 2024a). Also, in 2023, the City of Phoenix broke its record with having the hottest summer on record with continuous daily extreme temperatures reaching as high as 119 degrees Fahrenheit. 2024 beat 2023 in being the hottest summer on record with average temperatures from June through August being two degrees higher than the previous summer (Evans, 2024).

The Southwest region, already the hottest in the U.S., is expected to become even warmer in the years to come. Climate change is expected to increase average annual temperatures by 4 to

10 degrees Fahrenheit (NPS, 2017). Climate experts believe that atmospheric circulation patterns will change in the future, making the Southwest region more arid, especially during La Niña events, which will increase the intensity of droughts. As climate change progresses, the Southwest will receive less snowpack, resulting in a decrease in surface runoff and even further decreases in water levels within major waterbodies, such as the Colorado River. According to Overpeck and Udall (2020), the implications of climate change on the Southwest are dire for water scarcity, with dust storms and heat waves expected to increase the impacts of aridity.

Water Production

The City of Phoenix has five water treatment plants: the Val Vista Water Treatment Plant, the Deer Valley Water Treatment Plant, the 24th Street Water Treatment Plant, the Union Hills Water Treatment Plant, and the Lake Pleasant Water Treatment Plant. The City of Phoenix's daily potable water production is 264,000,000 gallons of water, equating to 96,360,000,000 gallons of water annually delivered through the distribution system and utilized by customers (COP, 2022c). The City of Phoenix receives 40% of its surface water from the Central Arizona Project, the city's second-largest water supplier (COP, 2022a). Central Arizona Project water is primarily delivered to the Lake Pleasant and Union Hills Water Treatment Plants, but thousands of miles of interconnected pipes between the plants allow all plants to receive and treat CAP water during routine maintenance or drought. The city has managed to decrease its per capita use for city residents and businesses through water efficiency and conservation education and measures. Still, these efforts have not been enough to ease the pressure on its available water supplies. According to C. Campbell (personal communication, August 27, 2024), "The City of Phoenix utilizes its full CAP allocation, and with 40% of the city receiving water from the CAP means that any reduction within the Colorado River that affects water deliveries on the CAP would present a significant challenge to meeting water demands and would force the city to withdraw from its reserves."

Wastewater Treatment

The City of Phoenix has three wastewater treatment plants: the 23rd Avenue Wastewater Treatment Plant, Cave Creek Water Reclamation Facility, and the 91st Avenue Wastewater Treatment Plant. The 23rd Avenue Wastewater Treatment plant has a peak design capacity of 80 MGD and treats on average 43 MGD, as seen in Appendix B (Water and Wastewater, n.d.), the Cave Creek Water Reclamation Facility has a design capacity of 8 MGD, as seen in Appendix C (Heiderscheidt, 2022), and the 91st Avenue Wastewater Treatment plant has a design capacity of 230 MGD and treat on average 140 MGD, as seen in Appendix D (AMWUA, 2019). Phoenix, Glendale, Mesa, Tempe, and Scottsdale collectively share ownership of the 91st Ave. Wastewater Treatment Plant, but the City of Phoenix operates and manages all activities associated with this plant. The City of Phoenix treats 66,556,371 hundred cubic feet, or 49,787,622,982 gallons of wastewater a year and roughly 136,404,446 gallons of wastewater a day (COP, 2024d). Currently, the city recycles 97% of its wastewater for purposes that include irrigation for nearby parks, schools, golf courses, ponds, and agriculture, recharging groundwater, cooling water for the Palo Verde Nuclear Generating Station and is used to sustain water levels within the artificially created Tres Rios Wetlands. The remaining 3% of wastewater not recycled is discharged into the Salt River, which runs adjacent to the 91st Avenue Wastewater Treatment Plant. The primary treatment utilized by the City's wastewater treatment plants is conventional treatment. Conventional treatment follows the standard layout of this type of treatment process involving screening, primary and secondary treatment, disinfection, and sludge dewatering.

Barriers to Direct Potable Reuse

The City of Phoenix only uses conventional treatment, particularly conventional activated sludge, to treat wastewater. If the City were to implement DPR, many barriers would need to be overcome for this type of activity and change to come to fruition. According to the City of Phoenix's Assistant Water Services Director Nazario Prieto (personal communication, September 17, 2024), "The barriers to the City of Phoenix implementing DPR are infrastructure, regulations, cost, and training, with the largest barrier being public relations."

Infrastructure

The City of Phoenix does not have the infrastructure to implement direct potable reuse. Although the city has eight treatment plants, with 7,000 miles of water pipeline, 5,000 miles of sewer lines, hundreds of reservoirs, lift stations, wells, and pump stations, it would not be able to take in, treat, or distribute treated wastewater to potable water conditions. To implement DPR, the City must start by studying its existing infrastructure, including lift stations and sewer lines. Lift stations and sewer lines are the front-line pieces of infrastructure that collect the wastewater discharged from homes, businesses and industries and convey this wastewater many miles to wastewater treatment plants. Having efficient and properly operating lift stations and sewer lines ensures that the wastewater does not become stagnant, which reduces the chances of wastewater becoming septic and causing issues for treatment at the wastewater plants. It also ensures that all available wastewater is collected for treatment and not lost due to sewer leaks, which equals greater water conservation at the end of the DPR process. The wastewater plants themselves would need improved grit and solid removal processes and equipment, which reduces the amount of suspended material in the wastewater, resulting in less suspended material discharged from the wastewater plant. The benefit of having a lower amount of suspended material in the effluent discharged from a wastewater plant is that it increases the efficiency of the advanced water purification process to produce high-quality potable water and decreases the wear and tear on the advanced water purification equipment.

City management would then need to decide if the current conventional treatment process produces adequate effluent required for the advanced water purification stage or if changing its conventional treatment processes to some membrane bioreactor process would be more efficient. The next and arguably most important step is deciding which type of process and equipment would be used in the advanced water purification process and constructing this advanced water facility. According to N. Prieto (personal communication, September 17, 2024), "The wastewater treatment process before the advanced water treatment would consist of microfiltration membranes, and the advanced water treatment process would consist of ultrafiltration membranes, reverse osmosis, ultraviolet advanced oxidation, and granular activated carbon treatment." Ultrafiltration and reverse osmosis will remove the majority of all solids and contaminants, while any contaminants that do make their way past these two steps will ultimately be removed by ultraviolet advanced oxidation. Granular activated carbon would then be utilized to remove all taste and odor issues to make the water produced from the advanced water process aesthetically pleasing to taste and smell and make it visually appealing.

One of the most critical aspects of implementing DPR is the continuous monitoring of water quality throughout the treatment process. To aid in this process, analyzer stations would need to be constructed and placed at the exit of the wastewater plant, throughout the advanced water filtration process, and leaving the advanced water facility. Once the advanced water filtration facility was finished, new reservoirs and pump stations would need to be constructed not only to store the water produced by the advanced water filtration facility, but also to provide enough pressure to allow for this advanced water to make its way into the potable distribution system and eventually to the various customers. Given that wastewater plants provide lakes, parks, and golf courses with reclaimed water, now that DPR would raise the cost of water beyond the typical cost of water treated at a designated water treatment plant, an essential decision by City management would be needed to determine which water source would provide water to these public locations.

Regulations

In 2010, Governor Jan Brewer, of Arizona, formed a water panel known as the Blue-Ribbon Panel. The Blue-Ribbon Panel was tasked to identify how Arizona could improve its water conservation and research water reuse and the various technologies available to aid in water reuse. The panel provided methods to enhance conservation and emphasized the need for all water and wastewater utilities to pursue reuse programs. In 2013, the Steering Committee for Arizona Potable Reuse was established to research whether DPR could be used as another option for a potable water supply. In 2015, Arizona's Recycled Water Committee reviewed the findings from 2010 by the Blue-Ribbon Panel and recommended to ADEQ that the restriction on DPR should be removed. The Arizona Department of Environmental Quality accepted the Recycled Water Committee's recommendation; and in 2016, it began the process of revising its regulations and rules regarding reclaimed water, gray water, and DPR. In 2017, ADEQ developed a draft interim regulation that removed the total restriction on DPR and allowed individual permits to be issued to water and wastewater utilities. With this interim regulation, water and wastewater utilities can implement DPR for demonstration, education, and pilot program purposes. ADEQ is revising its interim regulation or rule and its regulatory standards regarding DPR while also investigating a direct and more straightforward approach to the permitting process. According to

N. Prieto (personal communication, September 17, 2024), “Right now, we wouldn’t be able to implement DPR fully, but we have heard that ADEQ will be finalizing its regulatory standards sometime between 2025 and 2026, and once this happens, we’ll be able to fully implement DPR with water leaving our advanced water facilities and reaching its way to customers.”

Cost

Direct potable reuse utilizes equipment and processes not typically found within water or wastewater treatment plants because it is costly and is considered by many industry professionals prohibitively expensive. Typical water and wastewater plants could pursue DPR equipment and processes; however, it is mostly an unnecessary route for them to follow because conventional methods are much less expensive. The City of Phoenix considered DPR in the past when ADEQ announced various measures to increase its knowledge of the process and pursue applicability studies regarding DPR for the state of Arizona. Still, nothing was set in motion. "We've had discussions about transforming our Cave Creek Water Reclamation Plant to an advanced water treatment plant, and the monetary amount we've come to for this retrofit is $300 million" (N. Prieto, personal communication, September 17, 2024). The Cave Creek Water Reclamation Plant would be the first plant the City of Phoenix retrofits because it is the smallest wastewater treatment plant and serves the least number of customers, which means the plant would serve as the best test facility for such technology and processes. "If the Cave Creek Water Reclamation Plant were a success, then we would retrofit our 91st Ave Wastewater Treatment Plant, which would cost upwards of $1.5 billion to $2.5 billion and possibly more given that it would be the largest advanced water facility in the country producing more than 50 MGD of advanced water" (N. Prieto, personal communication, September 17, 2024). The exact cost to treat upwards of 50

MGD at an advanced water treatment plant is unknown, given that there are no other advanced water treatment plants that come close to treating such a volume of wastewater.

The total annual operating and capital costs for implementing direct potable reuse are in the range of $820 per acre-foot to $2,000 per acre-foot, or $2.50 to $6.00 per thousand gallons of water (Scruggs & Thomson, 2017). One person typically utilizes 100-150 gallons per day of water, which every month would average about 3,000-4,500 gallons of water. The City of Phoenix charges a typical household $4.64 for up to 3,740 gallons used, with $5.26 per unit of 748 gallons used after 3,740 gallons (COP, 2024c). According to C. Campbell (personal communication, August 27, 2024), "The City of Phoenix water customers would be looking at $11.00 per thousand gallons of water, given the cost it would take to build the infrastructure and utilize advanced technology daily while also paying for the resources to maintain the system." A single person consuming water from a City of Phoenix advanced water purification facility could pay $33.00 to $49.50 a month, compared to $4.64 to $9.90 monthly with water produced from one of the existing water treatment plants.

One of the most expensive aspects of the process of DPR is the brine removal due to the brine produced from the reverse osmosis process. The reverse osmosis process produces substantial amounts of brine, which is the salt, solid particles, and contaminants expended or wasted from the RO process. The most popular methods of removing water from the brine and having the brine ready for disposal are drying beds and evaporation ponds. Drying beds are raised platforms with small perforations that allow the brine to dry out as the water drips down through the perforations, and the water is sent to the beginning of the advanced water process. The second method is evaporation ponds, which consist of large ponds carved out of dirt and lined by plastic liners where the brine is allowed to sit and dry out in the sun, leaving behind the remaining salt waste when the water evaporates. This brine is then transported to a waste facility that accepts this type of waste, which are limited. When utilizing the reverse osmosis process, the cost of disposing of brine when evaporation ponds are used is $155 per acre-foot. (Dow et al., 2019). When considering the City of Phoenix's Cave Creek Water Reclamation Plant and the 91st Ave Wastewater Treatment Plant would most likely see the addition of advanced water purification facilities, with the Cave Creek facility producing 8 MGD and the 91st Ave Wastewater Treatment Plant producing 50 MGD, brine disposal for these two facilities would be $3,805 per day and $23,783 per day respectively. Although the cost for DPR would undoubtedly increase rates paid for by City of Phoenix water customers, according to N. Prieto (personal communication, September 17, 2024), "When you look at how much DPR is going to cost compared to what it would cost to bring water from an outside location the costs are comparable to each other and yet with DPR we would have more control over the source of the water." "Water rights for more Colorado River water in the future are going to cost more than what it would cost to implement DPR, and even if we were to pay this higher cost, there's no guarantee that the physical water will be available or flowing in the Colorado River" (C. Campbell, personal communication, August 27, 2024).

The federal government has, in recent years, provided funding to states in the southwest, including California and Utah, for large-scale water conservation and reuse projects. In 2021, the Bureau of Reclamation allocated $8.3 billion to be invested over the next 5 years, with $3.5 billion for more than 530 projects declared within the first three years in various water infrastructure projects, including desalination, water storage, and water purification and reuse (U.S. Department of the Interior, 2024). Although federal funding has not been allocated to Arizona just yet, these investments signify that the state of Arizona and the City of Phoenix, in particular, have the potential to receive federal funding to aid in implementing DPR. Such funding would assist the City of Phoenix in constructing the necessary infrastructure and relieve some of the cost that would be passed on to the ratepayers.

Training

Because no facilities in the Southwest implement the DPR process currently, water and wastewater treatment operators and professionals do not have the necessary experience to operate and run an advanced water purification facility. Although various equipment and processes utilized in the DPR process can be found on their existing water or wastewater plants, like granulated active carbon or reverse osmosis, having all of the processes operate in a sequence, with each depending on the efficiency of the previous process, is a new concept for those in the water and wastewater industry in the Southwest. The State of Arizona requires each water and wastewater utility to have operators who are certified to perform work in this industry. The Association of Boards of Certification (ABC) is the authority within the water and wastewater industry that designs the certification tests distributed to potential operators, which is administered by the Arizona Department of Environmental Quality, as seen in Appendix E (ADEQ, 2024). The tests are created for four disciplines: water distribution, water treatment, wastewater collections, and wastewater treatment, and have levels one through four. ABC plans to develop an advanced water purification exam in the future; however, without an advanced water purification exam for operators to take currently, their knowledge can only be tested within the facility. Until these exams and trainings are available, operators will need to be trained by third-party contractors and safety professionals until the operators' level of expertise has reached a point where outside help is no longer needed.

With direct potable reuse comes an even heavier responsibility of protecting public health, a responsibility not currently experienced by operators at the level that DPR requires. With typical water and wastewater treatment, the operators follow state and federal water quality regulations that allow for leniency when needed, due to equipment failures or when outside influences effect the efficiency of the treatment processes. With DPR, given the source of the water and what pathogens and chemicals are present within it, operators and the advanced water purification facilities they operate will likely not have the prior leniency.

Operators must monitor the DPR process and equipment much closer than typical water and wastewater treatment. Redundancy must be present within the advanced water purification facility, including infrastructure to bypass one series or train of equipment to another train when some aspect of the process is not efficiently treating the wastewater. This requires knowledgeable operators, who can identify when this need occurs and how to carry out the task. Operators must also understand how various analyzers and analyzer probes constantly monitor and measure constituents throughout the process and must be able to identify trends and patterns. Operators who are well trained with DPR will ensure that no pathogens, chemicals, or toxic substances to human health are present within the water leaving the advanced water purification facility.

Public Relations

For the City of Phoenix, getting the public on board with drinking treated wastewater is its most significant challenge. According to N. Prieto (personal communication, September 17, 2024), "Speaking for the City of Phoenix, we believe public perception, public acceptance, and public relations, in general, is the largest barrier to overcome with implementing DPR." The City of Scottsdale, next door to the City of Phoenix, was issued the state's first Recycled Water Individual Permit for an Advanced Reclaimed Water Treatment Facility in 2019 (ADEQ, 2019).

This permit allows the City of Scottsdale to use water produced by the advanced water facility within the facility at its drinking fountains, conduct taste tests, and deliver this water to outside beverage manufacturers, as seen in Appendix F (Water Use It Wisely, 2019). Brian Biesemeyer, the Executive Director of Scottsdale Water, believes that even though the City of Scottsdale has obtained the necessary infrastructure to implement DPR, for now and well into the future, the goal is to get the public over the "ick" factor (TUOA, 2019). The majority of Arizonans understand the situation regarding water resources and how precious the resource water has become, given the extended drought and increases in population/development. Therefore, they largely support efforts in water reuse that serve water conservation and protect the environment by sustaining aquatic environments have increased. According to a survey by Rock et al. (2012), Arizonans support water reuse activities such as watering non-edible crops, fighting fires, controlling dust on roads, watering golf courses, and cooling power plants. Arizonans are most receptive to water reuse when the use does not get too personal. When Arizonans were asked how receptive they would be to water reuse activities that affected them personally when advanced treatment was applied, they responded 71% in support of reuse water for laundry, 65% for household cleaning, and 51% for bathing, but only 41% in support of water reuse for cooking and 35% for drinking (Rock et al., 2012). These percentages highlight the public's strong opposition to DPR and the gap that the City would need to overcome to receive more substantial public support. Most of the public has opposed recycling wastewater for potable uses based on their fear of waterborne diseases, which have historically caused negative relationships between humans and water (Kenney, 2019).

Many factors exist for the City of Phoenix to receive more public support for implementing DPR. When DPR was first being researched, the common term for it was toilet-totap, which is a broad description detailing the process; however, with this phrase comes a negative connotation, not well received by the public. The terms reclaimed water and water reuse have become more popular terms to use to appease the public. However, even these still carry an understanding or a reminder of where this water originates; and there are mixed reviews on how the terms are received. The term now used by the City of Phoenix along with other utilities that have implemented DPR, or are in the process of trying to receive public support, is advanced purified water. This title has a more positive connotation because many brands of bottled water have the term purified on their packaging, which in turn gives assurance to consumers that it has been treated to the greatest extent possible.

Most City of Phoenix water customers are not currently knowledgeable about the wastewater treatment process, let alone the process of advanced water purification or direct potable reuse. The City must engage with the public by educating them through conventional and unconventional methods in order to gain their support for the process. Educating the public is the most significant method to receiving public acceptance of DPR. The City can conduct this education through technical educational videos and pamphlets that describe the technology used, environmental, social, and safety considerations or risk. Conducting pilot programs that allow for the public to experience the process first-hand and up-close is another educational option to consider (Moesker et al., 2024).

Many of the questions asked by the public pertain to how direct potable reuse can be accomplished, with skepticism around the possibility that the necessary equipment and results exist to clean the water enough. The public must come to accept that the technology available to implement DPR is scientifically proven to produce an A+ product. According to N. Prieto (personal communication, September 17, 2024), "We are not concerned about the technology aspect of DPR. The equipment available has been proven and tested to remove all that is harmful in wastewater. We are industry professionals who have seen the data, but the public must be convinced that this equipment has proven to provide safe and high-quality water". City of Phoenix customers can be educated with as much data as possible; however, they need to be able to see precisely what DPR consists of for their understanding of both the process and the need for higher water rates. Increasing public confidence in the process and in the City of Phoenix as the water utility providing advanced purified water is one of the city's highest priorities. According to N. Prieto (personal communication, September 17, 2024), "We know that for us to be successful in implementing DPR, we need to bring our water customers into our advanced water purification facilities and let me see, hear, touch the equipment or process and let them smell and taste the water because that is how we are not just going to gain trust from the public, but we are going to develop a great relationship with our customers that we believe will transcend into greater support for what we want to accomplish." Receiving greater public acceptance and support is accomplished by emphasizing how the end users of the water will benefit, while also allowing for public involvement in the decision-making process throughout the implementation and incorporating transparent communication (Harris-Lovett et al., 2015). The City of Phoenix has the potential to gain full public support and acceptance by bringing its water customers closer and allowing them to have a more prominent presence during the process of implementing DPR. The City of Phoenix can follow the blueprint set forth by the City of El Paso. The City of El Paso was in a similar situation regarding water resources. The City of El Paso overcame barriers to implementing DPR, which paved the way for the city to become more sustainable and have a more robust water resources portfolio.

Direct Potable Reuse in Texas

There are three case studies to be explored as a blueprint for Phoenix, in relation to Direct Potable Reuse. Two of these case studies are small towns and will be discussed briefly for framing. The other, El Paso, Texas, is the true map for Phoenix to implementing DPR. In 2013, the first Direct Potable Reuse facility in the United States came online in Big Spring, Texas. The Big Spring DPR facility treats two million gallons of wastewater daily using microfiltration, reverse osmosis, and ultraviolet disinfection. Once the water is treated at the DPR facility, it is sent through a pipeline connected to a nearby water treatment plant, and on the journey to the water treatment plant, it is mixed with raw water from a nearby lake. Once this blend reaches the water treatment plant, it is treated with conventional treatment techniques, and then held in storage reservoirs, until being pumped into the distribution system for potable consumption. Big Spring decided to research DPR in 2002 as another source of potable water as the area was experiencing extreme drought. In 2014, Wichita Falls, a city just 230 miles away from Big Spring and experiencing similar extreme drought conditions, followed steps taken by Big Spring to implement DPR. Wichita Falls implemented the same DPR treatment process and delivered this treated wastewater to 150,000 people.

El Paso is the sixth largest city in Texas and the 22nd largest in the United States, with a population of 884,432 in 2024 (City of El Paso, 2022). El Paso is situated within the Chihuahuan Desert and experiences frequent droughts and unreliable water supplies. In 2026, El Paso will be the largest city in the United States to implement Direct Potable Reuse and have the first direct-to-distribution DPR facility in the United States. Unlike the process in Big Spring and Wichita Falls, which sends effluent from an advanced water purification facility to a water treatment plant for further conventional treatment, the El Paso Advanced Water Purification Facility will pump its effluent directly into the potable water distribution system, relying solely on its process and removing all extended treatment of the effluent. The El Paso Advanced Water Purification Facility is expected to transform 10 MGD of treated wastewater from the nearby Roberto Bustamante Wastewater Treatment Plant into potable water. The Roberto Bustamante Wastewater Treatment plant typically treats 39 million gallons per day. The new advanced water purification facility utilizes membrane filtration, reverse osmosis, ultraviolet disinfection with advanced oxidation, and granular activated carbon filtration, which is a process that will be responsible for removing all viruses, pathogens, and chemicals from the water. This advanced water purification facility will be capable of increasing the City of El Paso's potable water production by 10 MGD immediately after start-up, which will increase its potable water production in a relatively quick timeframe and expand the city's water resource and conservation portfolio.

Infrastructure

The City of El Paso did not have the necessary infrastructure when it decided to pursue direct potable reuse. It needed to construct an advanced water purification facility and improve its treatment process at the nearby wastewater treatment plant. Improvements made at the Roberto Bustamante Wastewater Treatment Plant include upgrading the screening process at the beginning of the treatment plant, which helps filter out small to large solid particles, grit, and trash. Upgrading the aeration basins aided in enhanced aeration diffusers helps remove contaminants while also fostering an environment for positive bacteria growth and increasing the number and size of the primary and secondary clarifiers that aid in removing all suspended solid particles within the wastewater (El Paso Water, 2023). Next door to the Roberto Bustamante Wastewater Treatment Plant will be the advanced water purification facility. The advanced water purification facility consists of membrane filtration at the beginning, reverse osmosis, ultraviolet disinfection with advanced oxidation, and ending with granular activated carbon filtration, as seen in Appendix G (Villalobos, 2023). New infrastructure in pipes and valves will be installed between the Roberto Bustamante Wastewater Treatment Plant, the advanced water purification facility, and the advanced water purification facility and distribution system.

Regulations

The Texas Commission on Environmental Quality (TCEQ) regulates direct potable reuse on a case-by-case basis within the state of Texas. The TCEQ started researching and developing its own regulations toward direct potable reuse in 2012, with the first advanced water treatment plant coming online just one year later. The TCEQ developed a guidance manual that walks utilities through the process of submitting their proposed plans and how to meet approval criteria. The process consists of identifying the source water's characteristics and the advanced water's desired characteristics, conducting a pilot study, submitting results, and submitting construction plans.

The TCEQ is responsible for reviewing all construction and treatment plans before construction begins, as well as inspecting construction once completed. If state and federal discharge permit requirements are satisfied, the TCEQ can approve proposed plant designs and treatment processes, even if the process design is not typical of adopted direct potable reuse processes (TCEQ, 2022). Once a utility is approved for implementing DPR, it must always have an operator, with at least a Class B Surface Water Operator license, present at the facility while water is being produced. As the regulating body for all of Texas, the TCEQ is responsible for conducting inspections of all advanced water treatment facilities and ensuring that they are operating with the intent to protect public health by staying in compliance with the Safe Drinking Water Act, as well as federal and state discharge regulations.

Cost

The City of El Paso's advanced water purification facility will cost roughly $300 million, and the Roberto Bustamante Wastewater Treatment Plant will undergo a series of upgrades that will cost $757 million (Moyers, 2024). The Bureau of Reclamation awarded the City of El Paso $20 million to construct the advanced water facility (El Paso Water, 2022). El Paso's water rates have increased for the last nine consecutive years. Given the costs of new water and wastewater infrastructure throughout the city, including the initial and operating cost of the Roberto Bustamante Wastewater Treatment Plant and advanced water purification facility, the city's new annual budget for water and wastewater will total $1.06 billion, and this will result in El Paso water customers paying $220 more annually for water and wastewater services (Moyers, 2024).

Training

The Texas Commission on Environmental Quality (TCEQ) has no restrictions on direct potable reuse and Senate Bill 905 was signed into law in 2021, highlighting TCEQ's regulations and operating manual for direct potable reuse (EPA, 2024b). TCEQ does not have direct potable reuse exams and does not have plans to create a DPR-specific exam. For the advanced water facility in El Paso, TCEQ, through its review of the initial construction and implementation plans, required the equipment manufacturers to provide hands-on training and support until it was determined that the operators were sufficiently trained.

Public Relations

The City of El Paso put a great deal of effort into receiving public support for direct potable reuse. The City is said to have a robust community engagement program, which created a Citizens' Academy allowing community members to receive information about what the City of

El Paso has planned regarding water projects. It has constructed a visitor center that teaches about water conservation, as in Appendix H (TecH2O, 2025), the desert-type ecosystem in El Paso and how the City of El Paso is taking innovative steps in water conservation (Asch, 2024). The City formed a Speakers' Bureau, involving El Paso water employees, who relay information to the community through various media channels. It has conducted focus group meetings, developed multimedia communications, such as text messages, newspaper, television ads, and radio broadcasts, to educate the public about the advanced water purification facility, and administered customer surveys at various stages throughout the implementation of the DPR process (Maseeh et al., 2015). The city was also able to get support from local medical professionals, which aided in shifting public opinion with thoughts and feelings of the water being safe to consume. The City of El Paso put forth a great effort to create a strong relationship between its water utility and the public. The City has also decided that the public will be involved in all decision-making moving forward.

Discussion

The City of Phoenix supplies water to 1.7 million people; and its population is expected to increase to 2 million by 2040. Phoenix relies primarily on surface water as its source water and closely monitors its groundwater use because it is considered a finite resource. Since 2000, the Southwest has experienced a megadrought, which has seen the largest reservoirs decrease to alarming levels, according to the Bureau of Reclamation. With Lake Mead and Lake Powell decreasing to levels not seen since the filling of the reservoirs, along with less runoff resulting in decreased volume of water in the Colorado River, the Bureau of Reclamation declared shortages for the region. Arizona, California, and Nevada have agreed to save or withhold pumping 3 MAF of Colorado River Water. However, with 2024 being a dry year in terms of precipitation and snowpack, and Lake Mead being at 37% of full capacity, the future looks concerning in relation to water resources. According to the City of Phoenix's Water Services Director Troy Hayes, as the drought in the Southwest intensifies, and with the Colorado River being over-allocated and declining due to climate change, it is imperative that the City of Phoenix embraces innovative ideas and is proactive in preparing for more profound water shortages (COP, 2022a). The City of Phoenix can increase its water supplies by implementing direct potable reuse. Direct potable reuse consists of an advanced water purification facility that receives already treated wastewater from a nearby wastewater treatment plant and, through new technology, treats this wastewater or treated effluent to standards considered safe for humans to consume. In treating 136,404,446 gallons of wastewater daily, if the City were to implement DPR, this would equal 51% of its current potable water production. If Colorado River water supplies were to get to a point in the future that the City of Phoenix could no longer rely on it within its water resources portfolio, the City would be able to replace its entire Colorado River water allocation with the implementation of DPR. The City of Phoenix faces many barriers to implementing DPR, including infrastructure, regulations, cost, training, and public relations.

If the City of Phoenix implements DPR, it would need to construct a new advanced water purification facility at each of its three wastewater plants and upgrade its current wastewater treatment plants to produce higher quality effluent in preparation for advanced water treatment. Advanced water purification facilities are necessary, and so is the construction of new water storage facilities, water quality monitoring stations, pumping stations, and piping to connect the treatment facilities and the water purification facilities to the current distribution system. The State of Arizona is allowing private and municipal utilities to pursue direct potable reuse by issuing permits to conduct in-house pilot programs and is in the process of developing a regulatory framework for DPR with full permission to implement DPR expected within 2025-2026.

DPR costs are substantial, and City of Phoenix water customers will see a substantial increase in their monthly bills. Each person will pay $33.00 to $49.5 a month, compared to $4.64 to $9.90 monthly. A household of four people with typical water usage of 100-150 gallons a day will pay $130-$200 a month. The City could apply for funds from the federal government to shoulder a portion of the cost to implement DPR. With the attention such a large city would receive to carry out this large task, it would seem likely that the Bureau of Reclamation would fund some portion of the City of Phoenix's efforts. Training of the wastewater operators and management will require new certification testing that all staff will need. As DPR is constructed, the staff will need to receive hands-on training from those knowledgeable about the DPR process.

Public relations will be the most challenging barrier to the City of Phoenix, though, getting the public past the disgust factor. The City will need to engage in a massive public relations campaign by distributing technical and general information to the city's water customers, engaging in radio and television commercials, and engaging in meetings the public can attend to receive the newest information on the topic. The City will also need to earn the public's trust and build its relationship with them by bringing them into the advanced water purification and wastewater facilities to let them see the process firsthand. In doing so, the public will become more informed and educated about the process, which fosters support.

The City of El Paso, although a lot smaller than the City of Phoenix, is the largest city to fully implement direct potable reuse, with treated wastewater being pumped directly into the city's distribution system. The City of El Paso was in a very similar situation as the City of Phoenix, experiencing severe droughts and having water resources that significantly decreased year after year. The City of El Paso set the blueprint for other cities, like the City of Phoenix, to follow. El Paso Water needed to construct an advanced water purification facility and upgrade its largest wastewater plant to produce higher quality effluent for its advanced water facility. El Paso brought officials from the Bureau of Reclamation in to become a part of the project, and in doing so, the city was awarded $20 million to be applied to the construction of infrastructure. Every contract signed between the city, equipment manufacturers, and contractors contained an agreement that all individuals involved with operating the advanced water purification facility would receive hands-on training until the personnel felt comfortable enough to run the facility by themselves without help. Although costs have significantly increased for El Paso water customers, the City prepared its customers by holding open meetings where community leaders could relay that information from the start, as well as bring the public in at different stages of construction being completed. El Paso constructed a Visitor's Center dedicated to teaching the public about its water and wastewater projects, which kept them informed. The City also developed a Speakers' Bureau, which utilized various types of media channels to keep the public informed at all times. The City of Phoenix has the ability to replicate how the City of El Paso connected and built trust between its utility and the public. Phoenix could receive more public support for implementing DPR by following the City of El Paso in having local medical professionals approve the DPR process, resulting in a decrease in public fear of consuming DPR treated water.

Conclusion

The barriers preventing the City of Phoenix from implementing direct potable reuse are infrastructure, regulations, costs, training, and public relations. The City of Phoenix is in a desperate situation regarding water resources. Climate change contributes to the drastic decrease in water supplies throughout the Southwest, and climate officials predict that water supplies will decrease even further. Increases in population and development are also contributing factors to diminishing water supplies. For City of Phoenix officials, the time has come to decide how it will sustain water resources for an increasing population and development. The easiest source to access that would increase the City's water supply is the sewer system, where wastewater could be treated to potable water standards, known as direct potable reuse. The City of Phoenix would need to construct an advanced water purification facility, adopt operating and maintenance standards according to ADEQ regulations, train its operators and staff on how to operate an advanced water purification facility, acquire funding from the federal government and determine how the cost would be distributed to its customers and develop a supporting and trusting relationship between its water and wastewater utility and the public that lasts for decades into the future. The City of Phoenix, through direct potable reuse, could replace its entire Colorado River water supply, which would not only make the City's water portfolio more robust but would also provide a buffer or resiliency if the Colorado River were to decrease to a level that is not sustainable to pump anymore.

The City of El Paso, the largest city to pursue DPR, has excelled in its implementation and benefits immensely from the decision. The City of Phoenix can follow the blueprint El Paso has created to recognize and overcome the barriers to implementing direct potable reuse. Implementing direct potable reuse has occurred in nature since the beginning of time, but instead of waiting days, weeks, and years for the environment to cleanse the water, DPR plants could make it happen within hours. Now is the time for the City of Phoenix to take control of securing enough water resources to sustain itself well into the future.

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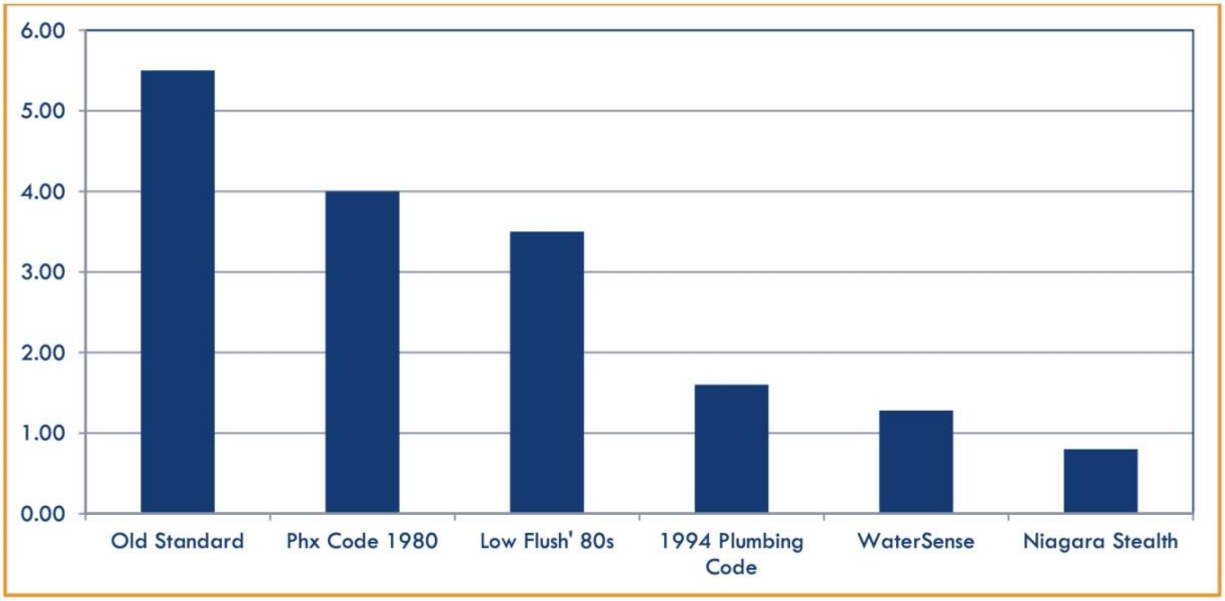
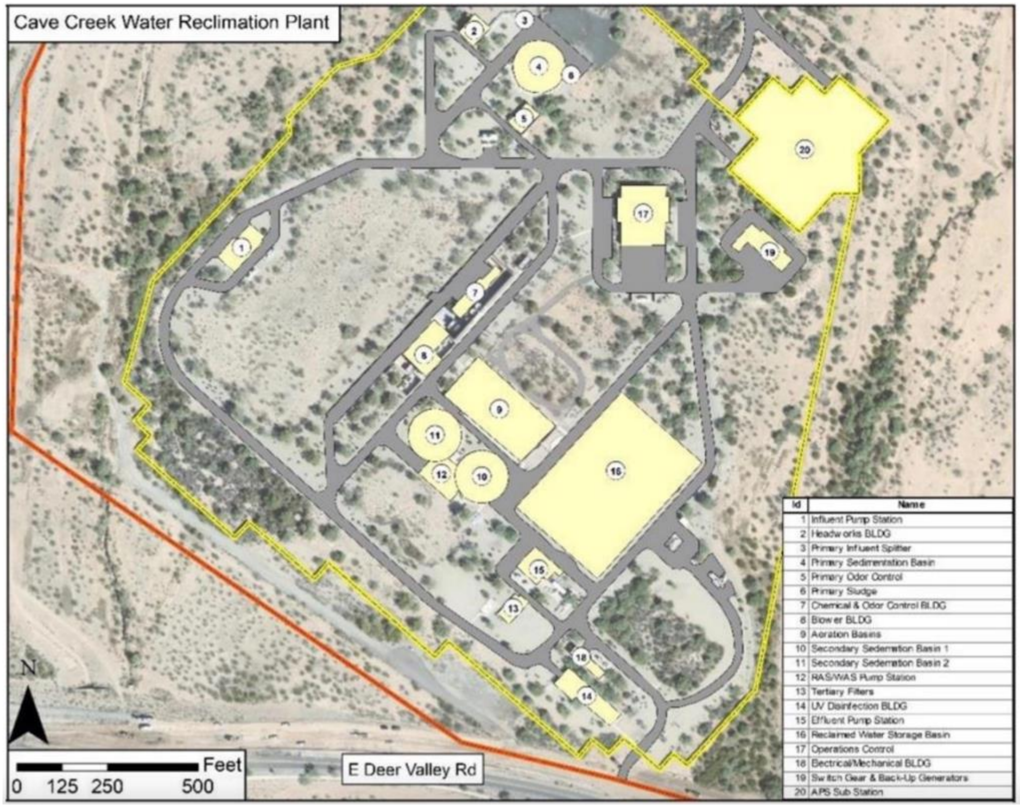
Appendix

Appendix A: Toilet efficiency gains from 1970s to present (COP, 2021)



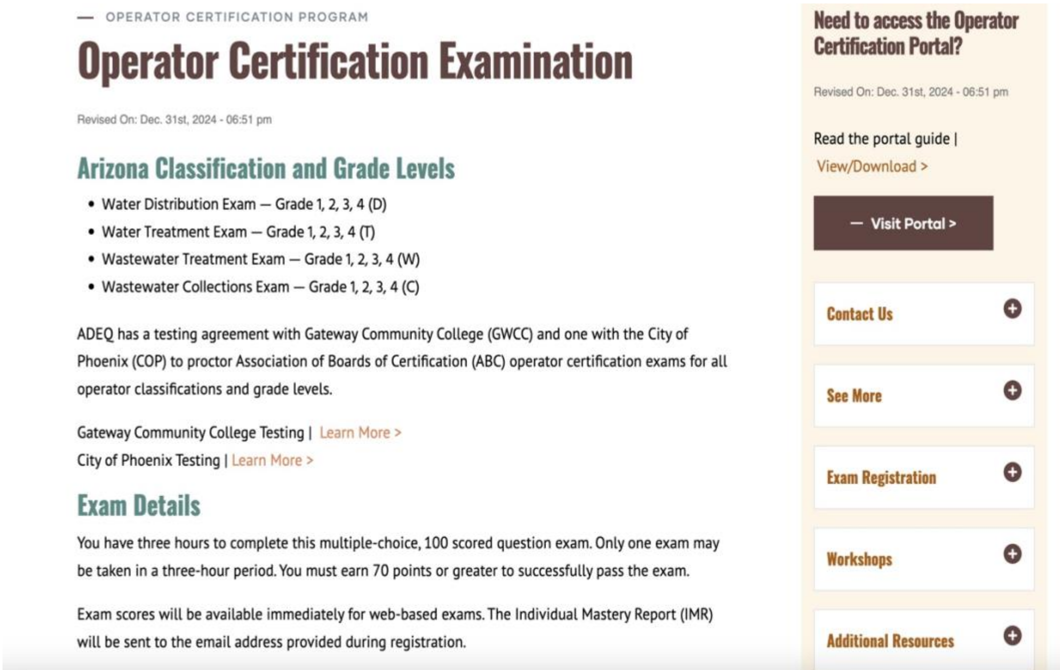
Appendix B: Aerial view of the City of Phoenix 23rd Avenue Wastewater Treatment Plant

Appendix C: The building layout of the City of Phoenix Cave Creek Water Reclamation Plant (Heiderscheidt, 2022)



Appendix D: Aerial View of the City of Phoenix's 91st Avenue Wastewater Treatment Plant (AMWUA, 2019)

Appendix E: Arizona Department of Environmental Quality Testing and Certification Portal (ADEQ, 2024)



— OPERATOR CERTIFICATION PROGRAM

Operator Certification Examination

Revised On: Dec. 31st, 2024 - 06:51 pm

Arizona Classification and Grade Levels

- Water Distribution Exam — Grade 1, 2, 3, 4 (D)
- Water Treatment Exam — Grade 1, 2, 3, 4 (T)
- Wastewater Treatment Exam — Grade 1, 2, 3, 4 (W)
- Wastewater Collections Exam — Grade 1, 2, 3, 4 (C)

ADEQ has a testing agreement with Gateway Community College (GWCC) and one with the City of Phoenix (COP) to proctor Association of Boards of Certification (ABC) operator certification exams for all operator classifications and grade levels.

Gateway Community College Testing | Learn More >
City of Phoenix Testing | Learn More >

Exam Details

You have three hours to complete this multiple-choice, 100 scored question exam. Only one exam may be taken in a three-hour period. You must earn 70 points or greater to successfully pass the exam.

Exam scores will be available immediately for web-based exams. The Individual Mastery Report (IMR) will be sent to the email address provided during registration.

Need to access the Operator Certification Portal?

Revised On: Dec. 31st, 2024 - 06:51 pm

Read the portal guide | View/Download >

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See More

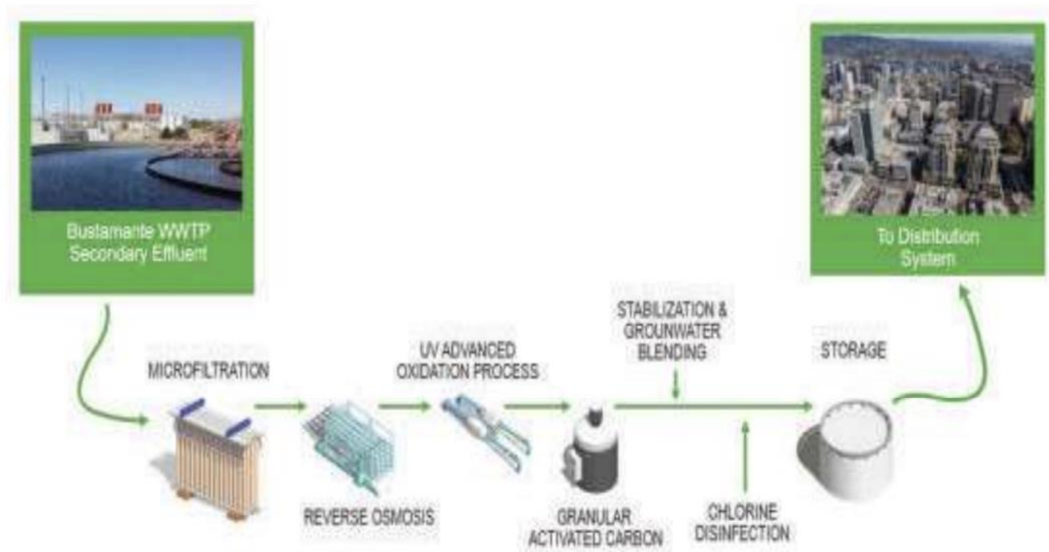
Exam Registration

Workshops

Additional Resources

Appendix F: City of Scottsdale's direct potable reuse water delivered to local breweries (Water Use it Wisely, 2019)

Appendix G: Diagram depicting the treatment train implemented at El Paso's Advanced Water Treatment Facility (Villalobos, 2023)



Appendix H: The City of El Paso's visitor center that teaches the public about water conservation (TecH2O, 2025)