Augmenting Coastal Georgia’s Fresh-Water Supply while Reducing Local Salt-Water Intrusion into Groundwater Reservoirs

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Fresh water is not a guaranteed resource. Most of Georgia’s fresh-water sources are refilled by rainwater, and any form of drought or decrease in rainfall levels would result in Georgia’s fresh-water supply becoming vulnerable to over-extraction. This would potentially lead to serious issues including monetary losses in industries which require the use of water in their operations. However, another issue with fresh-water loss is that when fresh water does not flow at expected levels towards the Georgia coast, salt-water begins to intrude into the major available fresh-water reservoirs of the coastal region, particularly the Upper Floridian aquifer. This salt-water intrusion is already contaminating the fresh-water supply in the aquifer that the cities of Savannah and Brunswick depend on for fresh-water. While progressive water conservation and reuse methods are already being planned and implemented, production of freshwater, particularly from desalinated seawater and brackish water, should be reconsidered. If the state waits any longer to install such infrastructure, the process could become more difficult and costlier. This capstone project will discuss the need for new freshwater sources, the dangers of saltwater intrusion, and how seawater and brackish water desalination could potentially fulfill this need.
AUGMENTING COASTAL GEORGIA’S FRESH-WATER SUPPLY WHILE REDUCING LOCAL SALT-WATER INTRUSION INTO GROUNDWATER RESERVOIRS.

by

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B.A., ANTHROPOLOGY, GEORGIA STATE UNIVERSITY

A Capstone Submitted to the Graduate Faculty of Georgia State University in Partial Fulfillment of the Requirements for the Degree

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## I. Introduction
1.1 Worldwide Climate Change and Freshwater Loss

While 70% of Earth’s surface is covered by water, less than 3% of that water is freshwater with most of that freshwater is trapped in icebergs or is otherwise inaccessible; a smaller amount (29%) is found in groundwater, and 1% is stored as surface water. ¹ With some regions of the world benefiting from more access to water than others, the current status of available freshwater worldwide is being diminished at a rapid rate due to a number of factors including increases in average global temperature that lead to increased rates and severity of droughts, changes to climate patterns, major population growth, and a lack of planning for inevitable or potential freshwater losses. ² Reductions in freshwater availability due to the impact of global climate change is perhaps the direst issue that has only recently been taken seriously.

It is important for local governments to recognize the difficulty in predicting future freshwater losses due to worldwide climate changes. ² In the past, relatively accurate predictions regarding when and where rainfall could and would occur were possible. However, changes to weather patterns due to global climate change have made these predictions increasingly less accurate. ² A few other results of global climate change are increased temperature, extended periods of drought and possible increased evaporation from surface water freshwater reservoirs. ² With global warming causing these unpredictably more frequent and longer periods of drought, shown in Figure 1, the situation is also exacerbated by increases in the world’s population due to that increase causing a potential increased strain on the freshwater supply. ²
It is because of these extreme changes to the climate that the United Nations has declared that the world has been in the midst of a major water crisis since the early 2000’s. In 2007, experts working for the UN declared that 20% of the world’s water shortage is a direct result of global warming. On top of that, the UN’s World Water Development Report, released in 2012, reported that by 2025 1.8 billion people will be living in regions with absolute water scarcity, and two-thirds of the world’s population could be living under water stressed conditions.

1.2 Freshwater Supply in Georgia

The state of Georgia cannot expect to be immune to the impacts of global climate change. While many of Georgia’s freshwater resources have headwaters within the state itself, Georgia does share three crucial river basins with three other states. The Savannah River defines the border between South Carolina and Georgia, and its mouth ends at the Georgia city of Savannah. The cities of Augusta and Savannah depend heavily on the Savannah River for their freshwater supply. The Chattahoochee River which begins in Northern Georgia and...
supplies most the city of Atlanta’s water is also shared with Georgia by Alabama and Florida. The Chattahoochee River, connected to Lake Lanier, supplies not only the metropolitan area of Atlanta, but also the city of Columbus, and the Athens/Gainesville area with freshwater. A third major river basin is the Flint River basin, which provides Florida with crucial amounts of water that the panhandle region depends on to maintain a healthy local ecosystem. Other important river basins within Georgia include the Altamaha River Basin, which exits into the Atlantic Ocean at the city of Brunswick, and the Ogeechee and Satilla Rivers, which each headwater in Georgia, both flowing into the Atlantic Ocean. Any loss in freshwater to the State’s major cities or the agricultural and industrial infrastructure could be catastrophic for the state of Georgia. Figure 2 shows which cities of Georgia have a river flowing through them and Figure 3 shows the volume of flow from each major Georgia river.

Figure 2. Reference map of GA from "The National Atlas Of the USA".
1.3 Freshwater Loss from Population Changes and Increased Demand

Population increases, combined with reduction of streamflow, in the central, southern, and coastal region of Georgia are also causing a potential freshwater crisis. Central and Coastal Georgia lie on the 100,000 square mile Upper Floridian (UF) Aquifer, and can utilize this groundwater source, an asset that North Georgia does not have, as seen in Figure 4 below.
North Georgia’s dependence on surface water makes it especially vulnerable to drought conditions, so withdrawals from distant surface water resources would be necessary to supply the North Georgia, particularly the Atlanta metropolitan region, with water in times of lower freshwater accessibility.\textsuperscript{1} Though surface water resources such as the Savannah and Altamaha rivers are valuable freshwater resources to central and southern Georgia, much of the freshwater used in these regions is supplied from the local aquifer.\textsuperscript{6} Due to increases in population and irresponsible well use, the UF aquifer at the cities of Savannah and Brunswick has seen increased saltwater intrusion and contamination, which has spoiled some of the available well water in these cities.\textsuperscript{6} If population increases resulted in increasing water use from central Georgia, the agricultural heart of the state, the amount of freshwater input being sent to the coast would at risk of slowly decreasing, causing further saltwater intrusion into previously brackish-water ecosystems, which would be, and is, damaging to the local ecosystems, but also making traditional drinking-water production more difficult and costly.\textsuperscript{6} If the central, southern, and coastal regions of Georgia are going to be expected to withstand increases in water consumption from the Northern regions which supply its surface water, then the amount of freshwater available in central and coastal Georgia will have to be increased.
somehow. This increase will also help prevent further contamination of the UF aquifer and further ecological damage.

1.4 Georgia Freshwater Withdrawal

It has been estimated that the entire state of Georgia withdrew 4.44 billion gallons of water for all purposes from available resources in 2010. As shown in figure 5 from the US Geological Survey, the public supply, which represents the distribution of water through a system of constructed conveyances to at least 15 service connections or that which regularly serves an average of at least 25 individuals daily at least 60 days out of the year, was responsible for more than 1 billion gallons of use. This was only surpassed by thermoelectric use and followed by irrigation, industrial, domestic, aquaculture, livestock, mining, and commercial use. The majority of the water supplied coming from surface water sources.

\[ \text{Figure 5. Source and Use of Freshwater in GA as of 2010, from the "US Geological Survey".} \]

With the state of Georgia’s population expected to reach between 12 to 15 million by 2030, the strain on Georgia’s freshwater supply could prove to be unsustainable. Roughly half of the
population of Georgia lives in and around Atlanta and if the area reaches over 8 million by 2040, then it is entirely possible that the freshwater currently available to the Atlanta area would quickly become insufficient during a drought for an extended period of time.  

1.5 Georgia at a Crossroads

As of 2019, the state has designed and implemented several programs to collect more rainwater, reduce wasted water from industry, recycle grey water, and reduce the overall water consumption rate of each individual by utilizing new technologies and techniques that are available. 10, 11 These measures are crucial to prevent a statewide freshwater crisis in the short-term but may not be enough in the event of long-term changes in rainfall levels, an extended drought from climate change, massive population increases, or changes to the water demand from industry and agriculture. 7

The Coastal Georgia region relies on freshwater flow from rivers upstream in the agricultural heartland of central Georgia, as well as the UF aquifer with some instances indicating that competing regions and communities depending on these sources for their freshwater supply. 5 In order to prevent a freshwater crisis in the coastal Georgia region, infrastructure capable of producing additional freshwater from available resources should be considered and built while the state can afford it. 2 While conservation and greywater recycling efforts are growing in practice 10, the Coastal Georgia region should also be considering alternative methods such as seawater and brackish water desalination in the event that conservation and recycling are not enough to fulfill the freshwater demand.

1.6 Desalination as a Solution to Freshwater Loss

Desalination is defined as “the removal of salts from water to produce a water of lesser salinity than the source water”, with the end goal being water with a salinity of < 0.1%. 12 Desalination is typically done by two different processes: distillation or reverse osmosis. 13 Distillation involves heating salt or brackish water and collecting the desalinated vapor. Reverse osmosis involves passing salt and brackish water through membranes and other chemical processes which filter out the salt and other contaminates. The desalination process itself separates intake water into two different streams; a freshwater stream, or product water, and a concentrate waste stream of effluent, or brine. 14 While distillation produces a higher
freshwater yield than reverse osmosis, it is far more energy intensive and produces more waste brine than reverse osmosis, therefore reverse osmosis is currently the preferred method. Despite the benefits of desalination, it is in no way a substitute to conservation efforts.

In order to prevent a potential freshwater crisis, the construction of a coastal seawater and brackish water desalination plant, along with a capable distribution network capable of distributing desalinated water throughout the region, has to be considered immediately. Desalination of seawater is already being done worldwide with high levels of success, but resistance to the installation of seawater desalination infrastructure is typically the result of three factors: cost of construction and powering the infrastructure, strain on the energy grid, and what to do with the waste brine produced during the desalination process. These issues will be addressed in this paper. As mentioned before, all solutions must be considered, and in many ways all solutions have already been considered, and if there are genuine solutions available to resolve these issues then desalination efforts have to be implemented as soon as possible for the benefit of all regions involved.

II. Georgia’s Experience with Freshwater Loss and Saltwater Intrusion

2.1 Historical Georgia Droughts

Drought is not a new phenomenon in Georgia. Between 1680 and 1956 there have been at least 12 droughts, clarified as extremely reduced rainfall periods lasting at least 2 consecutive years. The historical data was gathered by utilizing tree ring analysis. Some events, particularly the 1925-1927 drought, resulted in the mass migration of people from rural areas to urban areas, resulting in population decreases in rural areas which to this day have not recovered. That drought resulted in permanent changes to the demographics of the state, and therefore it should be considered that future droughts could have similar effects. Based on the climatological record from before 1960, Georgia would be able to expect droughts lasting two or more years every 25 years, not including short-term droughts or agricultural droughts, which are harder to predict. However, after 1956 the state of Georgia experienced a mostly drought free period until droughts occurred from 1998-2002, 2004-2009, and periods of
drought throughout the 2010’s. It is important to note that along with these historic droughts came ecological damage to ecosystems and communities downstream.

In past droughts, the estuaries at the end of the Savannah, Ogeechee, Altamaha, and Satilla Rivers experienced serious saltwater tidal intrusion deep into the rivers themselves and the local ecosystems suffered long-term damage from this the local communities also dealt with an increase in price and energy for freshwater production from the increase in salinity in the freshwater resources needed to supply these coastal Georgia’s municipalities. With global climate change ruining previous models capable of predicting future weather patterns, the uptick in drought conditions in recent years has already shown that predicting future droughts will be more difficult in Georgia due to the inability to accurately model climate patterns based on historical data.

2.2 Georgia’s 2004-2009 Water Crises

The Georgia drought of 2004 to 2009 is of particular interest because of its severity and length. The mean annual rainfall of North Georgia is an average of 127 cm/year, ranging from 76 to 178 cm/year. The 2004 to 2009 drought resulted from below average rainfall levels which especially impacted the Atlanta metropolitan area due to the regions almost exclusive dependence on surface water reservoirs, particularly Lake Lanier and Lake Allatoona, supplying 87% of the water used by the region. Both the Lake Lanier and Lake Allatoona reservoirs have a generally low volume to surface area ratio and the average water depth is relatively small. Additional surface water is obtained from smaller allocations from the Flint [5.0%], Ocmulgee [8.1%], Oconee [0.2%], and Tallapoosa [0.1%] river basins. By 2007 the drought had become so severe, and water levels in Lake Lanier were so low, that it triggered a level 4 drought emergency, and the State banned all outdoor watering activities except by essential businesses. To make things worse, the organization responsible for managing Lake Lanier was found to have replaced the lake water level gauge in December 2005 but made an error in the calibration of the gauge. This caused the water level to be overestimated by 0.5 meters relative to its real value. Because of this error, environmental releases were allowed that caused more than 83 million m$^3$ of excess water, or 6.3% of the conservation pool capacity, to
pass downstream through the Buford Dam. \(^7\) The Lake Lanier stage reached a record low in December of 2007 at an elevation of 320.28 meters. \(^7, 20\)

At the time the drought was at its worst, there were no feasible alternative water sources capable of supplying the entire Atlanta metropolitan region with water if the drought continued its severity and the surface water reservoirs became deplete of water. Rainfall levels returned to normal levels by 2009 but the allocation of water from various reservoirs had already been changed to help supply the Atlanta metropolitan region with water in the event that an extended drought occurred again. \(^7\) The problem with the changes in water allocation was that regions downstream of and dependent on these newly or increasingly tapped water sources experienced reduced streamflow and suffered numerous consequences for these actions. \(^20\) Because of these changes, the already existing litigation regarding water rights between Georgia, Alabama and Florida intensified, \(^4, 7\) to be discussed further in section 2.4.

### 2.3 Contamination of the Upper Floridian Aquifer

Prior to the industrial development and population growth of the early 1900’s in the coastal region of Georgia, groundwater in Georgia’s aquifers flowed from recharge areas in an east-southeast direction, extending in a broad arc from Valdosta to Waynesboro, eventually discharging offshore. \(^6\) After World War II, as the coastal region developed, centers of groundwater pumping formed in Georgia around Savannah, Brunswick, Jesup, Riceboro, and St. Mary’s. \(^6\) The bulk of the groundwater pumped is from the Upper Floridan aquifer, which is a porous limestone geologic formation having extremely high productivity. \(^6\) At areas of high pumping, cones of depression formed in the potentiometric surface and flow directions changed. \(^6\) Contaminated groundwater with high salinity, from excess groundwater extraction from wells, and high levels of the chloride ion, from pollution and waste seepage from industrial plants on the Georgia coast, began to flow toward or into the Savannah, Hilton Head, Brunswick, and Jacksonville areas. \(^6\)

With the existence of contamination in groundwater resources, it demonstrates that reductions in rainfall, and the resulting reductions in streamflow and freshwater availability are clearly not the only issues facing Georgia. Not only is groundwater contamination a problem in general, but coastal and southern Georgia benefit from groundwater resources that the more
populated North Georgia region cannot utilize due to the lack of groundwater available in North Georgia. The more southern groundwater resources supply the coastal cities of Georgia with water for everything from home consumption to agriculture and other industries. It does not help that these groundwater resources have also been over-tapped and have suffered from the previously mentioned saltwater and chloride ion intrusion. Both the Savannah and Brunswick regions have had to deal with the issues with contamination into the local aquifer and have had to adapt to these conditions with appropriate, but intensive actions. The Savannah region has put caps on groundwater withdrawal and the city of Brunswick has had to implement major restrictions on waste disposal from local industries. The Coastal Georgia Water & Wastewater Permitting Plan for Managing Salt Water Intrusion was developed to protect the region from reductions in freshwater availability. It also helped advance municipal requirements for water conservation, water reclamation and reuse, and wastewater management. However, the primary focus of the Plan is on stabilizing or halting the intrusion of saltwater into the Upper Floridan aquifer, which is a dominant water supply source shared by coastal Georgia and neighboring areas of South Carolina and Florida. The Plan also recognized that actions taken to halt the intrusion of additional salt water into the aquifer will not result in the halting of the migration of the salt water that has already entered the aquifer unless more extensive and alternative efforts were taken.

2.4 The Tri-State Water Wars

The Atlanta metropolitan area which, as mentioned before, contains roughly half of Georgia’s population relies almost entirely on surface water to supply its population. This puts great strain on the nearby Lake Lanier, a major reservoir on the Chattahoochee river, which alone supplies Atlanta with 70% of its water. As previously mentioned, the Chattahoochee and Coosa rivers and their reservoirs together supply 87% of Atlanta’s water needs, with the rest coming from the Ocmulgee, Flint, Oconee, and Tallapoosa Rivers and reservoirs along their basins. The reliance on these local surface water resources may make sense for North Georgia but has consequences on the population centers, agricultural regions, and industrial sites downstream. The Chattahoochee river, part of the ACF [Apalachicola–Chattahoochee–Flint] river basin, southwest of Atlanta forms the southern half of the border between Alabama and
Georgia, eventually flowing into Florida. The Chattahoochee river, part of the ACF [Apalachicola–Chattahoochee–Flint] river basin, southwest of Atlanta forms the southern half of the border between Alabama and Georgia, eventually flowing into Florida. Alabama, Georgia, and Florida all suffer greatly when there are reductions in flowrate to the Chattahoochee river. The Coosa river, part of the ACT [Alabama–Coosa–Tallapoosa] river basin with its headwaters in Georgia, also flows into central Alabama, where reductions to its water levels also have had devastating effects on communities relying on the Coosa river basin for its demands. Finally, the Flint river, a part of the ACF river basin, which flows down into Florida though central Georgia greatly affects Southwest Georgia and Florida’s ecosystem when reductions in streamflow occur. Metropolitan Atlanta’s increasing thirst for water has caused Alabama and Florida to take legal action against the State of Georgia due to these changes in downstream water flow levels, and this situation is currently still in litigation as of mid-2019, with no foreseeable end in sight. These many legal actions have been coined the “Tri-State Water Wars”. According to a report regarding the rivers that flow from Georgia into other States:

“The rivers used by the [North Georgia] region for water supply are not adjudicated basins that have established water rights allocated to specific entities within a legal framework similar to that found in western US water law or in some international water agreements. Two reservoirs [Lake Lanier and Allatoona Lake] were created on these rivers by the US Army Corps of Engineers [USACE] under an authorization from the US Congress, which specified the uses of the reservoirs to include navigation, power production, flood control, and downstream water supply [affirmed by the 11th Circuit Court of Appeals].

“Georgia’s interests are primarily related to the maintenance and expansion of water supplies to meet the needs of the metro Atlanta region and other cities located along the course of the rivers, but also include power generation and recreation. Alabama’s interests are downstream riparian water users who require water from the Alabama–Coosa–Tallapoosa [ACT] basin for agriculture, industry, fisheries, recreation, preservation of habitats and diversity [environmental flows], power generation, navigation, and water quality. Florida interests are in the Apalachicola–Chattahoochee–Flint [ACF] basin and are centered on the requirement for freshwater flows into Apalachicola Bay to maintain salinity balances for fisheries and shellfish harvesting.”
The U.S. Army Corp of Engineers acts as the primary management organization for the ACT and ACF river basins, and it is their seemingly preferential treatment of the Atlanta metropolitan regions water demands over the demands of regions downstream of North Georgia that is the cause of the Tri-State Water Wars.\(^4,7\) Alabama and Florida have challenged the USACE’s authority over its decisions to allow Lake Lanier to supply Atlanta with water and have also used the Endangered Species Act as reasoning for why maintaining downstream flow levels are important for regions outside of North Georgia.\(^7\) Courts have both accepted and then later rejected all arguments against the State of Georgia up to this point and no true resolution has been settled so the court cases continue.\(^7\) While these court cases continue on and begin
to pile up, the legal costs also increase and there appears to be no current solution which would satisfy each State’s needs based on the current possibilities. For these reasons, alternative solutions have been considered. 7

One solution that has been proposed is having Georgia tap into the Tennessee River, which lies only 4km from the North Georgia border, and filling new reservoirs in North Georgia. 7 The U.S. Congress originally defined Georgia’s northern border as being at the 35th parallel, but erroneous surveys conducted in the 1800’s placed Georgia’s northern border further south than what congress decided, and in 2007, at the height of the worst drought in modern Georgia’s history, Georgia raised the issue again as a way of gaining access to the Tennessee River at Nickajack Lake. 7 The problem with this plan was the political backlash it would inevitably create, which would mean adding a fourth state into the Water Wars, and then trying to negotiate with the managers of the Tennessee River’s water rights, the Tennessee Valley Authority who would grant water withdrawal rights. 7 Another considered solution was a water exchange program with the city of Savannah. Atlanta would subsidize Savannah’s freshwater production infrastructure in exchange for the “rights” to tap the Savannah River for water. 7 The plan was seriously considered but, as with the Tennessee River plan, the Savannah River is shared with another state, South Carolina, so involving another state in the Water Wars would result in further money spent on additional litigation, also, the city of Savannah did not have the authority to sell its “rights” to the Savannah River, and the water supply in Savannah relies heavily on wells tapping into the Upper Floridian Aquifer but has been capped at 95,000 m³/day meaning other methods of water production would have to be built amidst the likely legal battles started over rights to the water of the Savannah River. 6, 7, 21 The last seriously considered option, is the use of seawater desalination to fulfill the needs of Atlanta, which would create a new source of freshwater while not taking freshwater from other states. 7

2.5 Desalination as a Solution to Freshwater Loss

The construction of seawater desalination plants has been considered so that desalinated seawater could be distributed from the Georgia coast to North Georgia. 7 To research this possibility the Joint Comprehensive Water Desalination Study Committee was created in the early 2000’s. 7 It was thought that if Georgia could begin creating its own new
freshwater sources, then the need for North Georgia to take freshwater from interstate shared river basins could help put an end the Water Wars and stop the state from wasting money in court cases regarding which state has the rights to which water sources and how much water each state owns access to. It was also thought that freshwater produced from desalination could supplement the States needs in the event of freshwater loss.

The construction of the proposed desalination and distribution infrastructure was, however, rejected by the original planners for a several reasons. First, subsidizing the city of Savannah to build a desalination plant and a distribution network connected to Atlanta was considered but rejected due to the cost of pumping water the long distance to Atlanta, over 400 km, which would also have to deal with the change of elevation, 305 meters, up from sea-level on the coast. The subsidizing of a desalination plant to supply just the Savannah metropolitan area by Atlanta, in exchange for the rights to access to the Savannah River, was also considered. The distance of a pipeline from the Savannah River to Atlanta would only be 62 km and the distribution of pumped water would feature a downhill grade, making the costs significantly cheaper, but the involvement of South Carolina in potential litigation and the potential negative environmental impact downstream on the Savannah River made the possibility of this option unlikely. For these reasons, desalination infrastructure with a distribution network to the metropolitan Atlanta area was considered to be unfeasible. It was decided that water conservation efforts, increased grey-water recycling, and better rainwater collection, along with the utilization of newly built reservoirs was the best option for the state of Georgia.

However, the issue of freshwater loss and saltwater intrusion into the freshwater supply of the cities of coastal Georgia was overlooked. The needs of the coastal Georgia region should not be ignored and increases in freshwater demand for a number of different reasons could cause a water crisis to occur in this region. Increases in populations, increases in water use, reduction in flow from upstream water resources, and saltwater intrusion into groundwater resources are all factors which have already been observed and can be expected to increase over time. While conservation methods have to be implemented state-wide, the previously considered seawater desalination infrastructure should be reconsidered as a way to
supply coastal Georgia’s freshwater needs, instead of as a solution to North Georgia’s water demand needs. If the cost of desalination and distribution is an issue, then ways to reduce these costs, such as subsidization and the sale of excess produced freshwater, should be thoroughly examined. Some potential ways to reduce the energy consumption costs of desalination and distribution could be to utilize renewable energy throughout the network, so that the power needed is generated within the system and outside energy production will not need to be increased to fill any needs of the system. \(^{15}\) If disposal of the brine produced in the desalination process is an issue, then ways to harvest the minerals and elements found in the brine produced in the desalination process should be considered. \(^{13,14,23}\) The harvesting of and then sale of elements and minerals from the brine could also prove to be profitable in the end, so this could be used as another way to offset costs in the long run. \(^{13,23,24}\) If the arguments against seawater desalination are preventing its construction, then removing these hurdles also removes the arguments against desalination, allowing for such a system to be truly considered. If desalination can be used to produce a new source of freshwater, then this would provide the state, particularly the coastal region, with an invaluable resource which would minimize reductions to freshwater availability that may occur for whatever reason, \(^{7,23,24}\) while creating a profitable enterprise.

### III. Existing Desalination Models

#### 3.1 Australia’s Coastal Freshwater Woes

A good way to look at Georgia’s potential freshwater loss scenario, is to look at somewhat similar situations worldwide. One example of a relevant examinable scenario is that of South East Queensland [SEQ] and Perth in Australia. SEQ, the northeastern state of Australia, home to the cities of Brisbane, Sunshine Coast, and Gold Coast, experienced a drought from 2001 to 2009. \(^{25,26}\) The city of Perth, on Australia’s west coast, has also experienced an extreme decrease in rainfall levels since the 1970’s. \(^{25}\) Actually, the entire country of Australia experienced the “Millennium Drought” which began in Queensland in October 1994, spread to the rest of the country by 1996, and only ended in 2010 when La Niña
returned resulting in some of the largest nationally recorded rainfall levels on record which also resulted in widespread flooding and a subsequent mouse plague which negated most of the ecological benefits of the returned rainfall. Despite the nationwide Millennium Drought ending, Western Australia, particularly Perth, did not get the increased rainfall that the rest of the country experienced from La Niña, and still to this day has to deal with the decreased rainfall levels it has been experiencing since the 1970’s. While each region utilized water conservation methods to help alleviate the strain of freshwater loss during the drought, it is the utilization of seawater desalination that had some of the biggest impact and is therefore of special importance. One of the most important aspects of the studies between these two regions during the drought, and Perth’s continued rainwater reduction, is that researchers can see exactly how each effort [conservation and desalination, etc.] was able to alleviate the strains of freshwater loss as it occurred.

The cities of the SEQ area obtain most of their freshwater from lakes within the region. During the drought, the main water supplies dropped to 16% of its capacity. The SEQ area mostly mitigated its freshwater losses through the utilization of water conservation methods. However, towards the end of the drought in the SEQ area more effort was needed to relieve the pressure from freshwater loss, so the government set up two climate-independent freshwater sources: The Gold Coast Desalination Plant [GCDP] and the Western Corridor Recycled Water Scheme [WCRWS]. Along with these new sources, previously segregated freshwater sources were connected via newly built pipeline systems. On the other side of Australia, unlike SEQ, the Perth area obtained most of its freshwater from groundwater reservoirs, such as The Gnangara Mound, and also experienced extreme freshwater loss. In Perth, it was decided that two desalination plants would be the first infrastructure built, as opposed to immediately transferring freshwater from other sources, such as the available and underutilized South West Yarragadee aquifer. The two desalination plants constructed were the Perth Seawater Desalination Plant [PSDP] and the Southern Seawater Desalination Plant [SSDP], which by 2014 both supplied nearly 40% of the Perth area’s water for consumption. As mentioned before, both regions benefited from extensive conservation methods, shown in Figure 7, such as the national Home WaterWise Rebate scheme equaling $321 million AUD for
homes and businesses who invested in water efficient devices and rainwater collection tanks, the setting of residential water consumption targets, and improved pressure and leakage management in the municipal water supply network. 25, 26

<table>
<thead>
<tr>
<th>Water use pattern and household stock comparison.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household having a water-efficient shower head in 2001 (by state)</td>
</tr>
<tr>
<td>Household having a water-efficient shower head in 2013 (by state)</td>
</tr>
<tr>
<td>Household having a dual flush toilet in 2001 (by state)</td>
</tr>
<tr>
<td>Household having a dual flush toilet in 2013 (by state)</td>
</tr>
<tr>
<td>Average shower duration in 2010 (Brisbane)/2009 (Perth) (min)</td>
</tr>
<tr>
<td>Household with a garden using mains water for gardening in 2001 (by state)</td>
</tr>
<tr>
<td>Household with a garden using mains water for gardening in 2013 (by state)</td>
</tr>
<tr>
<td>Households installed with rainwater tanks in 2013 (by capital city)</td>
</tr>
</tbody>
</table>

Figure 7. Southeastern Queensland vs. Perth's Water Use Patterns Before and After Conservation Efforts 25

However, research has shown that these conservation methods alone were not enough to completely compensate for reductions in rainwater levels and freshwater losses from extended droughts. 25 In order to further reduce the impact of droughts and unpredictable freshwater loss, it has even been considered that excess desalinated seawater and treated wastewater could be used to recharge local groundwater systems, especially in Perth where rainwater levels still continue to drop. 25, 26 Figures 8 and 9 show how each region of Australia attempted to address freshwater losses compared to energy consumption levels across the same time frame.

Figure 8. Water Consumption vs. Energy Use Rates in SEQ During Efforts to Reduce Freshwater Losses from 2002 to 2014. 25
Perth and SEQ also differed in the way that behaviors changed during the drought. While SEQ and Perth managed to instill a somewhat permanent change in water consumption rates from water conservation methods, resulting in a reduction to energy use rates in SEQ, Perth did not experience the same levels of reduction in energy or water use. Figure 10 shows how the SEQ and Perth regions compared in regard to their per capita energy and water use from 2002 to 2014.
One of the main reasons that SEQ was able to reduce energy consumption after the installation of the new wastewater recycling plant and seawater desalination plant was because of the drought ending and the return of the region to its normal rainwater input levels, even increasing those levels at times due to La Niña. This has allowed the SEQ region to put its plants on “stand-by” or distribute water to other lakes when needed. Perth, however, has continued experiencing its reduced rainwater input levels, which have been reduced since the 1970’s and the region continues to rely on groundwater from aquifers and desalinated seawater to supply its freshwater. This means that Perth does not have the benefit of being able to turn off its plants like the SEQ has been able to. Also, Perth participated in fewer conservation efforts which, if continuously implemented and increased, would have helped to reduce energy levels and allow for more urban wastewater recycling. Each region shows the reality of differences in climate by region and the benefits of desalination systems depending on combining with conservation efforts. Most of the state of Georgia is expected to go the route of SEQ as far as climate and weather goes, but some parts of the state depend heavily on groundwater, particularly on the coast, and more on surface water around Atlanta and North Georgia, meaning different regions have different needs. A seawater desalination system, which would supply freshwater to the coastal Georgia region could act not only as a safeguard against the negative impact of droughts and rainwater reductions, but also supply freshwater into existing or new surface water reservoirs in preparation for freshwater loss, as well as help recharge groundwater reservoirs.

3.2 Israel’s Need for Freshwater

Another example of a model desalination system is those of Israel. By 2007, Israel had the world’s largest membrane-only desalination plant called the Sorek plant, capable of producing 624,000 cubic meters of fresh water a day. It was important for Israel to build many desalination plants due to their lack of natural freshwater resources capable of satisfying the needs of the population. The United Nations defines a water shortage at a redline of 500 cubic meters per person annually, and Israel’s natural water sources by 2007 were only capable of providing 200 cubic meters per person, meaning that Israel was well below the UN redline, and therefore in the midst of a water crisis. The average Israeli was estimated to have used
300 liters of water a day, with a yearly increase in individual water consumption. With the nation in the throes of a water crisis, the government tried to implement a plan to locally produce 400 million cubic meters of freshwater from desalinated seawater a year while importing 100 million cubic meters of freshwater from Turkey. Another aspect of the government’s desire to resolve the water crisis was the implementation of water conservation methods and techniques in the urban areas. While it was determined that through increased seawater desalination, along with freshwater importation from Turkey or elsewhere until more desalination plants are built and capable of providing the needed amount of fresh water, Israel would eventually be capable of producing enough water to meet the UN requirements needed to escape the water crisis, but only if the conservation methods needed to reduce consumption were implemented. When the decision was made to build the desalination infrastructure and import the freshwater from Turkey, the necessary conservation methods needed to be implemented in order to reduce consumption were not enforced. Because the conservation methods were not enforced, the amount of energy needed to produce a sustainable amount of fresh water was exacerbated and the amount of water consumed per individual continued to increase. The energy needed to run the desalination plants was also provided from energy plants utilizing polluting and exhaustible resources such as coal, petroleum, and gas. With the increase in energy consumption from the new desalination systems, the amount of pollution from energy production increased, which in turn further contaminated the water that was intended to be desalinated. This further increased the cost of desalination and put further strain on the energy supply.

3.3 Desalination in California

California’s water woes present a good example of how reactions to freshwater loss looks in the US. California currently deals with groundwater overdraft and negative climate change induced effects on water availability, which results in severe pressure on the State's water resources and its ability to sustain tremendous population growth, and is projected to rise from roughly 38 to 51 million by 2050. Due to the severe nature of the State’s water loss, the State’s government authorized research into producing freshwater reliably and sustainably, and especially looked into seawater desalination for its potential as a freshwater source.
California has already planned on building almost 20 desalination plants across the state, but before these plants are all activated it is important to know what these plants will truly be capable of, so research has been done to determine this information. The main goal of the State’s research was to determine if alternative ways of producing freshwater would be worth the costs of the efforts. However, it does acknowledge that when demand exceeds supply there must be some kind of “backstop” capable of supplying freshwater to meet demand, and that while cost must always be considered, the need to supply freshwater is vital to the stability of the State, with Gleick and Palaniappan in 2010 saying:

“The ultimate water backstop is still water, from an essentially unlimited source, for example, desalination of ocean water. The amount of water in the oceans that humans can use is limited only by how much we are willing to pay to remove salts and transport it to the point of use, and by the environmental constraints of using it.”

There was resistance to desalination due to its cost and environmental impact, but as pointed out, there may come a point where conservation and recycling alone would not be enough to supply enough freshwater to meet the demands of the State. One benefit that California has over other states is that it had a GDP of $2.31 trillion in 2014 and while economic concerns over desalination are legitimate, the State can afford to build the necessary desalination infrastructure.

California already benefits from having the largest seawater desalination plant in the western hemisphere, capable of producing 50 million gallons of water a day, currently supplying the San Diego region, from Carlsbad, with freshwater. While the plant is only capable of providing enough freshwater to supply 7-10% of San Diego’s demand, it provided a good framework for how desalination looks in the US and how desalination can be used to supplement the needs of municipal centers, even if it does not totally supplement the cities freshwater needs. Problems with the Carlsbad plant were that it took nearly 18 years to be completed and will not be at full capacity for another 20 years, showing that if seawater desalination is going to be considered then all efforts must be made for ensuring that the plant is built as quickly as possible and at full capacity as quickly as possible. In order to commit to the costs involved in seawater desalination, the California government must implement extensive and intensive freshwater conservation efforts so that costs of desalinated freshwater are minimized. The main conclusions that the research of seawater desalination in California
came to were that the costs of seawater desalination are currently high but decreasing every year as technology improves and as the infrastructure settles into place, that desalination alone will not be able to supply the entire State’s needs so conservation and recycling are essential to freshwater availability for the foreseeable future, and that the main benefit of seawater desalination is that it can act as a backstop with regions of unsustainable water use levels and will have difficulty in reaching sustainable water use levels. \(^{12}\) The combined capability of the proposed 17 desalination plants for the state of California should be capable of providing the urban areas of California with as much as 7% of their freshwater needs, showing the possibilities of seawater desalination but also revealing its limitations without the necessary conservation efforts. \(^{28}\)

3.4 Lessons to be Learned from Other Coastal Regions

The lessons to be learned are that seawater desalination efforts are rendered ineffective when conservation efforts are not simultaneously enforced, but as in the case of Israel, conservation alone is not always enough to produce sufficient amounts of freshwater, and as in Australia, resistance to, and weak efforts of, conservation are not enough to produce sufficient amounts of freshwater. Israel plans on becoming a major freshwater producer for the region and has been building the infrastructure necessary to do so but has hindered it’s efforts by not taking the proper steps needed to ensure conservation in enforced and the energy supplied to the desalination systems does not harm the environment. Australia’s West Coast was saved by the return of steady rainfall but it’s East Coast still suffers from reductions to rainfall and will depend on extensive seawater desalination and conservation efforts in order to supply the region with freshwater for the foreseeable future. If Georgia is going to create its own seawater desalination system, it is vital that these lessons are taken to heart, so that conservation efforts and environmentally conscientious techniques are utilized concurrently with the building of desalination infrastructure. Without the utilization of these methods, seawater desalination efforts will result in increased pollution which will put excess strain on municipal freshwater producers, damages to the ecology of the area which will result in economic loss in the long-term, as well as many other negative impacts. California showed that desalination can be used when a region has unsustainable water use rates but that the costs of
the effort are high, and that conservation and recycling will always need to be paired with desalination efforts.

**IV. The Proposed New Infrastructure for Georgia**

**4.1 Infrastructure Intent**

The desalination infrastructure needed to help Georgia avoid the problems caused by global climate change and population increases must take into consideration the lessons learned by previous desalination infrastructure built worldwide, because outside of brackish water desalination, seawater desalination is not done on a massive scale in many places inside the United States. 7, 15 The coastal Georgia desalination infrastructure built would need to provide both Savannah and Brunswick, as well as the rest of the smaller coastal Georgia towns, with enough desalinated water to ensure that the plant or plants for these cities could cover the freshwater demand in the event of an extended drought. It would also have to be designed so that any and all waste produced in the desalination process is safely collected and distributed to facilities capable of extracting minerals and elements from the waste and producing products from the remaining waste so that there is never an increase in pollution in any ecosystem in Georgia, which would result in economic loss, ecological damage, and detrimental health effects.

The type of desalination systems that should be built in Georgia in order to satisfy current and future demands can be picked based on previously published relevant data because other researchers have already considered the question as to which type of seawater desalination system would be best. The basic structure of a proper seawater and brackish water desalination system has been examined and the parameters of each potential type of system have been identified. 15, 29

**4.2 Design of the Freshwater Production Infrastructure – Seawater Desalination**

unit, [5] an energy recovery unit, in particular to the desires of this system regarding proper brine utilization, a [6] brine processing unit, and for the production of fertilizers and other useful biological byproducts, [7] a microalgae cultivation system, as shown in Figure 11. 23 If Georgia installed one or more high recovery seawater reverse osmosis [SWRO] desalination plants, one in or near Savannah or one in or near Brunswick, each with brine processing units, then the state could begin creating freshwater from seawater on a massive scale, while helping to compensate for the energy consumption needed to operate such a plant, especially if utilizing renewable energy sources.

Georgia would not be the first place to create such a plant. For example, by 2015, the Sorek SWRO plant in Israel was able to produce 624,000 cubic meters \(^3\), one cubic meter equaling approximately 1,000 liters, of freshwater a day from desalinated seawater. \(^3\,\text{,}27\) With Israel’s
population being roughly 8.5 million in 2019, having such a dense population, and having the most efficient SWRO desalination plants in the world \(^3\), it can be a great example of how the future Georgia SWRO desalination should be modeled. High Recovery SWRO systems, such as the Sorek plant, should be the desire of those who build the system, with efficiency being the factor of most concern. \(^{14, 15, 29}\) Optimization of the desalination system, similar to how Israel’s Sorek desalination system operates or a massive-volume hybrid plant, must be the goal for the engineers designing and building the infrastructure so that the maximum amount of freshwater is produced from desalinated seawater, and also so energy consumption is minimized. \(^{15, 23, 30}\)

4.3 Design of the Freshwater Production Infrastructure – Brackish Water Desalination

The installation of a SWRO system should be done with the intention of dealing with saltwater intrusion into the Upper Floridian Aquifer, as well as the production of freshwater for immediate use. In order to better prevent saltwater intrusion into the UF aquifer, it is necessary to expand the proposed seawater desalination and distribution system to include infrastructure specifically for the improvement and recharging of the UF aquifer around the Brunswick and Savannah areas. \(^{23, 30}\) This would include the utilization of Integrated Fresh-Keeper [IFK] wells, along with High Recovery [HR] Brackish Water Reverse Osmosis [BWRO] systems. \(^{19, 22}\) South Carolina and Florida already have BWRO systems in place so the infrastructure would not be unique locally. \(^{30}\) While any new IFK wells would be a more locally implemented solution based on each counties willingness to implement ordinances, the HR-BWRO system could be included in either Brunswick or Savannah’s SWRO desalination infrastructure, and the other city’s existing freshwater production system. \(^{12, 22, 23, 30}\) The added HR-BWRO system could utilize the lower energetic demand and easier process of brackish water desalination, with minimal brine production, and pump the newly desalinated brackish water directly into the UF aquifer itself, diluting the saltwater contaminated aquifer water and helping reduce overall contamination. \(^{22}\) The HR-BWRO system would also be able to help reduce bacterial and microbial growth in the aquifer through filtration and disinfectant processes. \(^{22, 31}\) If the strain and contamination of the UF aquifer can be alleviated with controlled freshwater augmentation directly into the aquifer itself, then any increases in population and consumption from the aquifer would be alleviated and pressure on local coastal
freshwater producers would be controlled. This would mean that the construction of new wells would no longer be such a damaging influence. So long as further local measures are taken to prevent saltwater intrusion, the HR-BWRO system should be effective in reducing UF aquifer contamination and augmenting enough freshwater to supply the populations of coastal Georgia so that saltwater intrusion into the UF aquifer is no longer an issue. If a HR-BWRO desalination system was included in any new SWRO desalination plant, then it could be integrated into a multi-functional system capable of producing freshwater from both brackish water and seawater for each municipality for whatever needs that area of the State might have.

4.4 Design of the Brine Extraction and Harvesting Infrastructure

Perhaps the biggest issue with continuous desalination operations would be the production, control, and removal of brine waste. It would be essential that brine produced in the desalination process never makes its way back into the waters of Georgia, especially off the coast. Saudi Arabia has lost most of its commercial fishing industry due to the dumping of seawater brine back into its nearby offshore waters. This dumping has increased the salinity of the waters around Saudi Arabia and destroyed the previously active and healthy ecosystem. These actions have also made the local seawater desalination process more difficult because the high salt content of the seawater extracted requires more processing to be viable than normal seawater. Georgia has a very profitable and active fishing industry which cannot be made to suffer due to irresponsible offshore brine disposal. It is for this reason that the brine produced in seawater desalination should be utilized to the fullest and kept from all water resources.

Seawater contains many valuable minerals and elements which are not readily available in Georgia. Even the minerals and elements that are available on land in Georgia that can also be found in the brine usually require destructive and environmentally damaging actions in order to extract them. It is for these reasons that the brine produced in seawater desalination should be looked at as a serious source of profit for the state. The act of extracting minerals and elements from the brine would be a major enterprise which would require further processing infrastructure and create jobs in the extraction, distribution, and sales processes. Figure 12 provides examples of what the expected extracted minerals and
elements would be used for. While this would also be a large endeavor, the money-making potential once the infrastructure is in place could be immeasurable and potentially last indefinitely. The opportunity to create products such as “saltcrete”, and to extract chlorine, sodium, magnesium, sulfur, calcium, potassium, bromine, carbon, strontium, boron, uranium, other valuable metals, and especially lithium from the byproduct of a process necessary for keeping Georgia productive and healthy is too good to pass up. 32

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Major uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na [NaCl, Na₂CO₃, Na₂SO₄]</td>
<td>Food, glass, soap, detergent, textiles, pulp and paper industries, road de-icing</td>
</tr>
<tr>
<td>Mg (MgSO₄, MgCO₃)</td>
<td>Al, steel, chemical and construction industries, fertiliser, soil amendment, construction industries, fertiliser</td>
</tr>
<tr>
<td>Ca (CaCO₃, CaSO₄)</td>
<td>Fertiliser, fire retardant, agriculture, well-drilling fluids, petroleum additives</td>
</tr>
<tr>
<td>K (KCl, K₂SO₄)</td>
<td>Glass products, soap and detergents, fire retardants, fertiliser</td>
</tr>
<tr>
<td>Br</td>
<td>Ceramics, glass and pyrotechnics industries, ceramic ferrite magnets, fireworks, phosphorescent pigments, fluorescent lights, oil and gas industry as drilling mud batteries, glass manufacturing, lubricants and greases, pharmaceutical products</td>
</tr>
<tr>
<td>Li</td>
<td>Fibre optics, lamps, night vision devices, laser technology</td>
</tr>
<tr>
<td>Rb</td>
<td>Nuclear fuel in nuclear power reactor</td>
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<td>U</td>
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</table>

Though using only reverse osmosis desalination would produce less waste brine than the traditionally used multistage flash [MSF] or distillation-based desalination systems 23, 32, brine is still produced during the RO process and it is not acceptable for any amount of brine to be disposed of in the environment. In dryer regions, evaporation from solar radiation is an acceptable way to drain the brine of moisture 13, 23, but this may not always be the case for the state of Georgia unless there is a drought occurring.

The process of mechanically extracting minerals and elements involves filtering, drying, grounding, and sieving the brine. 13, 23, 32 A vacuum pan system can be used to remove moisture from wet brine, as well as ion exchange membrane electrodialysis, which is especially useful for the extraction of crystal salt, sodium sulfate, hypochlorite, sodium bicarbonate. 13, 23, 32 From the diluted brine, potassium salts and magnesium salts can be extracted. Chlorine can be recovered from brine with the process of electrolysis, or a modified electrolytic process. 13, 24, 32 Bromine can be recovered from chlorinated brine by steam distillation where the halogen-containing vapor is condensed, with the bromine separated by gravity. 13, 24, 32 Pure sodium is extracted through electrolysis of fused sodium chloride of sodium salts. 13, 24, 32 Magnesium is recovered from magnesium chloride obtained from the brine via the Dow Chemical Process, which also allows for calcium recovery from gypsum. 13, 24, 32 Potassium can be recovered
through a three-step process; caustic soda refining, potassium concentrating, and potassium recovery.\textsuperscript{13, 24, 32} The dipicrolylamine method is the most feasible process for the recovery of potassium. Lithium has perhaps the biggest potential for all extractable metals because of its abundancy in seawater and high potential for profitability.\textsuperscript{13, 24, 32} The process for Lithium recovery and purification is already well documented and is shown in Figure 13 below.

![Figure 13. Selective Recovery and Purification of Lithium from Seawater.](image)

In addition to Lithium, valuable metals, such as gold, are able to be recovered when activated carbon is added to the calcium chloride processing method.\textsuperscript{13, 24, 32} For rare elements such as uranium, it is suggested that uranium recovery plants be installed alongside the desalination plants themselves due to the volume of seawater required for profitable extraction.\textsuperscript{23, 32} Uranium recovery requires ion exchanging methods such as titanium hydroxide, galena, activated coal, and zeolite ultramarine.\textsuperscript{23, 32} It has been estimated that the uranium available in seawater is enough to fulfil the global demand for more than 13,000 years, making uranium extraction a source of potential profit.\textsuperscript{23} While separate infrastructure for mineral and element extraction would be necessary for recovery of valuable substances, uranium processing plants
would need to be installed adjacent to any desalination system plants so that this resource could be extracted properly, and the levels extracted are enough to be sold for a profit. All of the extractable minerals and elements have many uses and can usually be extracted in a number of ways, including membrane distillation and crystallization [MDC], shown in Figure 14, electrodialysis [ED], shown in Figure 15, as well as the adsorption/desorption process.

Figure 14. Schematic Flow Sheet for Membrane Distillation and Crystallization [MDC].

Figure 15. Schematic Flow Sheet for Electrodialysis [ED] for the Recovery of NaCl, Br₂, and Mg(OH)₂ from Seawater.
The processes for harvesting a large variety of minerals and elements are already well known through previous research, as shown in Figure 16, and utilizing these processes in future SWRO/BWRO infrastructure would prove helpful in preventing waste brine from accumulating and contaminating freshwater resources.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Source/type of study</th>
<th>Mining method</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>Seawater</td>
<td>Solar evaporative ponds</td>
</tr>
<tr>
<td></td>
<td>Seawater BO brine (field study)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Simulated synthetic BO concentrate (laboratory study)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Artificial NF retentate solution (laboratory study)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seawater BO brine (laboratory study)</td>
<td></td>
</tr>
<tr>
<td>MgSO₄</td>
<td>Artificial BO brine (laboratory study)</td>
<td></td>
</tr>
<tr>
<td>MgCO₃·5H₂O</td>
<td>Sea water BO concentrate (pilot plant study)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Artificial NF retentate solution (laboratory study)</td>
<td></td>
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<tr>
<td></td>
<td>Seawater BO retentate (laboratory study)</td>
<td></td>
</tr>
<tr>
<td>Mg₂(NH₄)₂SO₄</td>
<td>Simulated synthetic BO concentrate (laboratory study)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Artificial NF retentate solution (laboratory study)</td>
<td></td>
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</tbody>
</table>

- **Figure 16.** Harvestable Minerals and Elements from Brine Produced from Desalination, and How They Are Harvested. 23, 32

Forrest Strickland 2019
The brine processing units of the proposed SWRO desalination plant should be able to conduct all of these processes, so that brine produced in the desalination process is collected and taken care of in the most profitable and environmentally sound way possible. Another benefit of harvesting the brine to such an extent is that such a system would allow for the realization of the highly desired zero-liquid discharge [ZLD] of any wastewater, and would negate any negative impact that would have occurred from the improper release of the brine into any Georgia ecosystem.22,23

4.5 Augmenting Georgia’s Water Supply

While one or even two plants off the Georgia coast would not be able to supply Georgia with enough freshwater to completely supply the state, one plant could be utilized in other ways such as filling existing and new reservoirs during periods of normal rainfall, a condition that places such as Western Australia and Israel do not have the benefit of experiencing. If more freshwater was needed to be produced for other parts of the State, then Georgia would only need to build new SWRO desalination plants based on the already available models, add them into the existing infrastructure, and build a reasonable distribution network, making meeting any freshwater demands for the entire State simpler than it would be if no infrastructure existed. Making the decision to build this proposed SWRO and BWRO desalination and distribution system is going to come down to planning and costs, so ensuring that proper planning is done and that costs are minimized, including showing the potential for long-term profit and sustainability, is necessary to explain the systems feasibility to those who would have to approve of the funding to build this infrastructure. If the infrastructure proposed is built following the included criteria of this paper, and the SWRO plant is designed particularly from information included in the Diallo et al. article from 2015, and based on Israel’s Sorek SWRO plant but including ways to minimize pollution from the processes, then there should be no reasonable objection to the building of this system.

The urban areas of Savannah and Brunswick have populations of 387,543 and 118,119, respectively, according to the U.S. Census Bureau in 2018. Assuming a daily water use of 113 gallons of water a day, based on Cobb county’s water-usage rate 9, then each city would require 43,792,359 gallons in Savannah and 13,347,447 gallons in Brunswick, in total. If the SWRO
A desalination plant desired to be built on the Georgia coast is modeled on either the Sorek plant in Israel, capable of producing 624,000 cubic meters of freshwater a day, which is 624 million liters or 164,843,361 US liquid gallons, or the alternate hybrid Shuaiba 3 plant in Saudi Arabia, producing 1.282 million cubic meters of freshwater a day as of 2019, then the facility could potentially provide more than enough freshwater to take care of the entire region’s needs. This level of expected freshwater production would make the need for more than one SWRO plant, based on the Sorek model, exclusively for the production of freshwater to supply the coastal Georgia region unnecessary, unless other uses for this water are found, such as pumping the water to new and existing reservoirs around southern and central Georgia, and refilling local aquifers. If the proposed SWRO facility is capable of producing the desired minimum 624,000 cubic meters of freshwater a day, then there is a real possibility that the entire freshwater needs of the coastal region could be satisfied. Also, if done correctly, the amount of freshwater produced and then distributed to southern and central Georgia reservoirs could potentially help negate the effects of evaporation during a multiyear drought, with daily evaporation rates listed as high as 200 million gallons a day for Lake Lanier alone. Combined with the utilization of brackish water RO and brine harvesting, the entire system could have the ability to be environmentally sound and should be able to produce freshwater at the lowest cost possible so that operating costs are not a factor in the decision to build and operate such a system. This shows that the amount of freshwater produced by the proposed desalination plant should be more than enough to satisfy the goals set forth. Combined with further water conservation actions and technology installed across the state, as well as additional greywater recycling plants, then any excess desalinated freshwater produced could be used for a number of alternative purposes if the proper preparations are made. Storing the excess water in further inland reservoirs or selling it to water starved neighbors, for example, could prove beneficial to other regions and Georgia together.

Ensuring that droughts and other forms of freshwater loss do not impact the coastal Georgia is dependent on maintaining available freshwater levels in municipalities along the Georgia coast, ensuring that streamflow levels are maintained from rivers flowing down into the Georgia coast, preparing for freshwater loss by providing an alternative to normal
freshwater resources in the event that these are not available or are not at a level sufficient enough to supply the region with enough freshwater, and making sure that the local groundwater resources are not contaminated and are able to be regularly tapped for whatever purpose so that surface water resources are being entirely depended on to supply municipalities with freshwater. By preparing the coastal Georgia region for these events, it puts the region ahead of the future effects of freshwater loss while also providing options for other regions in the event that they experience their own freshwater loss and need to tap into shared freshwater resources. If it turns out that the state does not need the excess freshwater produced from desalination, then the plant could be placed on stand-by, similar to the SEQ region of Australia so that when drought condition reappear, as they can be expected to do for the foreseeable future, and the plant could be used as a safeguard against drought only when needed. While there are benefits to running the plant constantly and pumping new produced freshwater inland to reservoirs, the cost may not prove practical so leaving the plant on stand-by may be the better option depending on the severity and length of a drought, as well as the freshwater needs and urgency of those needs by municipalities away from the Georgia coast.

V. Discussion & Conclusion

5.1 Discussion

Georgia experiences droughts at somewhat regular intervals according to data gathered in the past. However, recent data suggests that drought periods may become more frequent than previously thought and that global climate change has caused previous climate models to become inaccurate. In the past, drought has dramatically reshaped the demographics of the state and it is entirely possible that this could happen again if another extended drought were to occur. Not only are droughts occurring more frequently, but the intensity of droughts is expected to increase due to global climate change. The intensity of future droughts could result in devastating effects on the State of Georgia which could have long-term effects on the economy and ecology of the State.
Recently, drought has greatly impacted the state and was only reduced in severity by extreme conservation methods, changes in water use laws for a period of time, and the taking of freshwater allocated to other States for Georgia’s immediate use resulting in millions of dollars’ worth of ongoing litigation. These actions prevented catastrophe, but nothing prevented further catastrophe more than the return of normal rainfall levels, something that the State has no control over.

With global climate change altering the normal weather patterns that the State could rely on in the past, the State came extremely close, within 35 days actually, of losing all of the water in Lake Lanier, the primary source of freshwater for the entire Atlanta metropolitan area. Global climate change is expected to do two different things regarding freshwater in Georgia. It is expected to both increase the severity and intensity of rainfall during times when rain is occurring and increase the severity and length of periods of drought when they occur as well. This puts Georgia in the awkward position of not knowing which weather pattern will occur and for how long. Combined with the ongoing litigation regarding freshwater allocation between Georgia, Alabama, and Florida, the current freshwater resources available to the Atlanta metropolitan area may not be the same in the future, meaning other resources, such as the other minority freshwater resources supplying Atlanta, including the Savannah River, may have to be tapped in order to supply the areas thirst for water. Any increases in consumption and extraction from the freshwater resources that flow into the coastal Georgia region will have detrimental effects, as mentioned previously. It is therefore imperative that the coastal Georgia region prepare for this potential situation by taking the measures mentioned in this paper; building a seawater desalination plant likely based on Israel’s Sorek SWRO plant capable of providing freshwater to all the cities along the Georgia coast, installing brackish water reverse osmosis [BWRO] desalination infrastructure in Savannah and Brunswick so that the cities don’t end up over tapping the Upper Floridian Aquifer causing contamination which would potentially ruin this vulnerable freshwater resource, and installing brine harvesting and extraction processes into the SWRO and BWRO systems so that the highly toxic and environmentally harmful brine produced during desalination never makes its way back into the
Georgia ecosystem due to the detrimental environmental and economic impact that would have on the State.

While the proposed infrastructure would help solve many problems, none of it will be worth it without water conservation efforts implemented State-wide. Without conservation efforts, the annual household water consumption rates can be expected to slowly increase, meaning that population increases combined with household increases would result in exponentially more water being taken from freshwater resources around the state. Efforts such as more greywater recycling plants being built, increased use of technology to reduce household water consumption, and laws preventing excessive water use all have to be implemented regardless of any new infrastructure built to provide a new source of freshwater.

With new infrastructure capable of producing freshwater, cleanly, combined with conservation methods, alternative uses for the newly produced freshwater can be considered. The expansion of and building of new reservoirs around the state could be supplemented by the excess water produced in the desalination process, as long as the cost of distributing the freshwater to the reservoirs is not too costly compared to the need. Excess freshwater could also be sold to neighboring States in the event that they themselves are experiencing droughts and other types of freshwater loss. Where aquifer contamination is an issue, the pumping of excess freshwater directly into the aquifer could be considered as a way to dilute contamination and allow for additional groundwater allocation where needed. The excess water produced during desalination could be used across the State for so many purposes, it would just be a matter of creativity and a willingness to invest in the distribution infrastructure for this excess freshwater to be put to good use, otherwise the SWRO facilities would likely just be placed on stand-by, only to be used when droughts occur. The issue with using the SWRO facilities only in the event of droughts is that this is a reactionary response and not a preparatory or proactive response. Utilizing brine harvesting processes could help offset the costs of continuously running SWRO facilities year-round depending on the amount of money made from the sale of harvested elements and minerals found in the brine.
5.2 Conclusion

The question is then, “is all of this effort worth it?” Considering the cost Georgia had to pay for the consequences of the 2004-2009 drought, $1.3 billion in economic damage in 2007 alone, combined with how much increased salinity and contamination in freshwater resources affects the coastal Georgia ecosystem and economy, and the overall dangers of freshwater loss seen world-wide, it is argued here that all of this effort is absolutely worth it. If the State of Georgia does not start preparing for droughts in a more proactive manner, then the State will suffer greatly from this inaction and be dependent on the unpredictable return to normal weather that global climate change has made unreliable. It is argued here that the investment in desalination infrastructure, distribution, and its complimentary processes is not as much of an option as it is a necessity for the future of the State. Any further opposition to the construction of desalination infrastructure need only look and the results of inaction world-wide in order to see the consequences of inaction or delay in action regarding finding new sources of freshwater.
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