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# RO & NF MEMBRANE APPLICATIONS IN THE SOUTHEASTERN USA

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## Introduction

The intent of this paper will be to review a broad Spectrum of reverse osmosis and nano-filtration membrane plants located in the Five Southeastern United States. These States include plants located in Virginia, North Carolina, South Carolina, Georgia, and Florida. The plants selected will address both inland and coastal designed facilities as well as various plants using nano-filtration membranes, brackish water membranes and low pressure energy efficient membrane processes. Discussions for each plant selected will include plant location, water supply source, and selection of membrane type, projected operating pressures; permeate water quality projected, operating temperature, and projected power costs for the generic type of membrane used.

Various water supplies sources will be reviewed including brackish well water sources, surface water sources, barrier island well water sources, and water supplies from both the Biscayne and Floridan Aquifers will be evaluated. Discussions will include operational experience of the plant design to avoid scaling and fouling as well as dealing with high organic laden well waters and limiting the organic fouling potential.

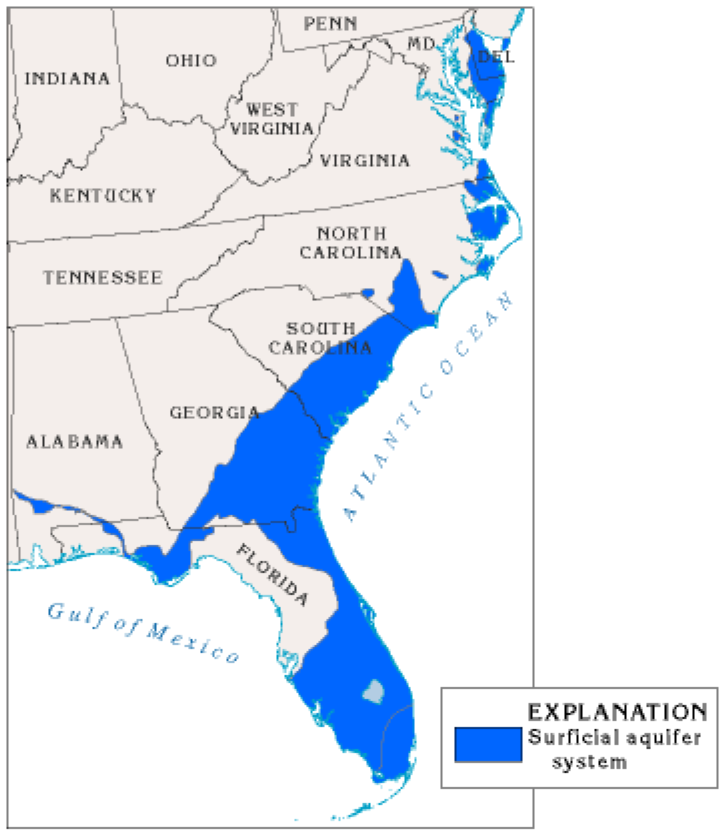
System design configurations will include both 6 and 7 element long pressure vessels and systems incorporating both energy recovery devices as well as inter-stage booster pumping designs. Special attention will be given to plants that required advanced design considerations that utilized both Hybrid Design arrangements as well as Double-Hybrid Design arrangements. These types of plant designs are becoming State-of-Art design configurations. Understanding the need for these types of designs and the acceptance of these designs as well as understanding of the benefit of these types of designs can improve the thinking and artistic consideration on future membrane facilities.

One of the goals of the presentation will be to promote artistic design ideas to the audience for use and consideration in the design of future membrane treatment facilities. This will both optimize the design for the plants in the pipeline and allow some flexibility in the selection of the specific membrane for each specific application and water quality target design parameters. The use of different types of membranes in any specific system design can improve the over-all operational efficiency and improve the ability to meet specific targeted goals to allow maximum operational efficiency and maximum blending flexibility.

The membrane facilities selected will range in plant capacity from approximately 500,000 gallons per day to over 40 million gallons per day. Further discussions herein will provide the audience with a wide range view of plant design considerations and offer a solid overview of the Southeastern USA operating membrane facilities. Offering the readers an overview of historical designs can and will improve the design of future membrane facilities. The writer hopes to help offer understanding to new plant engineers and facilitate out of the box thinking for future reverse osmosis and nano-filtration plant designs.

## Five Southeastern States (1)

Membranes systems located with-in the five southeastern States including Virginia, North Carolina, South Carolina, Georgia, and Florida will be discussed here-in. The main Surficial Aquifer System runs from Southern Florida through to North Carolina and up as far as the Delmarva Peninsula.




The Surficial aquifer system extends throughout large areas in the Coastal Plain of Florida, Georgia and South Carolina. The Surficial aquifer is the uppermost aquifer in the Northern Atlantic Coastal Plains aquifer system. The surficial aquifer extends over large parts of the Delmarva Penninsula and the eastern coastal plain of North Carolina.

(1) Courtesy of the USGS

## Plant Selection Criteria

Consideration was given to over one hundred plants located through-out the Southeastern United States. In order to attain a broad spectrum of locations, types of feed water sources, membrane types, and system configurations, we selected plants that both are under the final design stage, in the final start up stage, and also some that are in operational for many years with historical operational data.

Plants from **Virginia** use both surface water and well waters and include both brackish and low pressure membranes. They utilize designs that incorporate single element as well as Hybrid arrangements for specific flux balance.

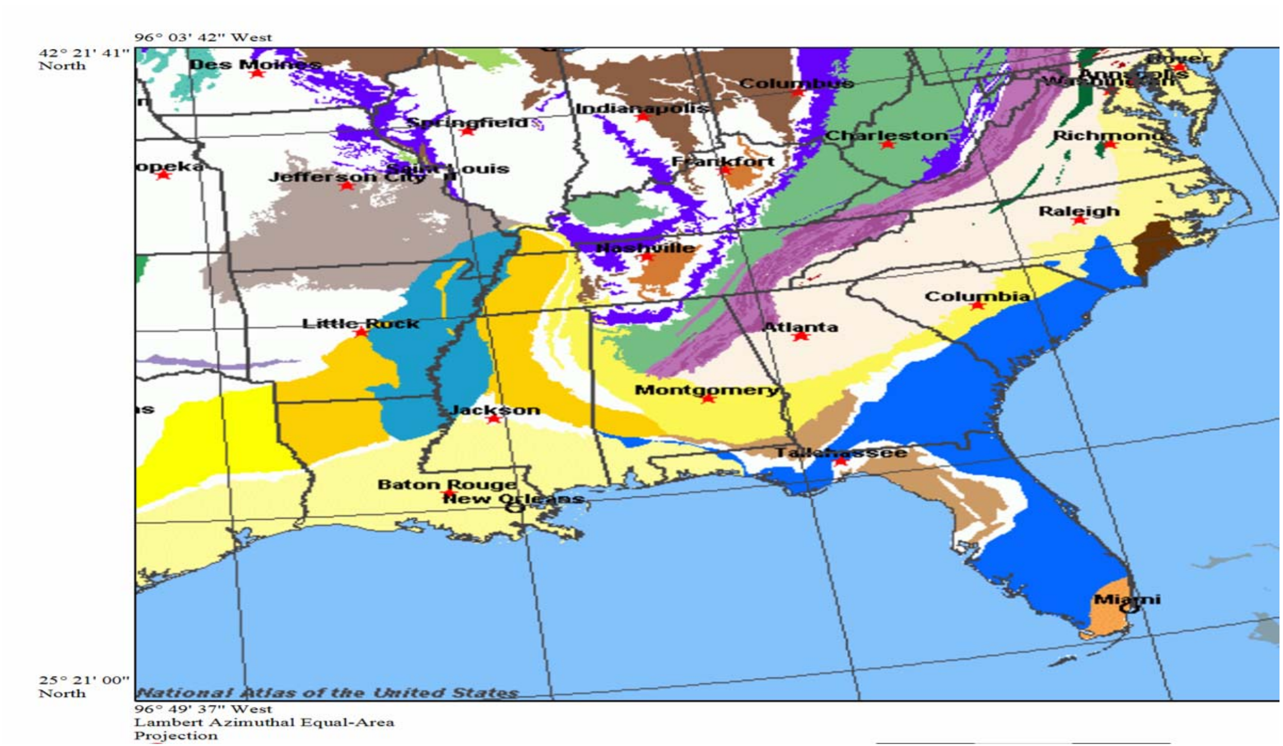
Plants from **North Carolina** operate on barrier island well supplies as well as coastal well water sources. These plants use both highly brackish water membranes as well as low pressure membranes. Also discussed will be future nano-filtration plants currently under construction.

Plants from **South Carolina** operate with the use of low pressure membranes arranged in a Hybrid design as well as high pressure brackish water membranes operating on a higher salinity well water supply.

The plant from **Georgia** operates on a unique Hybrid design using a nano-filtration membrane in the first stage and an ultra-low pressure reverse osmosis membrane in the second stage. This design optimized the power usage on the over all system design.

The plants from **Florida** operate on both the Biscayne Aquifer and the Floridan Aquifer. Discussions will pertain to both brackish water supplies using high pressure brackish water membranes, hybrid designs using low pressure brackish water membranes, straight nano-filtration membranes facilities, and plants operating in double hybrid design arrangements that utilize two different types of membranes in the second stage. Specific permeate quality ranges were able to be met and maintained with unique design considerations that can be used for future plant considerations.

## Ground Water Aquifer System (2)




(2) Courtesy of National Atlas of the United States

The Southeastern United States ground water supply is fed mainly by the most productive aquifer in the World. This aquifer is known as the Floridan Aquifer. This aquifer system underlies an area of about 100,000 square miles in southern Alabama, southeastern Georgia, southern South Carolina, and mostly all of Florida. The Floridan is a multiple-use aquifer system. Where is contains freshwater, it is the principle source of water supply. In several places where the aquifer contains saltwater, such as along the southeastern coast of Florida, higher pressure membranes are required to convert the higher saline supply to fresh drinking water. Most of the municipal fed water systems in Florida draw water from the Upper Floridan aquifer due to its high porosity. The Lower Floridan aquifer is generally higher in salinity level and is mainly used as a receiving zone for industrial and municipal waste disposal through injection wells. The re-charging of the aquifer from membrane reject discharge is becoming the only option for new system designs. This brackish water aquifer is treated with both high and low pressure brackish water reverse osmosis membranes.

The Floridan Aquifer is directly above the Southeastern Coastal Plain aquifer located in southern Georgia. These two aquifers systems are in direct contact, and ground water passes freely between them. The permeability of the Southern Coastal Plain aquifer is much less than the Floridan aquifer due to the substantial inter-granular porosity of the Floridan aquifer.

The Biscayne aquifer is located strictly in South Florida in parts of Dade, Broward and Palm Beach Counties only. This aquifer underlies an area of approximately 4,000 square miles and is a highly permeable aquifer. The Biscayne aquifer consists mainly of limestone and less-permeable sandstone and sand. The water from the Biscayne aquifer is mainly high in calcium and magnesium hardness with low sodium and chloride levels. The total dissolved solids from the Biscayne aquifer is generally between 400-800 ppm. The drawback to the use of Biscayne water is the high levels of iron and higher levels of organic matter. The benefit of using Biscayne water is the lower feed pressure requirements for the system operation and therefore a more cost effective water source. The development of low fouling and fouling resistant nano-filtration membranes makes the operation of producing potable water from the Biscayne aquifer very cost effective. In some instances ultra-low pressure reverse osmosis membranes in conjunction with nano-filtration membranes can produce a viable and cost effective method of meeting State Drinking Water limits for iron and hardness levels simultaneously.

## Reverse Osmosis Plants In The State of Virginia

The State of Virginia has predominately used surface water supplies for Municipal Drinking Water applications. The reservoir system and surface water availability provides for most of the Municipal drinking water in Virginia. Most recently new plants are coming on-line to meet surface water treatment rules and to supplement growing needs to find available fresh water supplies by utilizing brackish well waters. These membrane facilities will supplement the existing surface water plants and provide a reliable source of high quality drinking water. Plants in Virginia operate on both well water supplies and surface water supplies. Generally brackish water membranes have been used in this area of the country due to the higher dissolved solids levels required to be treated. Typical well water supplies in Virginia contain dissolved solids levels in the 2500 to 3000 ppm range. Surface water supplies in the Chesapeake area have operated on higher salinity feed supplies between 8,000 and 10,000 ppm total dissolved solids. This is made up primarily of sodium chloride ions and low in total hardness. The operational costs for this type feed water source could almost double that of the more cost effective low TDS well water supplies. Most recently James City County Services was brought on line operating on a feed water source containing approximately 3000 ppm total dissolved solids level. Some of the older plants that have been in operation for 5-10 years include Chesapeake Virginia, Gloucester County and Newport News Water Works.

The Gloucester County plant operates in a 16 by 8 array using 7 element pressure vessels. This plant utilizes a high brackish water membrane in the 1st stage followed by a low pressure energy saving membrane in the 2nd stage. This unique design allows the use of the energy savings membrane in the 2nd stage that provides for flux balancing without the need for inter-stage boosting. The feed water design basis for this plant was in the range of 2400-2500 ppm TDS range. The use of the 7 element long pressure vessels and operation at 80% recovery provides for good cross flow velocity and therefore low beta values. The high cross flow velocity will reduce the potential for membrane fouling over time. The permeate water quality from this 1.0 Million Gallon per day facility will be less than 100 ppm TDS.

| STATE OF VIRGINIA MEMBRANE FACILITIES | | | | | |
|---|---|---|---|---|---|
| | WATER SOURCE | FEED TDS | MEMBRANE TYPE | EST POWER* | PERMEATE QUALITY |
| GLOUCESTER COUNTY | WELL-INLAND | 2300 | BRACKISH/LOW PRESSURE | 2 KWH | LESS THAN 100 PPM |
| NEWPORT NEWS WATER WORKS | WELL/SURFACE | 2500 | BRACKISH | 2 KWH | 100 PPM |
| JAMES CITY COUNTY SERVICES | WELL-INLAND | 3000 | BRACKISH | 2 KWH | LESS THAN 100 PPM |
| CITY OFCHESAPEAKE | SURFACE | 8250 | LOW PRESSURE | 6 KWH | LESS THAN 500 PPM |
| *AT YEAR ZERO OPERATION ASSUMING TYPICAL PUMP EFFICIENCIES | | | | | |

## Reverse Osmosis And Nano-Filtration Plants In The State Of North Carolina

The State of North Carolina has a diversification of water supplies for Municipal Drinking Water sources. The Outer Banks of North Carolina has been using reverse osmosis membrane based systems for over 10 years. The sole source of drinking water for this barrier island is from well waters that are high in dissolved solids levels. As you can see from the Aquifer Map, the entire island is surrounded by water and the Cape Hatteras location is situated a significant distance from the mainland of North Carolina. This plant is being fed with very high sodium chloride levels from seawater intrusion, and uses a high pressure brackish water membrane. Therefore the operating pressure for this plant will be significantly higher than pressures from plants operating closer to the mainland or on the Mainland of North Carolina. The feed water from the original design of this facility was in the 11,000-12,000 ppm TDS range.

The Kill Devil Hills Plant which is one of the oldest of the plants on the Outer Banks is operating on feed water with a TDS in the 4500-8000 ppm range. Kill Devil Hills uses a typical brackish water membrane, and therefore the feed water pressure for this plant will be significantly less than that of the Cape Hatteras Facility.

Closer to the Mainland of North Carolina is the Currituck County Facility. This plant was built back in 2003 and is designed to operate on a feed water supply in the 8000 ppm TDS range. The use of brackish water membranes along with inter-stage booster pumps helps balance the flux in this high TDS feed water plant.

Moving down the coast of North Carolina are the most recent nano-filtrations applications. The City of Jacksonville North Carolina plant employs a low pressure nano-filtration process for producing potable water from the Castle Haynes Aquifer. This aquifer has a TDS level of approximately 500 ppm–800 ppm and contains a high level of organics.

New Hanover County North Carolina will also be a nano-filtration plant operating on the Pee Dee Aquifer and the Castle Haynes Aquifer. The Pee Dee Aquifer is high in color, total hardness and organics. The Castle Haynes Aquifer has high level of iron as well. This plant can utilize an ultra-low low pressure reverse osmosis membrane or a low pressure nano-filtration membrane and will operate at approximately 80% recovery.

The State of North Carolina has employed a spectrum of membrane types and designs. They operate from recoveries of 50% up to 85% and utilize feed water dissolved solids levels from 400 ppm to 12,000 ppm. Membranes selections vary from high pressure brackish, to brackish, to low pressure reverse osmosis and nano-filtration membrane technologies.

**STATE OF NORTH CAROLINA MEMBRANE FACILITIES**

| | WATER SOURCE | FEED TDS | MEMBRANE TYPE | EST POWER* | PERMEATE QUALITY |
|---|---|---|---|---|---|
| CAPE HATTERAS | WELL-BARRIER ISLAND | 12000 | BRACKISH HIGHPRESSURE | 4 KWH ** | 250-300 PPM |
| KILL DEVIL HILLS | WELL-BARRIER ISLAND | 6000 | BRACKISH | 2.5 KWH | 200-300 PPM |
| CURRITUCK | WELL | 8000 | BRACKISH | 3 KWH | 200 PPM |
| JACKSONVILLE | WELL-INLAND | 700 | NANO-FILTRATION | 1 KWH | 150-200 PPM |
| NEW HANOVER COUNTY | WELL-INLAND | 500 | NANO-FILTRATION | 1 KWH | 50 -100 PPM |
| *AT YEAR ZERO OPERATION ASSUMING TYPICAL PUMP EFFICIENCIES | | | | | |
| ** 50% RECOVERY | | | | | |

## Reverse Osmosis Plants in South Carolina

The State of South Carolina has membrane facilities dating back to pre-1990. Mount Pleasant Waterworks was one of the Pioneers into the membrane arena in the State. Being a coastal community and drawing water from the Middendorf Aquifer which is located below the Floridan Aquifer and at a level of between 1800-2000 ft deep. The water source has a TDS level in 1500- 1600 ppm range. The Aquifer also has a high Ph and alkalinity level and has a beneficial amount of Fluorides. The well water from this Aquifer is very warm. It averages approximately 98 degrees prior to reaching the surface. Due to the high operating temperature the power costs for the reverse osmosis system is reduced. The system employs a highly efficient 2-stage Hybrid design using a low pressure membrane in the 1$^{st}$ stage followed by a high flow lower rejecting membrane in the 2$^{nd}$ stage. The design operates at a recovery of 80% with the utilization of 7 element long pressure vessels. The permeate TDS averages between 200-250 ppm and some blending is utilized to maintain a less aggressive water supply through-out the distribution system. Mt Pleasant Waterworks supplements the reverse osmosis treated water with surface water supplied from The Charleston Water System.

South Island Public Service District also uses low pressure brackish water membranes on a feed water source which has an extremely high geothermal operating temperature. Cooling of the feed water prior to reverse osmosis system is required to prevent membrane damage.

The Upper Floridan Aquifer is the current source for about half of the water supplied to Hilton Head Island. Salt water intrusion into the Aquifer at various wells on the island have caused the district to abandon there use. At least 4 wells have experienced 350% increase in salt levels since the year 2000. The district will employ the use of a new reverse osmosis system being fed from the 600 ft deep Middle Floridan Aquifer starting sometime in 2008. This system will use a brackish water membrane to provide over 3 Million Gallons per day of purified drinking water to the district.

The Hilton Head area will continue to experience the loss of ground water supplies due to the high rate of pumping occurring from the Floridan Aquifer. Alternative economical water sources are not available and therefore without management of the usage from the existing aquifers the only alternative water source will eventually become the Atlantic Ocean. Seawater desalination will be the only option in the future without implementation of water management and re-use.

| STATE OF SOUTH CAROLINA MEMBRANE FACILITIES | | | | | |
|---|---|---|---|---|---|
| | WATER SOURCE | FEED TDS | MEMBRANE TYPE | EST POWER* | PERMEATE QUALITY |
| MT PLEASANT | WELL-COASTAL | 1500 | LOW PRESSURE/HYBRID | 1.5 KWH | 200-250 TDS |
| HILTON HEAD ISLAND | WELL-COASTAL | 8000 | BRACKISH | 4 KWH | 250-500 TDS |
| *AT YEAR ZERO OPERATION ASSUMING TYPICAL PUMP EFFICIENCIES | | | | | |

## Reverse Osmosis Plants In Georgia

The State of Georgia has predominately used available surface water for potable water purposes. Most recently the drought stricken state is looking for ways to improve the reliability for a continuous supply of safe drinking water. Consideration for seawater desalination as well as water re-use with various filtration technologies have been discussed.

The State of Georgia has limited use of reverse osmosis systems for potable drinking water applications. In 2001 Moody Air force Base installed a nano-filtration system operating on 3 ground water well supplies. The well water is low in TDS of approximately 250 ppm but has a high level of organics. The system is designed with a nano-filtration membrane in the 1$^{st}$ stage and an ultra-low pressure reverse osmosis membrane in the 2$^{nd}$ stage. The system operates at a recovery of 75% and produces 800,000 gallons per day of drinking water.

| STATE OF GEORGIA MEMBRANE FACILITIES | | | | | |
|---|---|---|---|---|---|
| | WATER SOURCE | FEED TDS | MEMBRANE TYPE | EST POWER* | PERMEATE QUALITY |
| MOODY AIRFORCE BASE | WELL- INLAND | 250 | NANO-FILTRATION ULTRA-LOW PRESSURE | LT 1 KWH | 100 PPM |
| *AT YEAR ZERO OPERATION ASSUMING TYPICAL PUMP EFFICIENCIES | | | | | |

# Reverse Osmosis and Nano-Filtration Plants in the State of Florida

The State of Florida has an abundant supply of membrane facilities to be considered. It was difficult to select which ones we should discuss in further detail. I have selected plants located through-out the State from North to South and plants that were unique in there own way. The plants will cover nano-filtration, ultra-low pressure reverse osmosis, low pressure reverse osmosis, and brackish water membrane applications.

Starting from the Northern part of Florida we have two new membrane facilities being constructed for St Augustine and Ormond Beach. Both of these facilities will utilize ultra-low pressure reverse osmosis membranes. The St Augustine facility will operate at 85% recovery in a 16 by 8 array utilizing 7 element pressure vessels. The plant is designed to treat a well supply in the 850 ppm -1000 ppm TDS range. This level of dissolved solids allows the plant to utilize the benefit of an ultra-low pressure RO membrane. The plant will produce a permeate containing les than 150 ppm TDS. The loose reverse osmosis membrane used for this application allows a minimum level of calcium hardness and alkalinity to pass through to the permeate. Two identical trains will operate in tandem producing 2 MGD of RO permeate water.

The Ormond Beach facility located just south from the St Augustine facility will employ the use of the same ultra-low pressure membrane. The membrane feed water TDS will be in the 600-700 ppm range and the plant will produce a permeate quality of less than 100 ppm TDS. In addition to energy savings, the benefit of the ultra-low pressure RO membrane for this facility is the fact that a minimum calcium level will be maintained. This plant will operate at 85% and utilize a 16 by 8 array will 7 elements per pressure vessel. Two identical trains will each produce 1 MGD of RO permeate water.

The City of Boca Raton operates on well water drawn from the Biscayne Aquifer. This Aquifer being highly contaminated with organics high in color and TOC, and rich in calcium hardness, requires the use of nano-filtration technology. This 40 MGD capacity facility is the Worlds Largest Nano-Filtration plant in the World. The system uses low-fouling nano-filtration membranes arranged in a 72 by 36 -2 stage array. Each pressure vessels contain 7 elements and operates at 85% recovery without the use of acid or anti-scalant. The goals of the plant were to produce a low level TOC while allowing a minimum amount of calcium hardness to pass to the permeate. The selection of the nano-filtration membrane required to produce a range of calcium hardness between 50-80 ppm as CACO3 was the challenge in the design.

The City of Deerfield Beach operates on a well source water drawn from the Biscayne Aquifer. The design basis for this plant also incorporated the need to reduce total dissolved iron from 1.5 ppm to less than 0.2 ppm, while producing a total hardness level between 26 and 82.5 ppm as CACO3. The plant also needed to reduce the TOC and, THMFP, and TAAFP to acceptable levels. The plant operates at an 85% recovery rate utilizing 7 element long pressure vessels arranged in a 48 by 24 2-stage array. This 10.5 MGD facility produces a total permeate with a TDS between 175-250 ppm. The permeability of the NF membrane employed at the Deerfield Beach facility is slightly lower (7500 GPD capacity) compared to the 7800 GPD capacity membrane used at the City of Boca Raton. Hence, the ability for the specific goals of the plant, with regard to iron reduction, to be met. The higher flow membrane used at Boca allows for a slightly lower net driving pressure.

The City of Pompano Beach has a similar water supply as the Deerfield Beach facility. Also drawing water from the Biscayne Aquifer, the supply is rich in organics and high in dissolved iron. The goal of the plant is to produce a drinking water quality containing a maximum iron level of 0.2 ppm while maintaining a calcium level between 8 and 33 ppm expressed as the ion. The system is comprised of 5 – 2 MGD trains arranged in a 36 by 16 2 – stage array with 7 element pressure vessels. The plant design is very unique in that it is a Double Hybrid-design. In order to achieve the specific water quality goals set out by the owner, extensive pilot testing was completed. The pilot testing utilized a number of configurations in order to develop the optimum design for the plant. That design was the one with the lowest operational cost that could still meet the maximum iron level of 0.2 ppm and contain enough calcium hardness for compatibility with the plant design. Therefore, the design needed sufficient rejection to maintain the maximum iron level and allow enough salt to pass in order maintain a minimum calcium level. By having a broad spectrum of membranes available it was possible to develop the optimum design by using a Double-Hybrid arrangement. The system will employ a nano-filtration membrane in the 1$^{st}$ stage with a flux capacity in the 8600 GPD range at a 92% rejection rate, with a combination of 2 different nano-filtration membranes in the 2$^{nd}$ stage. The 2$^{nd}$ stage will contain 5 membranes similar to the membranes in the 1$^{st}$ stage that will be followed by 2 looser nano-filtration membranes. These membranes will have a flux of approximately 10,500 GPD capacity at a slightly looser rejection rate of 86%. The combination of these membranes allows the system to maintain the iron level and at the same time meet the minimum calcium hardness levels at the lowest possible TMP.

The next facility to be discussed is the Highland Beach plant. This plant is located near the coast along A1A and therefore treats feed water with a much higher TDS. The well water ranges in total dissolved solids level between 7500 and 8000 ppm. Therefore, in order to treat this feed water source, a brackish water membrane was employed. The 3 train system is arranged in a 12 by 6 array with 7 element long pressure vessels operating as high as 80% recovery. Each train produces 750,000 gallons per day of permeate water. The use of a 400 ft2 brackish water membrane operates trouble free on a relatively clean feed water source. The design operating pressure on this highly saline feed water source is in the 400-450 psi range.

The City of Ft Lauderdale –Peele Dixie WTP is a 12 MGD facility with 4 trains producing 3 MGD capacity per train. The plant uses a low TDS well water supply ranging from 350-500 ppm but also contains a high TOC level in the 11 ppm range. The goals of the plant were very stringent and required extensive pilot testing to develop an optimum design configuration. The objectives of the plant were to produce a low iron permeate of less than 0.15 ppm and provide a minimum alkalinity level of 15 ppm as CACO3 while removing the hardness to a level of no greater than 30 ppm as CACO3. The system configuration is a 53 by 24 array with 7 element long pressure vessels. The design incorporates the use of an ultra-low pressure reverse osmosis membrane in the 1$^{st}$ stage followed by a 2$^{nd}$ stage containing 5 ultra-low pressure reverse osmosis membranes and 3 high flow low rejection nano-filtration membranes. This design known as a Double Hybrid-Design produces the clients required permeate water quality at a very low operating pressure. Pilot testing was required in order to develop a design basis and rejection criteria for each type of membrane employed. The position of each membrane in the over-system has an impact on the specific water quality that the train can produce. The artistic design used for this plant can be a model for future designs that require balancing of permeate water quality.

The final plant that we will be discussing will be the North Miami Beach, Norwood-Oeffler WTP. The 17 MGD facility combines nano-filtration treatment using Biscayne aquifer water along with a low pressure reverse osmosis system treating Floridan Aquifer water. The engineers took advantage of the unique location of this plant and the uses of both available Aquifers in a single plant design to develop the optimum permeate quality water at the most efficient operating pressure. Three 2 MGD reverse osmosis trains will operate at a recovery rate of 75% using a 36 by 18 2-stage 7 element vessel design. The plant will blend 0.5 MGD with the reverse osmosis permeate to provide 6.5 MGD total blended RO permeate. The RO trains are designed for future expansion to produce 2.5 MGD per train by adding pressure vessels to increase the array to a 44 by 22. The design for the RO system has been optimized by using a high rejecting low pressure membrane in the 1st stage and a higher flow lower rejecting membrane in the 2nd stage. This configuration, along with inter-stage boosting, provides for virtually perfect flux balancing. The three-3 MGD nano-filtration trains each operate at 80% recovery in a 2-stage 54 by 27 array using 7 element pressure vessels. The 9 MGD nano-filtration portion of the plant will be blended with 1.5 MGD of pre-treated Biscayne Aquifer water to provide a total of 10.5 MGD blended permeate water. This plant has been design for a future build out to a total capacity of 25 MGD. Including 5- 3 MGD nano-filtration trains, plus 2 MGD blend and 3- 2.5 MGD (expanded RO trains) 7.5 MGD reverse osmosis plus 0.5 MGD blend. At the time of this writing, the plant is currently in the process of loading membranes for the initial performance testing.

**STATE OF FLORIDA MEMBRANE FACILITIES**

| | WATER SOURCE | FEED TDS | MEMBRANE TYPE | EST POWER* | PERMEATE QUALITY |
|---|---|---|---|---|---|
| ST AUGUSTINE | WELL | 1000 | ULTRA-LOW PRESSURE | 1.5 KWH | LESS THAN 150PPM |
| ORMOND BEACH | WELL | 700 | ULTRA-LOW PRESSURE | 1.2 KWh | 100 PPM |
| BOCA RATON | WELL | 500 | NANO-FILTRATION | LT 1 KWH | LESS THAN 200 PPM |
| DEERFIELD BEACH | WELL | 500 | NANO-FILTRATION | 1 KWH | LESS THAN 250 PPM |
| POMPANO BEACH | WELL | 495 | NANO-FILTRATION | LT 1 KWH | LESS THAN 250 PPM |
| HIGHLAND BEACH | COASTAL WELL | 8000 | BRACKISH | 4.5 KWH | 200-300 |
| FT LAUDERDALE | WELL | 500 | LP-RO /NANO HYBRID | 1 KWH | LESS THAN 100 PPM |
| NORTH MIAMI BEACH-NANO | WELL | 400 | NANO-FILTRATION | LT 1 KWH | LESS THAN 100 PPM |
| NORTH MIAMI BEACH-RO | WELL | 4000 | LOW PRESSURE RO-HYBRID | 2.5 KWH | LESS THAN 200 PPM |

*AT YEAR ZERO OPERATION ASSUMING TYPICAL PUMP EFFICIENCIES

## Conclusion

In conclusion it is important to understand that while we have only barely touched on the number of existing and proposed membrane facilities in the Southeastern States we have discussed plants that utilize over 10 different types of nano-filtration and reveres osmosis membranes. Without having diversified available technology along with astute engineering and design firms it would be difficult to develop the most optimum solution for each individual site. Continued membrane Research and Development will provide a vital role in the development of future membrane faculties.