Florida Brackish Water and Seawater Desalination: Challenges and Opportunities

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Florida has historically been the pioneer in desalination in the United States. As a matter of necessity, it was one of the first states to embrace desalinated groundwater as a source of drinking water. Florida installed its first desalination facility in 1969, which was a small electrodialysis (ED) facility in Siesta Key. Today, Florida boasts more than 150 desalination facilities, with a combined capacity of more than 515 million gallons per day (mgd) and accounting for nearly 25 percent of Florida's total water supply (Figure 1).

From groundwater to seawater, no state has more operating desalination capacity. Florida accounts for more than 50 percent of the U.S. desalination market. There are several reasons for this. Much of the state has historically relied upon groundwater for public water supply. This is due not only to the widespread availability of groundwater resources, but also to the limited availability of reliable, fresh surface water. As the population of Florida has grown and the availability of fresh groundwater has diminished, there has been a movement towards alternative water supplies, including brackish groundwater, surface water, and seawater.

Desalination and Water Supply Planning

Florida's five water management districts are responsible for sustainable management of its water resources. Each of the districts develops a regional water supply plan (RWSP) every five years that evaluates the adequacy of existing drinking water supplies and identifies potential future supplies. The most recent RWSP for each of the districts identify a total of 126 brackish water and 11 seawater projects with combined capacities of up to 545 mgd and 290 mgd, respectively (Figure 2).

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In the mid-2000s, much of Florida was facing looming water shortages and the need for alternative water supplies was imminent. As a result, many water providers maximized existing supplies and began developing alternative supplies. Now, in the midst of the national housing and economic crises, many of these same water suppliers find themselves flush with underutilized supplies built for growth that has yet to come. In other cases, while the need for alternative water supplies and desalination still looms, the urgency has been reduced significantly. The economic downturn has resulted in

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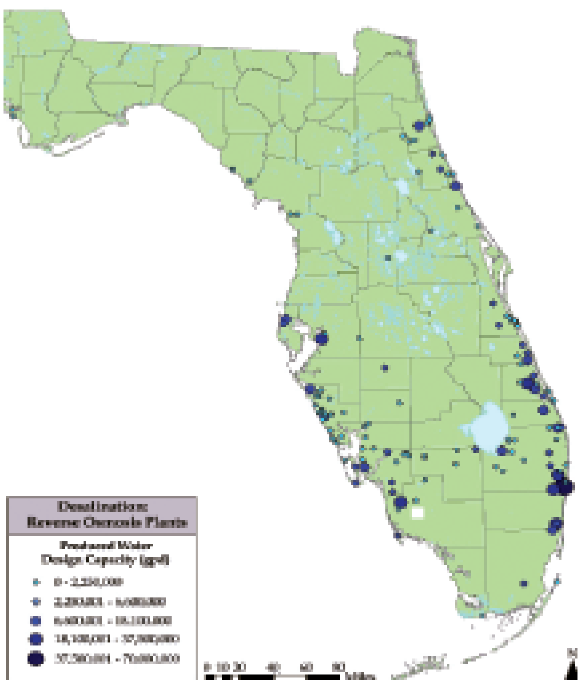

Figure 1. Florida Desalination Facilities
(Florida Department of Environmental Protection, 2010)

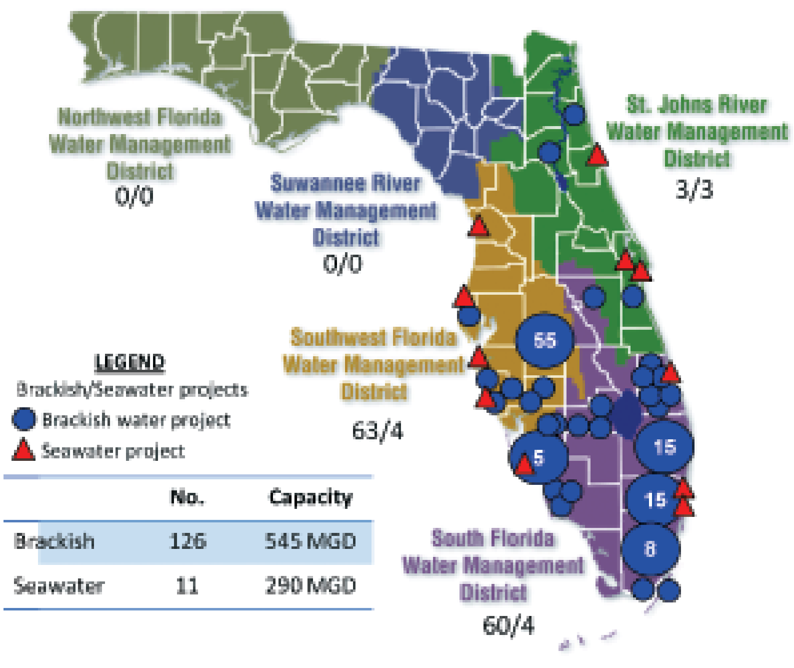

Figure 2. Brackish and Seawater Supply Projects Contained in Regional Water Supply Plans
(Northwest Florida Water Management District, 2006; Suwannee River Water Management District, 2010; St. Johns River Water Management District, 2009; Southwest Florida Water Management District, 2010; South Florida Water Management District, 2006).

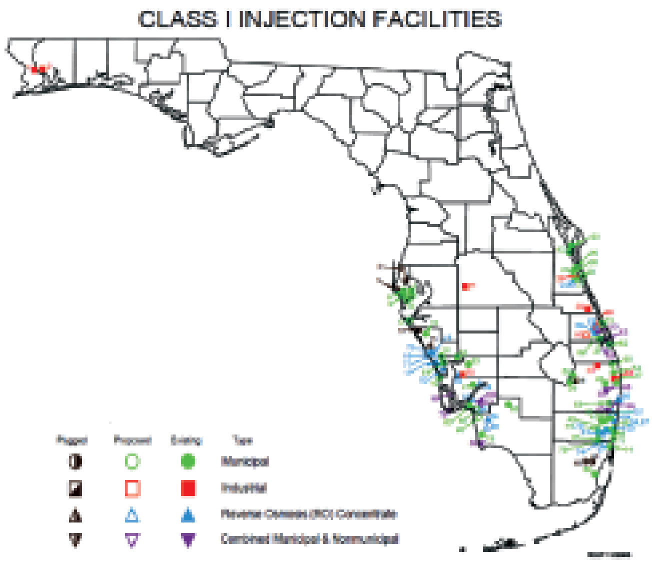

Figure 3. Deep Injection Well Locations within Florida
(Florida Department of Environmental Protection, 2012)

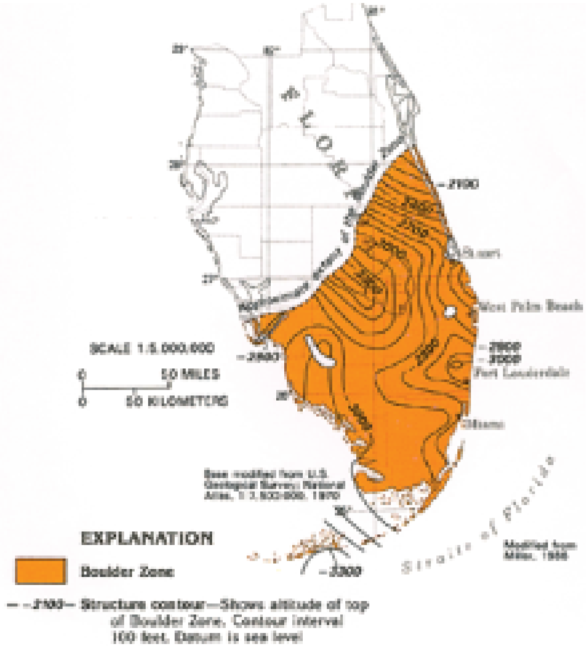

Figure 4. Map of the Floridan Aquifer Boulder Zone
(U.S. Geological Survey, 1990)

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a renewed focus on conservation, even though it is difficult to quantify in some cases. Although the need for seawater or brackish water is still present, economic necessity has resulted in protracted project delays.

Technical Challenges and Opportunities

As Florida continues to grow and fresh water supplies become increasingly limited, the use of brackish and seawater clearly will play an increased role in its future water supply. However, there are still a number of technical challenges facing public water suppliers and regulators within Florida, including concentrate management, marine impacts, energy management, and pretreatment.

Concentrate Management

Desalination processes, primarily nanofiltration/reverse osmosis (NF/RO) and electrodialysis, produce concentrate streams with salt concentrations from two to nearly ten times that of the source water. Concentrate management represents a significant technical challenge to brackish and seawater supply development. Many of the existing brackish water desalination facilities within the state currently discharge to deep injection wells (Figure 3).

Discharge to deep injection wells is possible primarily due to suitable hydrogeological and water quality conditions in the southern portion of the state. The "boulder zone" is a deeply buried zone of cavernous permeability in the Lower Floridan Aquifer that underlies a 13-county area in southern Florida (Figure 4). The permeability of the boulder zone is extremely high because of its cavernous nature, which prevents pressure buildup in injection wells, and coupled with the fact that the zone contains saltwater, makes it ideal for receiving concentrate.

Though many of the possible brackish water and seawater facilities shown in Figure 2 lie within the boundaries of the boulder zone, a substantial portion do not. For those facilities, particularly inland brackish water facilities, other alternatives to deep-well injection will be required. Though technically possible and feasibly permissible, surface water discharges will be a challenge for brackish water facilities (FAC 62-4). Surface water discharges could be required to provide dilution between 30:1 and 100:1 and would be subject to toxicity limitations, as well as antidegradation requirements of the state. As a result, other methods of concentrate management are likely to be required if brackish water desalination is to comprise any significant portion of future water supplies.

Brackish water desalination facilities may discharge between 15 and 35 percent of the volume of raw water pumped from the ground as concentrate. Furthermore, not only have they expended considerable capital and operating cost to withdraw that water, but it can be expensive to discharge it to a deep well that is several thousand feet deep. From that perspective, concentrate minimization and zero-liquid discharge (ZLD) technologies may not only make sense from a water supply perspective, but they may be necessary in regions with few options for concentrate discharge. Utilities in central Florida may see concentrate as another (albeit small) source of supply and choose to recover that water rather than discharge it. Veolia Water has patented zero discharge desalination (ZDD) wherein the concentrate is further processed to improve system recovery to as high as 97 percent (Figure 5). Concentrated salts from the ZDD process can be dried in evaporators/ crystallizers and evaporation ponds (not likely in Florida), and may even generate a usable product (such as gypsum).

Similar concentrate minimization schemes are already being used in Florida. The City of Palm Coast is utilizing lime softening to precipitate hardness from its RO concentrate and recycle the softened concentrate to the head of the treatment process. In California, the U.S. Army is planning to utilize lime softening and RO to recover the concentrate from an electrodialysis reversal (EDR) facility, resulting in an increase in recovery from 92 percent to greater than 98 percent.

Seawater desalination is frequently co-located with coastal power facilities to take advantage of their cooling water intake and discharge. For example, the Tampa Bay Water Seawater Desalination Facility is co-located with a Tampa Electric Company (TECO) power plant. The TECO plant utilizes more than 1.4 billion gallons of water per day and provides a nearly 70:1 dilution for the concentrate discharged from the Tampa Bay Water facility when operated at its design capacity. Co-location, however, will not always be an option. There is, for example, no existing power facility near the planned Coquina Coast seawater desalination facility centered near Flagler County. In this case, the Coquina partners are investigating off-shore dispersion fields as the most likely, most environmentally-friendly method of concentrate discharge.

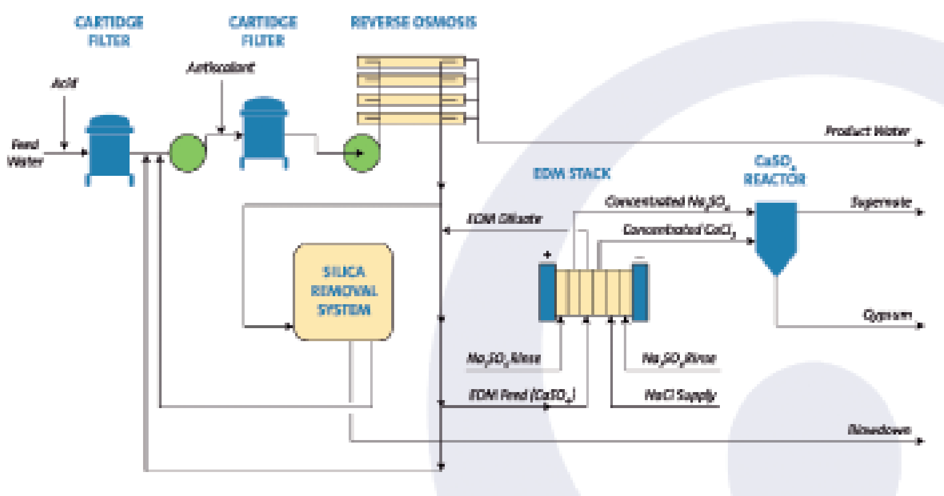

Figure 5. Zero Discharge Desalination Schematic
(Courtesy of Veolia Water, N.A.)

Marine Impacts

For seawater facilities, there are two significant opportunities to impact the marine environment: construction and operation of the intake, and construction and operation of the concentrate discharge. Co-location with existing power facilities has proven to be advantageous and can minimize the potential for adverse environmental impacts, but, as previously mentioned, co-location is not always feasible.

Minimizing the impacts of seawater intakes is relatively straightforward. Impingement and entrainment represent the two most significant seawater intake challenges. Beach wells and subsurface (i.e., below the seafloor) intakes can virtually eliminate the potential for impingement or entrainment; however, they require specific hydrogeological and bathymetric conditions to be technically feasible. For open ocean (either onshore or offshore), minimizing the intake velocity is critical. Figure 6 shows an open ocean intake at the Gold Coast seawater desalination facility in Queensland, Australia. In that design, it was determined that intake velocities at the screen should be less than 0.1 m/s (0.3 fps). During operation, it was found that this was very effective; in fact, smaller and bait fish actually use the intake as a shelter from larger predators. Wedgewire screens are also being considered for intakes (Figure 7) and West Basin Municipal Water District in California is currently conducting demonstration testing. The primary concern with regard to the wedgewire screen is fouling of the screen and reducing the feed water volume.

With regard to construction impacts, less obtrusive construction methods are preferred where possible and economical. For example, tunneling can minimize disruption of the marine environment; however, it requires specific geological conditions and can be expensive compared to conventional marine construction methods.

Disposal of concentrate from seawater desalination facilities represents a much more significant potential challenge. Concentrate must be managed to minimize the potential for adverse environmental and marine impacts. In south Florida, deep-well injection may be possible; however, in many cases, ocean discharges will be necessary. With regard to ocean discharges, the key is to dilute the discharge so as to prevent any significant impact to ambient water quality. There are several options available, including near-shore surface discharges, subsurface (below the seafloor) discharges, and offshore discharges below the water surface.

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Figure 6. Ocean Intake Structure
(Photo courtesy of Sinclair Knight Merz)

Figure 7. Wedgewire Ocean Intake Structure
(Photo courtesy of West Basin Municipal Water District)

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Near-shore discharges, absent a power plant cooling water system for dilution, are likely to be problematic, but several of the large seawater facilities in the Middle East utilize this type of discharge. Tidal patterns can seriously alter flow volume and direction, and dispersion of the concentrate may be difficult. Wave action could cause discharged concentrate to "roll" back to the coastline, further impacting coastal water quality. Nearby estuarine waters and outstanding Florida waters also represent a potential concern. Significant hydrodynamic modeling, water quality, and ecological studies would be required to get such a discharge permitted, as it would with the other options.

Subsurface discharges may be promising, depending upon local bathymetric, hydrogeologic, and hydrodynamic conditions. If the seafloor characteristic is such that it would allow for dilution, and hydrodynamic conditions would prevent rolling back to the coastline, it may be possible to construct such a discharge relatively near the coast. Further, engineered seafloors of filter bed-like sands may be promising, provided local climatic and tidal conditions are such that there is little danger of washing away the engineered floor.

Open ocean discharges, which are below the water surface and above the seafloor, may be the most practical option available, short of co-location with a power plant. In this application, a pipeline or network of diffusers is used to quickly disperse the concentrate. Figure 8 shows one such design for the Gold Coast facility. This particular installation was approximately 200 meters long and was able to disperse the concentrate to nearly background concentrations within several meters of the discharge. Similar experiences in Perth, Australia, have demonstrated that it is possible to diffuse the concentrate to near-background quality in the immediate vicinity of the diffusion field, such that sensitive marine life are able to grow and thrive on and around the diffusers themselves. As with the other types of discharges, extensive hydrodynamic modeling, and biological and water quality sampling, are required for such a discharge.

One last potential challenge facing seawater desalination in Florida is the ban of wastewater outfalls in south Florida. The Florida Department of Environmental Protection (FDEP) has indicated thus far that the ban does not apply to seawater concentrate. However, it merits consideration and should be monitored as a possible water supply issue in the future.

Energy Consumption

Desalination requires considerably more energy than more traditional fresh water supplies. The energy required to desalinate brackish groundwater can range from 1.5–4 kW/1000 gallons, depending on the technology and source water quality. Both NF and RO generally require slightly less (1.5–2.5 kWh/1000 gallons) than EDR (4 kWh/1000 gallons). Seawater desalination requires substantially more energy, approximately 10–15 kWh/1000 gallons.

Great efforts have been made to improve energy efficiency in desalination. The incorporation of newer, more efficient energy recovery devices has resulted in significant reductions in energy consumption. Early seawater facilities required up to 80 kWh/1000 gallons (Huehmer, 2011), but this has been reduced by a factor of nearly 10 over the past forty years. Although desalination still requires approximately three to five times the theoretical minimum required energy, the industry is nearing its best efficiency point (Chaudhry, 2010). Future advances in membrane materials and more efficient recovery devices will further reduce energy demands; however, what is needed in Florida, and the desalination market in general, is investments in renewable energy—solar, wave, and wind energy. One of the most significant hurdles to achieving public acceptance of seawater desalination is its greenhouse gas (GHG) emissions and carbon footprint. In Australia, for example, although renewable energy does not directly power the large seawater desalination facilities constructed there, wind farms were constructed to supply equal power to the grid for a net zero increase in GHG emissions. Incorporation of renewable energy into the project design, or to offset GHG emissions, will go a long way to increasing public acceptance of these projects.

Figure 8. Concentrate Discharge Diffusion Structure

(Photo courtesy of Sinclair Knight Merz)

Pretreatment

Pretreatment remains one of the most critical factors to successful desalination facility operation. A fully developed source water quality profile, including a clear understanding of source water quality variability and seasonal issues, is critical to continued successful long-term operation. For brackish water, chemical suppliers continue to develop more effective antiscalants, and the long history of brackish water desalination in Florida has provided a solid understanding of pretreatment requirements.

For seawater, understanding the potential variability in source water quality is the key to effective pretreatment. Biological fouling, red tide events, and turbidity and temperature (depending on intake location) can vary significantly. Designing an intake to minimize source water variability, and a pretreatment process to deal with these fluctuations, is critical. Oxidant-tolerant membranes (for biofouling control) and other advances in low-fouling membrane materials would go a long way to improving seawater desalination performance.

Technical Opportunities

The economic downturn has delayed the need for, and implementation of, brackish and seawater desalination within Florida. This provides significant opportunity to the drinking water community. The technical challenges discussed previously are not new; they are the same challenges that faced the industry during the rapid growth of the 1990s and early 2000s. They are also the same challenges that slowed implementation of every brackish or seawater project conceived over the last 10 or more years. The slowdown in the economy has given Florida the opportunity to take steps to address these challenges, to seize the opportunity to develop strategies to overcome them, and be prepared to better implement brackish and seawater desalination when the need for these alternative water supplies returns in the future.

In the meantime, there are several actions that can be taken by public water systems, regulatory agencies, and the engineering community:

- Develop strategies to deal with inland brackish water desalination, including increased focus on concentrate minimization and the value of concentrate as a water resource, demonstration of ZLD technologies, and development of new more efficient membrane processes.
- Develop requirements for hydrodynamic modeling, and water quality and ecological assessments. Conduct marine and ecological studies to determine concentrate toxicity and establish dilution requirements for seawater concentrate discharge.
- Conduct investigations to determine feasibility of wind, solar, wave, and other renewable forms of energy. Encourage power companies to invest in renewable energy investment and work with them in siting of new power facilities to consider co-location of seawater desalination facilities.
- Investigate alternative seawater intake and concentrate disposal alternatives that minimize pretreatment requirements and marine impacts, such as subsurface and well alternatives.

Non-Technical Challenges and Opportunities

Implementation of brackish and seawater desalination in Florida not only includes the technical challenges previously discussed, but also a number of potentially significant nontechnical challenges. These challenges, including permitting, financing and governance, water rates, and public acceptance, may represent an even more significant barrier to water supply development than the technical ones.

Permitting

Florida has established permitting requirements for brackish water facilities. Responsibility for the supply (the water management districts), the treatment process (FDEP), and concentrate discharge (FDEP) are consistent and well understood throughout the state. The same cannot be said for seawater. The very nature of a seawater project makes the issue of permitting much more complicated. Seawater projects move beyond the typical state boundaries and into marine and coastal environments over which statutory authority can vary. Though Florida regulatory agencies have seemingly been able to accept and permit seawater facilities much more readily than some other states, there are still several inconsistencies in the way in which permitting is handled within Florida, and there is a need for revised regulations designed to address seawater desalination.

There is no firmly established permitting process for seawater within the state. The Southwest Florida Water Management District (SWFMWD) determined that a water use permit was not required for the Tampa Bay Water seawater desalination facility because it had coastal water with total dissolved solids (TDS) concentrations in excess of 10,000 mg/L. Conversely, St. Johns River Water Management District (SJRWMD) determined in its review of the Coquina Coast project that it will indeed require a consumptive use permit and will be responsible for its issuance. The state needs a consistent policy regarding water/consumptive use permitting for seawater. It is also assumed that beach wells would fall within the purview of the water management districts, but clarification and consistency are required regarding this issue.

With regard to intake construction, FDEP will be the lead agency and issue construction permits within three miles of the coast. If it is located beyond this distance, responsibility will fall to the U.S. Environmental Protection Agency (USEPA) and the U.S. Army Corps of Engineers (USACE). However, even if the intake or discharge terminates beyond three miles, it will still traverse the boundaries of FDEP jurisdiction. In addition, intakes are also subject to the requirements of Section 316(B) of the Clean Water Act (40 CFR 125 and 125.90[b]) as provided in FAC 62-620.100, which protects against impingement and entrainment for cooling water intakes.

Similar to the seawater intake, FDEP would be the lead agency for any concentrate discharge within three miles of the coast or at depths of less than 90 feet. The USEPA would be the lead agency beyond three miles or in depths greater than 90 feet. Within three miles and 90 feet, discharges are referred to as coastal discharges; discharges beyond this are considered ocean discharges.

At this time, FDEP has not yet permitted a coastal or ocean discharge of concentrated seawater. The Tampa Bay Water desalination facility is co-located with a power facility and its discharge is diluted by the Tampa Electric Company (TECO) cooling water discharge. Most of the existing rules are written around discharge of concentrate from brackish groundwater, which has a much higher concentration factor (relative to the source water concentration), but lower overall concentrations. Further, the concentrate discharge rules are written around disposal to more conventional surface waters (e.g., rivers and streams) rather than ocean discharges. Requirements for permitting of concentrate discharge are defined in FAC 62-4.

The most significant individual permitting activity associated with a seawater desalination project is likely the preparation of required National Environmental Policy Act (NEPA) documentation. Though NEPA itself is not a permit, compliance with the requirements of NEPA has potentially significant impacts on the success of future seawater desalination projects. The NEPA compliance is required for federal funding. Given the need for an intake and concentrate discharge, USACE has its own NEPA regulations at 33 CFR Part 230, which governs actions directly undertaken by the USACE, including discretionary regulatory actions such as issuance of permits for major projects.

Financing and Governance

A significant hurdle to desalination implementation within Florida is funding, particularly in these economic times when utility and consumer budgets are limited. The water management districts have historically provided funding support for alternative water supply projects, and SWFWMD provided 50 percent co-funding of the Tampa Bay Water seawater desalination facility. The districts have stated that they intend to continue to provide financial support to alternative water supply projects; however, given state budget issues and a reduced tax base, those funds may not be as significant as in the past, despite the fact that more expensive alternative water supplies are needed.

Outside funding sources (i.e., those outside a typical utility's budget) can minimize water rate impacts on customers, which is particularly important during the current economic recession and downturn in the housing market. There are a number of state and federal vehicles that provide funding for alternative water supply projects such as seawater desalination, including grants and loans, legislative appropriations, and bonds. The difficulty is that these sources of funds are rarely sufficient to significantly impact the overall project cost. For example, SJRWMD has appropriated more than $26 million for the construction of the Coquina Coast project—a substantial sum of money. Unfortunately, that money will likely account for less than 10 percent of the total project cost.

Legislative appropriations at the state and federal level are truly needed to provide significant funding for desalination. The Water Resources Development Act (WRDA) is one potential source of funds, but no authorizations have been given under this program since 2000 and there is now a backlog of some 500 authorized projects awaiting appropriations. It is time for Florida and the United States to step forward and provide financing for water infrastructure.

The foundation of any funding application is greatly dependent on the organizational makeup or governance. Governance establishes ownership and accountability. The sig-

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nificance of the governance decision lies in its effect on the funding process, including the total dollar amount available to the project, interest rates, and the speed with which the funding process may proceed. Governance can include self-ownership and financing, or creation of a special district or authority.

Rate Impacts

Typical fresh groundwater within Florida may cost $1.00-2.00/1000 gallons. Brackish and surface water may cost $2.00-4.00/1000 gallons. Seawater generally costs between approximately $3.50 and $8.00/1000 gallons, depending on the size of the project and infrastructure required. Depending on the proportion of brackish water or seawater within a utility's water supply portfolio, addition of one of these new sources can significantly impact customer water rates. It is therefore imperative that utilities 1) maintain a well-balanced water supply portfolio, 2) seek financial support to lessen the rate impacts to customers, and 3) truly understand the impact of the addition of desalinated water to the water supply portfolio and the impact to their customers. It only takes one misinformed customer or media outlet to seize upon a value like $8.00/1000 gallons and begin touting the "eight-fold water rate increases over current rates."

Public Acceptance

Perhaps the most significant challenge to desalination, and seawater desalination in particular, is public opposition. For this reason, the public cannot be ignored in the planning and implementation process. Today's water customer is better informed than at any time in history. Information (and unfortunately, misinformation) is readily available to anyone with computer access in this age of electronic media. The Internet is a fabulous source of information, but is also a source of misquoted, misinterpreted, and deliberately misleading information. Special interest groups and other organizations use the Internet to distribute anti-desalination information under the guise of consumer or environmental protection. It is important for utilities to understand this and be *the first and best source of information.*

When developing a desalination project, it is important to involve the public early and throughout the planning and implementation process to determine what their concerns are and develop solutions that address those concerns. If the project requires NEPA compliance, USEPA will require that the public be included in the planning process. Invite key local organizations, such as homeowner associations and environmental groups, to participate in the planning so that their input is included and they understand the project, rather than rely on others as their source of information.

The most commonly asked question is, "Why can't we conserve our way out of this?" Be prepared with an answer, including details regarding the steps that have already been taken to reduce water consumption. Be prepared to address questions about impacts to growth and development, water rates, location, GHG and energy consumption, concentrate discharge, environmental impacts, and construction impacts. Listening to the public, answering questions (or telling them you will have the answer to a question), and incorporating their feedback into the process can help to eliminate opposition and gain support for the project.

Non-Technical Opportunities

Non-technical challenges likely represent the most significant barrier to implementation of desalination within Florida. The technical challenges will be addressed out of necessity, or by entrepreneurial spirit, but the non-technical challenges have the ability to derail a desalination project. The downturn in the economy has provided the following opportunities to address some of these challenges, such that when the need for these alternative water supplies returns, implementation will face fewer obstacles:

- Establish consistent regulatory policy regarding the permitting of seawater desalination, including water/consumptive use permitting requirements.
- Revise concentrate management regulations to include seawater, including establishment of hydrodynamic modeling and toxicity testing requirements.
- Engage the state and federal legislatures to enact legislation, provide appropriations through existing legislation, and otherwise support and provide funding mechanisms for alternative water supply development, and specifically, desalination.
- Educate, engage, and inform the public, and be proactive in being the first and best source of information—because the opposition is.

Summary and Conclusions

Brackish water and seawater desalination will play a significant role in Florida's future water supply. The economy will rebound and growth will eventually return; when they do, the conditions that drove the need for desalination will still be there. The technical challenges, for example, concentrate disposal, marine impacts, energy consumption, and pretreatment, are well-documented, and the water industry has spent millions of research dollars to investigate and develop solutions for these issues.

The industry is very adept at identifying and resolving technical challenges; however, desalination presents a number of unique nontechnical challenges. For example, permitting of desalination facilities is not necessarily a technical challenge; it is more likely that the lack of established permitting requirements for desalination make it difficult for regulators to evaluate and permit desalination projects.

Public acceptance is another challenge typically facing desalination projects. While opponents of desalination are constantly sending questionable information to the public and to politicians, the industry is slow to react due to lack of available resources documenting the environmental benefit and success of similar desalination efforts in Florida and worldwide, or an unwillingness to engage in public debate. The result can be catastrophic for a project and the industry as a whole.

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