Improving the Resilience of a Municipal Water Utility Against the Likely Impacts of Climate Change

A Case Study: City of Pompano Beach Water Utility

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1.0 BACKGROUND OF UTILITY

The City of Pompano Beach, FL is located in northeast Broward County, along the coast of the Atlantic Ocean (see Figure 1.1). The City is bounded by different municipalities such as Deerfield Beach on its north (limited by Sample Road), Hillsboro Beach and Lighthouse Point on its northeast (limited by Copans Road, Dixie Highway, and Federal Highway), Lauderdale by the Sea on its southeast, Fort Lauderdale on its south (limited by McNab Road), Margate and North Lauderdale on its southwest (limited by The Florida Turnpike), and Coconut Creek on its west (limited by The Florida Turnpike). The City includes three miles of beachfront that extends from the intersection of State Road A1A and Terra del Mar to the Hillsboro Inlet. Water bodies within the City include the Intracoastal Canal, and minor canals for drainage.

Figure 1.1 Location of Pompano Beach, FL (CDM, 2009)

The City of Pompano Beach, FL has a land area of approximately 22.5 square miles with an estimated population served of over 104,000 (Pompano Beach staff 2009). The South Florida Water Management District Lower East Coast Water Supply Plan (2005) Summary Sheet for the City of Pompano Beach shows a population of 89,182 in 2005 and projected growth over the next 20 years to a population of 116,371. The per capita water usage is projected to be 191 gallons per day. As a result, the projected annual daily average water demand will increase by 4.96 MGD during the indicated 20 year planning horizon from 2005 to 2025.

The City's water service area is 19 square miles and functions as a single service area. Within the service area, there are customers outside of the City limits, primarily located in the south part of the City of Lighthouse Point (south of N.E. 31st Court) and the north part of the Town of Lauderdale-by-the-Sea (north of Gatehouse Road). These customers are direct customers of the City's Utilities Department because the respective municipalities are not bulk users. Figure 1.2 shows the area served by the City's water treatment plant.

Broward County Water/Wastewater Services (BCWWS) provides water service to the remaining areas within the City limits, as shown in Figure 1.2. Both the BCWWS District 1 and 2 Water Treatment Plants (WTP) provides service to portions of the City (See Figure 1.2 – yellow, purple, red and blue areas).

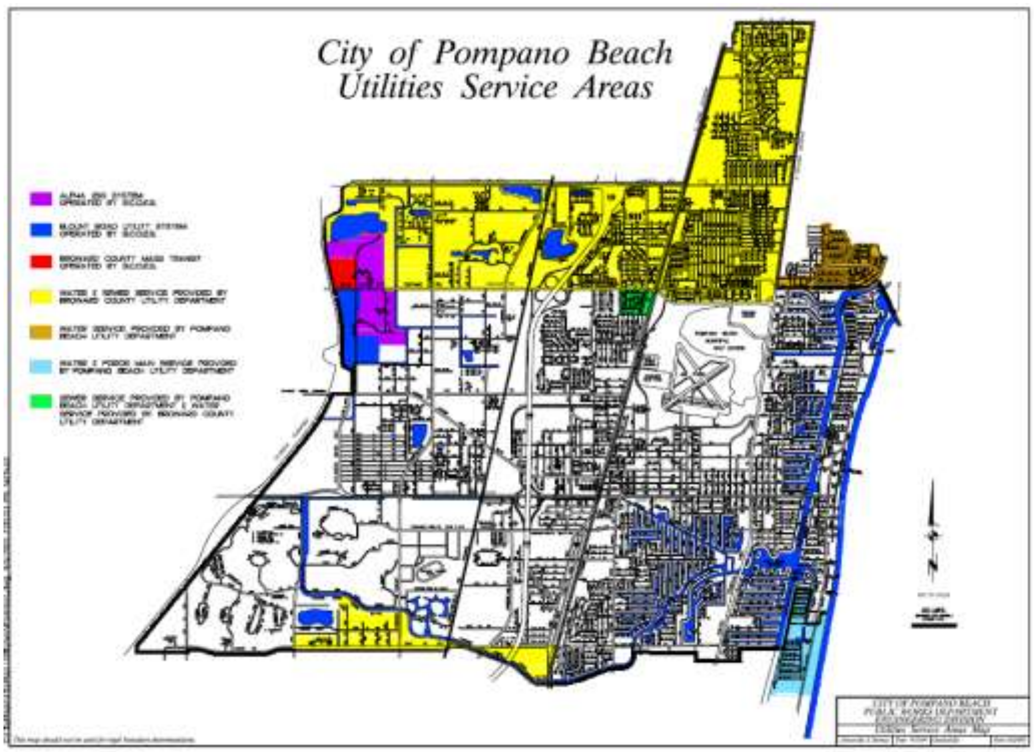

Figure 1.2 Water Service Areas in Pompano Beach, FL (provided by the City of Pompano Beach 2009)

2.0 UTILITY OPERATIONS

2.1 Raw Water Supplies

There are two wellfields that provide the City's raw water supplies (both located in the City – see Figure 2.1). The first is designated as the Eastern Wellfield (also known as the Airport Wellfield), and the other one is designated as the Western Wellfield (also known as the Palm-Aire Wellfield). The Eastern Wellfield is located near the City's municipal airport and WTP, and the Western Wellfield is within the Palm-Aire development (CDM, 2006). The wellfields have a rated capacity of approximately 46,000 gallons per minute (gpm), equivalent to approximately 66 MGD, but their permitted withdrawal limits, as established by SFWMD, are approximately 33 percent of their capacity.

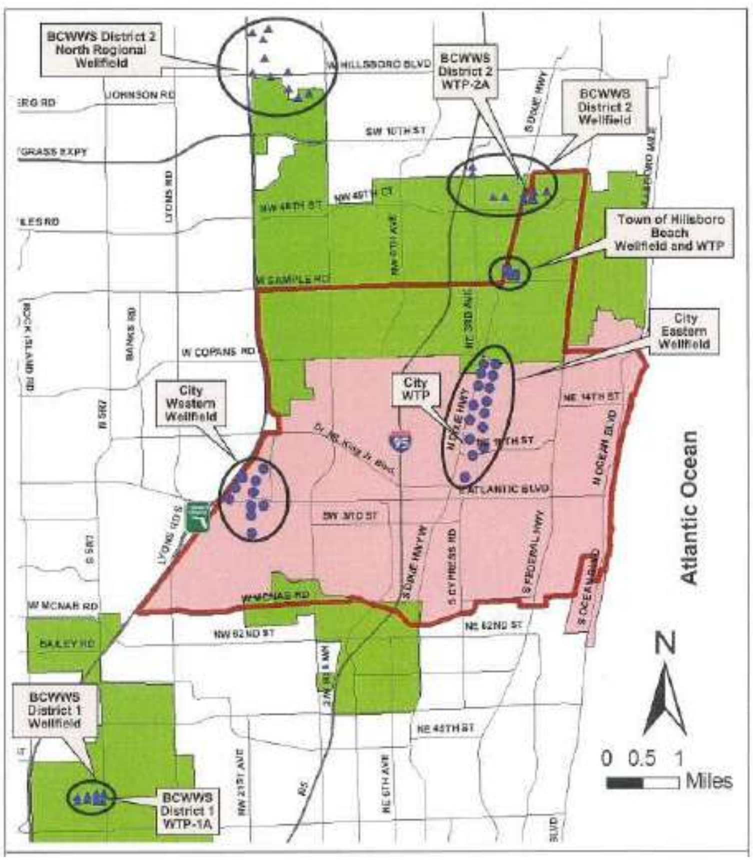

Figure 2.1 Location of Wellfields (CDM 2009). The dots are the wells. The green areas are Broward County service areas. The pink is the City of Pompano Beach's service area. The red line defines the corporate limits of the City. There are BCWWS District 2 wells within the city limits

The City is currently operating under the Pompano Beach Consumptive Use Permit (CUP) Number 06-00070-W, dated September 14, 2005, issued by the SFWMD for a 20-year period, which expires on September 14, 2025. This permit allows the City to withdraw up to 7,067 million gallons (MG) per year (19.36 MGD), with a maximum monthly withdrawal of 665.1 MG (22.17 MGD) until August 10, 2010. After this date, the annual allocation will be reduced to 6,478 MG or an annual average day of 17.75 MGD, and a maximum day of 20.33 MGD, until the agreement expires.

The Eastern Wellfield withdrawal has been limited by the SFWMD due to a potential for saltwater intrusion. The CUP specifies that the maximum monthly withdrawal from the wells in the east side of the City shall not exceed 186 MG (6.2 MGD) between November 1st and May 31st (dry season) and 279 MG (9.3 MGD), between June 1st and October 31st (wet season). To monitor the potential for further saltwater intrusions, the City implemented a groundwater monitoring program in 1996. As part of this effort, ten (10) fully-screened monitoring wells that are approximately 200 feet in depth were constructed on the east side of the City between 1996 and 1997. The water quality and water levels are monitored through monthly sampling. With this program, the City has been able to identify the saltwater interface and track its migration for the past ten years. The collected data suggests that there has been no significant change or movement of the saltwater front (2005 SFWMD staff report on water use permit renewal). The City's approved Water Supply Plan shows a projected offset of 2.33 MGD of potable water from reuse water by 2015 and a projected offset of 5.33 MGD by 2020 (see Table 2.1). With offsets from the reuse water, the potable water withdrawal required by the City will be at a similar volume as today. Additional irrigation from temperature rise will come from reuse.

Table 2.1
Projected Potable Water and Raw Water Demands for the Pompano Beach, FL

Year	Projected AADF Potable Water Demand (MGD)[a]	Projected AADF Raw Water Demand (MGD)[b]	Plant Capacity Rating (MGD)	Allowable Raw Water Withdrawal (MGD)[d]
2009	16.82	18.13	17.93	19.36
2010	17.13	18.46	17.93	19.36
2015	18.75	20.20	16.44	17.75
2020	20.34	21.91	16.44	17.75
2025	21.94	23.65	16.44	17.75

Notes:
a. Average Annual Daily Flow (AADF) potable water demand projection (City's Water Supply Facility Work Plan)
b. Raw water demand projection (City's Water Supply Facility Work Plan). Raw water is the water prior to treatment – some losses are expected in the membrane process
c. Potable water production from allowable raw water withdrawal (City's Water Supply Facility Work Plan
d. Allowable raw water withdrawal (per SFWMD water use permit).

Broward County operates two wellfields that serve areas in the City. One of the wellfields is partially in the City. BCWWS District 1 is currently operating under the Broward County District 1 CUP Number 06-00146-W, dated April 10, 2008, and expires on April 10, 2028. Pursuant to the

SFWMD CUP, No. 06-00146-W, the maximum daily and average annual daily withdrawals allowed from the District 1 wellfield are 12.4 MGD and 9.8 MGD, respectively.

BCWWS District 2 is currently operating under the Broward County 2A/North Regional Wellfield CUP No. 06-00142-W, dated March 13, 2008, and expires on March 13, 2028. Pursuant to the SFWMD CUP no. 06-00142-W, the maximum daily and average annual daily withdrawals allowed are 13 MGD and 11 MGD, respectively. Parts of this wellfield are in the City.

Table 2.2
Projected Potable Water and Raw Water Demands for the Broward County, FL District 1 and 2 Systems

Year	Projected AADF Potable Water Demand (MGD)	Projected AADF Raw Water Demand (MGD)	Plant Capacity (MGD) Rating	Allowable Raw Water Withdrawal (MGD)
2009	10.9	10.9	16.0	12.4
2010	11.1	11.1	16.0	9.8
2015	12.0	12.0	16.0	9.8
2020	12.8	12.8	16.0	9.8
2025	13.6	13.6	16.0	9.8

Note: District 1 has a portion of the system receiving bulk water form the City of Plantation (not included in total)

Year	Projected AADF Potable Water Demand (MGD)	Projected AADF Raw Water Demand (MGD)	Potable Water Production (MGD)	Allowable Raw Water Withdrawal (MGD)
2009	10.3	10.3	30.0	10.67
2010	10.3	10.3	30.0	11.0
2015	10.8	10.8	30.0	11.0
2020	11.3	11.3	30.0	11.0
2025	11.9	11.9	30.0	11.0

2.2 Water Treatment Facilities Descriptions

Three (3) water treatment plants (WTPs) provide service to Pompano Beach as shown in Figure 2.2. One is owned by the City (which is the focus of this report), while the County operates the other two. The water treatment plant operated by the City is located at 1205 N.E. 5th Avenue in Pompano Beach, as shown on the map in Figure 2.2. This plant serves the City's water service area as described in Section 1. The WTP site has an area of approximately 37 acres and is surrounded by the City's Municipal Airport and residential areas. The plant is located 3 miles from the ocean on the coastal ridge at an elevation of approximately 15 feet (Google Earth, 2009). The coastal ridge is high ground, generally exceeding 12 feet in elevation. The soil condition is generally sand that is highly porous. So between the elevation and soil conditions, the site is unlikely to be subject to significant flooding except under very severe storm events. The plant's elevation and distance from the coast are well in excess of those projected for maximum hurricane storm surge in the area. The wells in the eastern wellfield are also located on high ground and deep enough that short-term storm surge is not likely to be a significant factor in the short-term, although the upper levels of the sand might become contaminated with salt temporarily.

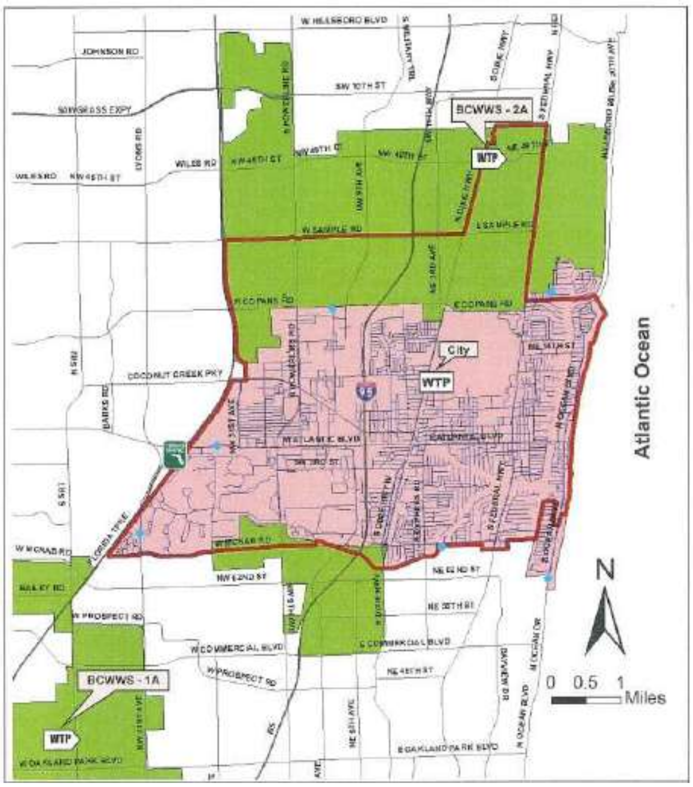

Figure 2.2 Water plant locations serving Pompano Beach, FL (CDM, 2009). The green areas are Broward County service areas. The pink is the City's service area. The red line defines the corporate limits of the City

Figure 2-3 presents the process flow schematic of the plant showing both the lime softening and the membrane softening processes. The plant has a design capacity of 50 MGD, split as a 40 MGD lime softening plant and a nanofiltration facility with a rated design capacity of 10 MGD which was added in the past 10 years. The water treatment plant site has an area of approximately 37 acres, surrounded by the City's Municipal Airport and residential areas. The City's current average daily demand is 17 MGD (34% of design capacity).

The lime softening facility has two reactors for lime softening that use slaked lime and polymer. Additional treatment includes: recarbonation, rapid media filtration, chloramine disinfection with chlorine and ammonia addition, and fluoridation. The lime softening facility has an efficiency of approximately 97 percent. The nanofiltration membrane facility uses reverse osmosis to separate hardness and alkalinity from water withdrawn from the western wellfield. This treatment process includes chemical pretreatment with sulfuric acid and antiscalant, cartridge pre-filtration (5-micron), nanofiltration, and degasification. The degasified membrane permeate is post-treated with fluoride, sodium hydroxide, chlorine, ammonia, and polyphosphate. The membrane concentrate is disposed into a deep injection well system located at the WTP site (CDM, 2009). The raw water recovery rate is 85 percent using a two-stage system. Higher recoveries are possible as demonstrated in Hollywood, FL and other facilities, so this is an area where added efficiency might help long-term water supply strategies, especially if there are concerns about contamination from storm surge.

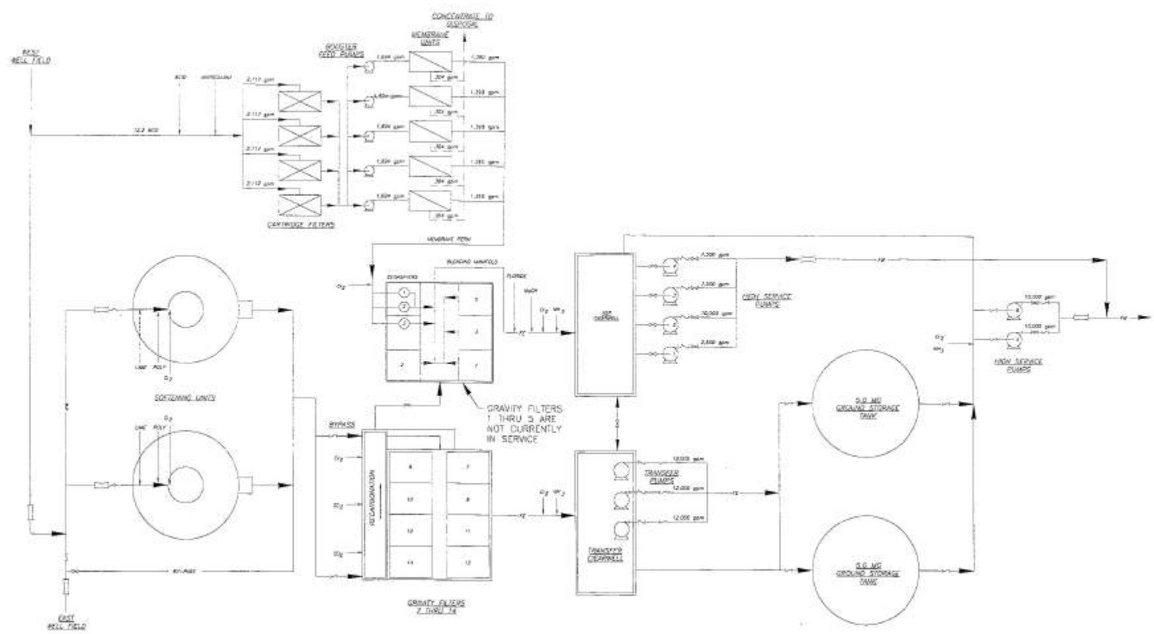

Figure 2.3 Process Schematic of the City's water treatment plant

The plant facilities also include two clearwells (the transfer clearwell and high service pump clearwell) for staging disinfected water prior to pumping to storage and two 5.0 MG pre-stressed concrete ground storage tanks for a total of 12 million gallons, or 65 percent of the average daily flow. As a result the City has 16 or more hours it can pump potable water off site from its storage tanks without treating water should emergencies dictate a need to stop treating water. Finished water is pumped to the distribution network with the high service pumping system consisting of six pumps ranging in capacity from 2,500 gpm to 10,000 gpm. High service pumps 1 through 4 draw from the high service pump clearwell, while high service pumps 5 and 6 draw from the ground storage tanks. The high service pump system has a firm capacity of 37,500 gpm or 54 MGD (CDM, 2006). The treatment plant has full back-up power, so if the power grid goes down, the City can continue to supply water to its customers. The City plans for 5-7 days without grid power.

Broward County's retail water system supplies potable water to retail customers in several sections of the County and to one significant wholesale water customer (City of Coconut Creek, FL). The service area represents a population of approximately 230,000. The retail water service area is divided into three (3) service areas - Districts 1, 2 and 3. These water service areas cover over 40 square miles. Two (2) water treatment plants, one each in District 1 and District 2, provide a combined water treatment capacity of 46 MGD (million gallons per day). Both provide service to parts of Pompano Beach, FL.

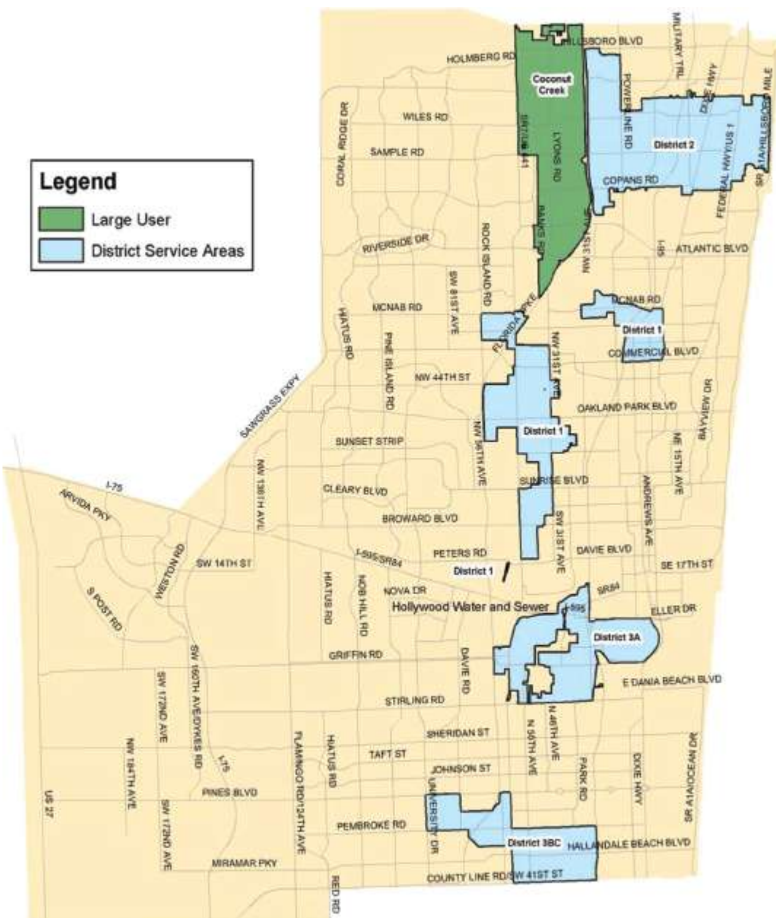

Figure 2.4 – Water Service Areas in Broward County, FL (Broward County, 2009)

District 1 has a combined service area of 12.06 square miles, and 236.54 miles of water distribution and transmission mains. The plant was expanded again in 1994 to a capacity of 16.0 MGD. The facility's operating permit number is 0658-00009. The plant uses upflow clarifiers and multimedia filtration to provide lime softening of the raw water supply. A portion of the system received water on a bulk basis from Plantation (but not any areas in Pompano Beach). BCWWS maintains District 1 water system interconnections with the systems of the City of Fort

Lauderdale, the City of Tamarac, the City of Plantation, and the City of Lauderhill to provide for emergency water supply (Bloetscher et al., 2009).

District 2 is located in the northeast part of the county and includes the County's largest wholesale water customer, the City of Coconut Creek. District 2, not including the City of Coconut Creek, has a service area of 14.79 square miles, a permitted plant capacity of 30 MGD, and contains 239.94 miles of water distribution and transmission mains. The District 2 water treatment plant was originally constructed in 1972 with a treatment capacity of 20.0 MGD and was expanded to a physical capacity of 40.0 MGD in 1994. The plant's permitted capacity is 30.0 MGD. The facility's operating permit number is 06-58-00010. The plant uses upflow clarifiers and multimedia filtration to provide lime softening of the raw water supply. The facilities of District 2 are interconnected with the City of Pompano Beach, the City of Deerfield Beach, the Town of Hillsboro Beach, and Palm Beach County to provide for emergency water supply. The County has an agreement with the City of Coconut Creek under which the County has agreed to provide the City of Coconut Creek with potable water for a term that exceeds by one year the last payment of any potable water system debt obligation of the County or 2040, whichever is less. The City of Coconut Creek constitutes approximately 22% of the total water consumption of customers of the Utility, which represents approximately 5% of the Utility's gross revenues. The agreement provides that, except by written consent of the County, the City of Coconut Creek will not purchase water other than from the County or pump water into its water distribution system from its own facilities. The County has agreed not to sell water to anyone else within the defined service area, and the City of Coconut Creek is not permitted to increase its water service area without the written consent of the County (Bloetscher et al., 2009).

Finished water storage facilities for the City and BCWWS Districts 1 and 2 water service areas consist of both "in-plant" and remote storage facilities. The total storage capacities for the City and BCWWS facilities are 13.0 MG and 13.8 MG, respectively. The City and BCWWS Districts 1 and 2 storage facilities are summarized in Table 2.3. Both of the County facilities are located over 4 miles inland on or just west of the coastal ridge. They are also located on sand so significant flooding of either facility from storms is unlikely. Both include back-up power and interconnects with neighboring utilities (including Pompano Beach) in the event the system has operational difficulties.

Table 2.3: City of Pompano Beach
Summary of Finished Water Storage Facilities, MG (CDM, 2006)

Water Plant Clearwells	2.0
Water Plant Ground Storage Tanks	10.0
Indian Mound Park Ground Storage Tanks	1.0
Subtotal	**13.0**
BCWWS Storage Facilities	
District 1 (3) In-Plant and (4) Remote Tanks	6.3
District 2 (4) In-Plant Tanks	7.5
Subtotal	**13.8**
Total Storage	**26.8**

2.3 Water Distribution System

City of Pompano Beach Utilities Department is responsible for the maintenance and repair of the potable water distribution and sewer collection systems located throughout the City. Currently there are over 247 miles of water lines ranging from 2 inches to 36 inches in diameter. There are also 1,707 fire hydrants and 5,219 gate valves. Materials on the water distribution system vary from cast iron and galvanized iron to PVC and ductile iron, depending on the age of the system. The oldest water lines exceed sixty years, which is beyond their useful life. Most of these water lines are located in the eastern half of the City and are thus more likely to be exposed to salt water. The main 36-inch diameter transmission line, located along N.W. 15th Street, feeds the west side of the City. It branches off on North Powerline Road and decreases its diameter to a 30-inch pipe along N.W. 21st Avenue. The southwest side of the City consists of several loops formed by the transmission lines that reduce down from 30 inches to 12 inches in diameter. The northwest side of the City consists of loops that are formed by transmission lines that are located mainly on North Powerline Road (30-inch), Hammondville Road (12-inch), N.W. 27th Avenue (10-inch), and N.W. 31st Avenue (10-inch). The east side of the City is being fed by the transmission line that is running west-east along N.E. 8th Street (18-inch) and Atlantic Boulevard (18-inch) and north-south along N.E. 5th Avenue (30/24-inch). The southeast part of the City relies mainly on the loop that is formed by the transmission line that is located along S.E. 14th Street (16-inch), South Ocean Boulevard (12-inch), S.E. 1st Street (24-inch), and South Federal Highway (16-inch). The northeast part of the City is being fed by the transmission lines along North Federal Highway (18-inch) and East Copans Road (12-inch) (CDM 2009). The City maintains interconnections with the systems of Broward County, the City of Fort Lauderdale, and the City of Margate. These interconnects are used for emergency purposes to maintain adequate water supply in the event of disruptions to the City supply.

An investigation of the condition of these pipelines should be undertaken (or comments recorded during repairs) to evaluate the state of deterioration of older pipelines and the priority for replacement. Any pipelines submerged in saltwater are likely to have particularly acute problems. Failures of these pipelines, especially large ones, will cause road damage and potentially property damage, so a proactive approach by the City is required. Fortunately, City staff advises that some of the 2-inch galvanized iron pipelines have been replaced with 6-inch PVC pipelines. Experience throughout Florida indicates that the acidic soil conditions do not promote long life of galvanized pipelines. Those that have not been replaced tend to be in rear yard alleys that are not easily accessible. Nevertheless, these pipelines remain a priority, and they may need to be moved to the front yards. In 2004/2005, the City replaced 5,728 feet of small 2-in water mains with larger 8-in mains and installed 326 feet of 6-in and 12-in water mains to improve water quality and water pressure delivered to the customer. Most of the City's service lines, including all of those on replaced water mains, are non-metallic, thereby eliminating corrosion potential. If any of the services attached to the cast iron lines are constructed with galvanized fittings and lead goosenecks. They should be replaced on a priority schedule. Standard materials for water lines are PVC C900 for the pipe, polyethylene tubing for service lines and brass fittings to connect them. All are appropriate materials to minimize corrosion issues and leaks.

The most vulnerable part of the utility system to storm events is the water distribution system. Trees are often planted in medians and rights-of-way which is too close to water mains. After Hurricane Wilma, the City of Boca Raton, similarly sized to Pompano Beach, had over 350 water main breaks, virtually all of which were caused by toppled trees. While small, the number of leaks can create a significant problem for the utility is trying to maintain pressure. Interconnects are helpful in this regard, but there is no defense against a catastrophic event that might create hundreds of leaks on the water system except to eliminate all trees in the right-of-way, but if more severe storms occur as some predict, this issue is worth further investigation.

2.4 Wastewater Treatment Plant Description

The 1973 Broward County 201 Plan designated the Southern Regional Wastewater Treatment Plant as the lead facility for its regionalization efforts (Broward County, 1973). Wastewater treatment service is provided to the City of Pompano Beach exclusively by Broward County via its North District Wastewater Treatment Plant, located at 2555 W. Copans Road (see Figure 2.4), which is over 10 miles inland and on ground that is in excess of 10 ft. The FEMA flood maps indicate that part of the plant is located in the 100 year flood plain as a result of canal proximity. However, the site is unlikely to be adversely impacted except in the most severe storm events, and then only temporarily. The plant is rated at 84 MGD. It is an activated sludge process to comply with secondary standards for deep injection wells and ocean outfalls, the primary disposal options. Existing treatment units include mechanically cleaned bar screens, grit chambers, influent pumps, aeration basins, secondary clarifiers, chlorination, effluent pumps, return and waste activated sludge systems, and post lime sludge stabilization facilities. The majority of the existing equipment is expected to provide service until 2020 or after. Recent WWTP performance has been generally in compliance with regulatory permit requirements. Back-up power is located on the site. Disposal of the bulk of the wastewater effluent continues to be via an ocean outfall and injection wells. The Florida Department of Environmental Protection desires to eliminate the outfalls, which is an issue the City should monitor and be engaged in. Elimination of the ocean outfall would create significant costs to Pompano Beach sewer customers to pay for alternative disposal options.

The City of Pompano Beach has no wastewater treatment plant, and no plans to construct one. The City relies on a Large User Partnership Agreement with Broward County and virtually all of the municipalities north of Fort Lauderdale to treat wastewater and dispose of the residuals and effluent on a regional basis. A large user agreement makes the County responsible for the operations, maintenance, regulatory compliance, and improvements to the wastewater treatment facility, although the costs are allocated to the Large Users. The County is also responsible for obtaining permits for the facility and complying with the pertinent regulations. The result is that the risks are the County's for any issue arising on any Large User's system.

The agreement has the following basic provisions:

- Defines the service area of each Large User
- Requires the Large Users to maintain their system (i.e. infiltration and inflow removal)
- Requires Large Users to monitor their system to insure wastes detrimental to the treatment process are not introduced
- Defines anticipated demands from the City of Pompano Beach to 15.71 MGD per amendment #2 to the large user agreement dated March 4, 2003
- Allocates costs by flow volume and requires an annual true-up
- Defines connection points and meter locations for each Large User, meter reading frequency, addresses meter inaccuracies, and provides a dispute resolution process
- Defines how the agreement can be terminated (requires the Large Users to pay all costs for service and for capacity that they are no longer using)
- Denotes a renewal, debt and depreciation cost are to be included in the rates charged to the Large Users

Effluent reuse is not available to the City of Pompano Beach from the County plant directly, although reuse is provided to Wheelabrator, nearby industrial users, some golf course irrigation, median irrigation near the plant, and some internal irrigation usage on the premises.

Maintenance crews address all equipment, structures, and grounds maintenance needs of the wastewater treatment plant on a routine basis, and as necessary. The work performed encompasses mechanical repair and installation, plumbing, carpentry, painting, masonry work, machining of parts, electric and electronic installation and repairs. A comprehensive stock of spare parts and equipment is maintained to respond to emergencies.

2.5 Reuse Facility Description

The City draws secondary treated wastewater from the Broward County wastewater treatment plant's outfall line for further treatment at its reuse water treatment plant (RWTP). This facility, which opened in August of 1989, is located in near the intersection of U.S. 1 and Copans Road. Treatment at the City's facility includes coagulation, a mechanical bar screen and conveyor press, a filter transfer pump station, 24 single granular media filter modules, chemical metering pumps, sodium hypochlorite storage, 2 MG storage tank, a 4.0 MG tank, a distribution pump station, and chlorination to comply with the requirements stipulated in Florida Administrative Code (F.A.C.), Chapter 62-610. The reuse water is used to irrigate the Pompano Beach Municipal Golf Course, Pompano Community Park, the landscaping along Federal Highway and Copans Road, City medians, and residential areas. In 1997, the City entered into an Interlocal Agreement with the City of Lighthouse Point to provide reuse water on center island medians, and currently is negotiating an agreement with Broward County to serve the southeast part of the BCWWS District 2 service area.

The current permitted capacity of the City's existing RWTP is 7.5 MGD (Permit No. FLA013581-004-DW1P). The 2007 RWTP average daily flow was 1.44 MGD. There is an existing high service irrigation system in place at the City golf courses. During storm event there would be no reason to operate the reuse system. The City has received a five year permit that expires April 25, 2010 from the Florida Department of Environmental Protection to operate the Reuse Water Treatment Plant. The utilization of the reuse water on golf courses and other areas helps to offset the withdrawal of potable water and reduce the potential salt-water intrusion into the Eastern Wellfield. The location of the existing and proposed reuse sites for land application located with the City limits are illustrated in Figure 2.5. Currently the total area being irrigated is approximately 300 acres. The reuse treatment plant is being expanded to serve additional areas; however for the purposes of this case study, it is assumed that the additional residential areas have a small enough flow as to not affect the wellfield at this time.

2.6 Sewer Collection System

The City's sanitary wastewater system was placed into operation during the last few months of the Fiscal Year 1963/64. Pursuant to the Large User Agreement between the City and Broward County, wastewater collected in the City's wastewater treatment system is transferred to the Broward County North Regional Wastewater Treatment Plant via 72 pumping stations. These lift stations each have a 24-hour per day telemetry monitoring unit, which improves operations in addition to avoiding back-ups and wastewater spills. The wastewater is pumped through approximately 58 miles of force mains that discharge to the County's plant. The pumping stations receive wastewater from 190 miles of gravity sewer ranging in sizes from 8-in to 42-in diameter., There are also 4,572 manholes and 15,498 service laterals,72 lift station wet wells and 73 miles of force mains ranging in size from 4" to 42" diameter (CDM 2009).

Figure 2.5 – Reuse Sites in Pompano Beach, FL (CDM, 2009)

There are a series of programs that any utility is expected to implement to maintain the value, life and condition of its sewer infrastructure. These programs have been collated into what is known as the Capacity Management, Operation and Maintenance Program (cMOM). The cMOM program makes the utility responsible for maintenance of its own lift stations and collection systems, and since keeping excess flows down benefits the utility financially, correction of leaks and infiltration should be priority projects. The City performs video inspection, cleaning/relining, and manhole rehabilitation programs to the gravity sewers to keep the wastewater flowing properly. Determining infiltration and inflow (I&I) in the wastewater collection system is accomplished by video camera inspection of gravity sewer lines looking primarily for cracks, breaks, and tree root intrusion into the wastewater collection system, among other sources (see Figure 2.6). By reducing infiltration and inflows into the gravity wastewater system the City can directly reduce costs from the County wastewater treatment plant, which charges the City by metering the flow. This benefits the City financially by keeping excess, unnecessary flows down to a minimum level, therefore, correction of leaks and infiltration should be priority projects.

Ongoing testing of the flows to Broward County and monitoring of the City's lift stations provides a measure to determine whether inappropriate amounts of infiltration are going to the wastewater plant. Condition assessments, inventories of assets, and evaluation of maintenance requirements are also part of cMOM.

However, by their very nature (buried pipes and protected facilities that are out of the public view), water and sewer utility operations are not in the forefront in the minds of elected officials, local government management and finance personnel. Water and sewer services are viewed as basic services, but they are not well understood by local government officials. The lack of obvious problems or critical failures, may lead local officials to believe that the water and sewer infrastructure is functioning at peak efficiency (Bloetscher, 2008). As a result, these piping systems may become neglected over time.

Gravity sewer collection systems consist of the gravity pipes, manholes, service lines, and clean-outs. Collection system piping throughout North America prior to 1980 was predominately vitrified clay. Since that time, asbestos concrete and various grades of PVC have been used. Ductile iron is rarely used due to the potential for crown corrosion from hydrogen sulfide gas. Vitrified clay pipe has been used for well over one hundred years. The pipe is resistant to deterioration from virtually all chemicals that could be in the water, and from soil conditions. It has a long service life when installed correctly and left undisturbed. However, vitrified clay pipe is brittle, so settling from incorrect pipe bedding, surface vibrations, or freezing can cause the pipe to crack. There are also limitations on pipe size. Temperature differences between the warm wastewater and cooler soils can cause the exterior pipe surface to be damp. The dampness encourages tree roots to migrate to the pipe, where they may wrap around and damage the pipe. In places that have pipe cracks, roots will enter the pipe, and over the long-term, the pipe will become broken and damaged from the combination of tree roots, vibrations, and freezing. Where the water table elevation is above the pipe level, significant infiltration of groundwater can occur, which reduces the capacity of the wastewater treatment plant to handle the volume of waste. Infiltration increases the base flow and will be indicated by lower strength wastewater during routine tests of BOD and TSS. Lining vitrified clay pipe is possible with many products, thereby extending the life of the pipe. The major focus to remove infiltration has been, and continues to be oriented to lining gravity pipe, which includes a significant amount of televising to find leaks. And where there are peaks in wastewater flows that match rainfall, inflow would appear to be a more likely candidate for the cause of the peaks than infiltration from pipes that are constantly under the water table (see Figure 2.7). Another concern with older vitrified clay pipe is the short joints used – as small as 2 feet prior to 1920 and 4 feet prior to 1960. Field joints were made prior to 1920, and even later. The joints were sealed with cement and cloth "diapers" wrapped around the joint. However concrete is not water-proof and will tend to crack over time. This particular pipe configuration results in networks with many joints, each of which has the potential to leak. Even today, the vitrified clay joints are short compared to PVC and ductile iron (20 feet and 18 feet respectively), although the joints and materials have improved substantially. Vitrified clay still remains the choice of material to use in industrial areas, where pipe protection is required.

The manholes and clean-outs are required for access and removal of material that may build up in the piping system. Manholes are access sites for workers and are also used for changes in direction and size of the pipe. Manholes are traditionally pre-cast concrete or brick. Brick was the method of choice until the 1960s. Brick manholes suffer from the same problems as vitrified clay sewer lines – the grout is not waterproof so the grout can leak significant amounts of groundwater into the manhole. In addition, the manhole cover may not seal perfectly, becoming another source of infiltration during a rain event or even from normal irrigation runoff. Pre-cast concrete manholes limit the number of joints, and elastomeric seals are placed between successive manhole rings; therefore, reducing these kinds of leaks. Many utilities will require the exterior of the manholes to have a coal-tar or epoxy covering on the exterior, which helps to keep the water out. Cleanouts for service lines are generally located on private property, and typically the utility has limited control over what happens there. Hence the removal or accidental breaking of a cleanout, or cracking of the service line pipe may be a significant source of inflow to the system. Both are potential sources of inflow during rain events. Simple methods can be used to detect them, and this should be part of ongoing maintenance efforts.

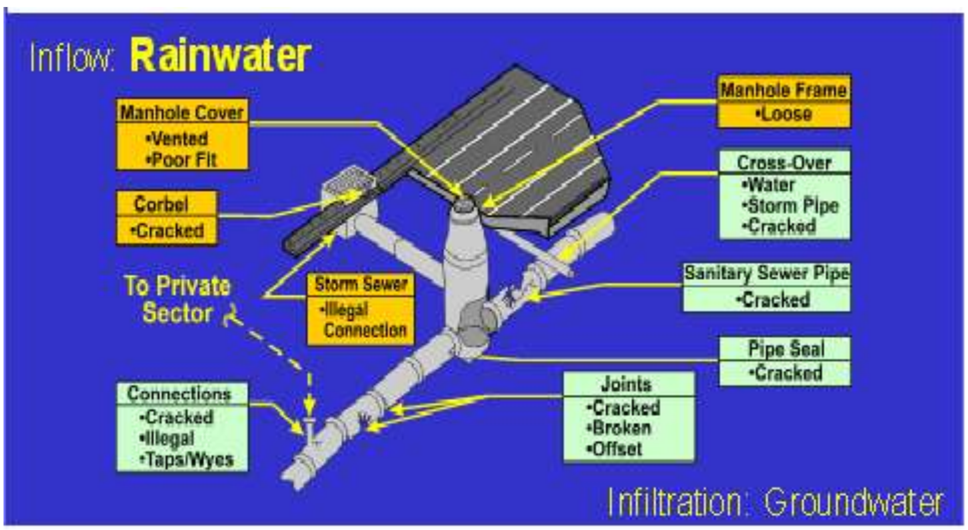

Figure 2.6 Potential sources of infiltration and inflow (Bloetscher, 2009)

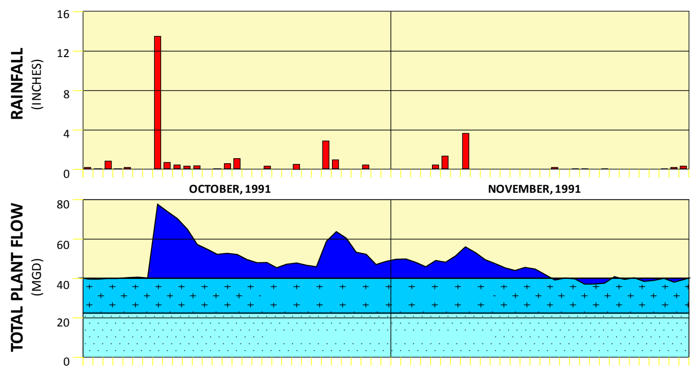

Figure 2.7 Example of indication of inflow to the sewer system (Bloetscher, 2009 - x-axis label is located in center area between the two graphs)

In addition to infiltration and inflow detection, maintenance and repair of the force main piping and gravity collection system includes the cleaning and video inspection of the gravity lines and manholes, the cleaning and adjustments to the force main air release valves, and response to complaints about stoppages (lift station alarms). Utility crews are responsible for insuring the reliable service of over 75 City-owned sewage lift stations and accompanying force mains and gravity lines that City crews maintain. Ongoing testing of the influent and monitoring of the lift stations by the utility provides a measure to determine whether inappropriate amounts of infiltration are going to the wastewater plant. This testing takes a variety of forms. The first is a review of lift station pump run times, followed by analyses of the influent wastewater quality (i.e. strength). There are also over 125 private lift stations and 4 stations outside the City that must be monitored.

The piping systems are subject to flooding as a result of storm surges. This is discussed in detail in the following sections. Most utilities have a significant number of back-up generators that are available. Also the utilities can associate with FlaWARN which is a consortium of utilities that pool their assets to help each other in the aftermath of storm events.

2.6.1 Septic Tanks

Throughout the State of Florida, where the water table is relatively high (less than 4 ft below land surface), septic tanks have proven to be problematic from a water resource perspective (Bloetscher and Van Cott 1999). Impacts are traced to a lack of regulation prior to the 1980s and to high densities of septic tanks on small lots. Moreover, many of these high-density developments were historically inhabited only in the winter months when the water table in south Florida is lower and septic tank performance is optimal. When the water table is high enough to interact with the drainfield, septic tanks cannot operate properly because the water table is above the drainage pipes, interfering with the normal hydraulic specifications and complicating pollutant migration modeling. Thus, the potential for groundwater and surface water contamination is increased, and clearly there is a need to quantify the contribution of environmental degradation attributable to on-site treatment and disposal systems (OSTDS) (Bloetscher et al 2008). In a previous study, Meeroff et al. (2005) suggested that septic tanks may not operate as designed when the water table is high, since inadequate distance between the drainfield and the groundwater level (<0.6m) leads to insufficient treatment. In many parts of Florida, particularly near the coasts, the water table is constantly high, often reaching ground level elevations during the wet season. Thus, the drainfield piping network may become submerged. Because of this fact, it was necessary to determine when the seasonal high water table elevation (SHWT) and the seasonal low water table (SLWT) events occur in the study area. To that end, several approaches were utilized. Broward County is subject to subtropical wet and dry seasons, so the SHWT is relatively easy to determine (September is the end of the wet season). The highest water levels occur in September, and the lowest levels occur generally in May through July.

The areas in Pompano Beach serviced by septic tanks or OSTDS are shown in Figure 2.8. While specific testing of these areas was not conducted, results from other areas of Broward County indicate that water quality impacts may be occurring, particularly during the SHWT event. Predicted adverse effects include:

- Overall, seasonality was observed in most variables, especially in Broward County.
- During SHWT, values of water temperature, nutrients, and bacteria are generally higher and values of DO are lower, when compared to SLWT.
- In Broward County, turbidity, pH, conductivity, TDS, and salinity variations are more affected by season.
- Overall, seasonal differences between OSTDS and sewer sites were more noticeable in the bacteriological results (Meeroff et al., 2008).

Hence septic tank areas could pose a groundwater hazard in the future if located near water bodies.

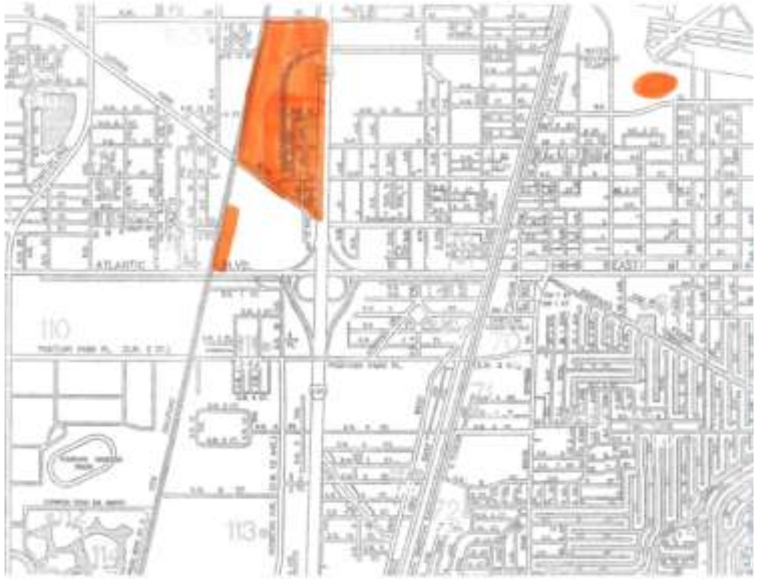

Figure 2.8 - Areas with septic tanks in Pompano Beach, FL (provided by City staff 2009)

3.0 SYSTEM-SPECIFIC VULNERABILITIES AND POTENTIAL SOLUTIONS FOR THE CITY TO CONSIDER

Climate change is likely to affect the City of Pompano Beach, just as it will the rest of the world. However the south Florida issues related to climate change may differ significantly from the concerns in the northwestern US or Europe. Melting glaciers, warmer climates and a loss of stream flow are not relevant to Florida. Instead, the likely responses that have been identified are changes in precipitation (primarily wetter wet seasons, and prolonged and drier dry seasons), changes in storm activity and sea level rise.

With regard to rainfall patterns, Southeast Florida is already a land of extremes. The summer months are characterized by significant convective storm activity that deposits 70 percent of the annual rainfall, but these rainfall patterns may already be part of climatic changes as data indicates the State is seeing decreasing convective storm activity (although the total annual rainfall remains above 54 inches). Marshall et al. 2003 proposed that land use changes were a part of the reason for changes in convective rainfall. Land use changes mean lower water levels in recharge areas, and less contact time for recharge on the surface. Climate change may further alter rainfall patterns, increasing the measured decrease in rainfall caused by terrestrial land use changes.

However it is thought that intensity of rain events may increase (IPCC, 2007). Heavy rains can lead to flooding, especially in areas that are developed and highly impervious. Much of Southeast Florida is urbanized so stormwater solutions are geared to removal of these flood waters. As a result much of the summer rains wash drain to primary canals and let out to tide, less is available for consumption, recharge, or storage. Heavily paved areas overwhelm stormwater drainage facilities during torrential rain events.

Heavy convective summer rains often result in saturated soils. The potential for flooding is compounded by hurricane and tropical storm activity. Thunderstorms and rain showers cause short-lived flooding of streets and property. Increased severity of storm events due to climate change may worsen the frequency and extent of these problems, but pumping stations are appropriately engineered to address short-term flooding. The City of Pompano Beach has significant experience with the issues associated with stormwater management during the wet summer months and in conjunction with storm events.

Increased storm activity may increase the short-term workload of City staff but less total rainfall would require a different approach during the winter and spring dry season when precipitation is generally well below the demands for the period. The natural system is geared to this variance, but the developed areas are not. Extended dry periods have been experienced in the past 10 years, and while these maybe part of longer term cycles as in the 1970s, increased population-driven water demand has driven public policy toward other solutions.

Under Florida law, water resources belong to the citizens of the state and are not a property right. Water supplies are allocated among the region’s water utilities such as Pompano Beach by the South Florida Water Management District (SFWMD), one of five regional agencies of the state divided according to the watersheds that are chartered to manage the state's water resources. SFWMD is the largest of these and is responsible for the Everglades watershed from the Kissimmee River to Lake Okeechobee through the Everglades to Florida Bay. The City has little if any control over its groundwater allocation (raw water supplies).

The SFWMD is also charged with responsibility for restoring the Everglades under the Comprehensive Everglades Restoration Program (CERP), a joint federal and state effort, that is the largest environmental restoration program ever taken anywhere in history of the world. The major goal of CERP is to restore the natural sheet flow to rehydrate what remains of the Everglades. Much of the water that was originally in the Everglades was diverted through major drainage canals to control flooding and to lower water levels to convert what was originally marsh to dry land for agricultural and urban development. Furthermore, Southeast Florida has been one of the fastest growing metropolitan areas in the United States stressing already limited water supplies and competing with the need to redirect water to meet CERP requirements. In order to reserve the water needed for CERP and to incentivize local utilities to develop the alternative water supplies needed to support municipal demands, SFWMD promulgated the Regional Water Availability (RWA) Rule. The RWA Rule requires that future water demands over and above the "base condition water use" must be provided from alternative water sources or offset with wastewater reuse and/or stormwater recovery. The "base condition water use" is defined as the five-year historical, highest twelve-month pumpage from any given wellfield before 2006, which limits the utility's withdrawals from the Biscayne Aquifer to a level of 5 years ago (17.75 MGD – see Table 2.1). The rule also suggests four "alternative water supplies," namely aquifer storage and recovery, reclaimed water, desalination and regionalization.

Because of South Florida's extremely low elevations, rising sea levels have the potential to inundate coastal communities. Furthermore low-lying inland areas are threatened by flooding due to rising water tables and compromised stormwater drainage. Because of the location of the City of Pompano Beach and its low elevation, sea level rise is likely to cause more significant and more constant impacts, while exacerbating the need to address storm impacts. While higher than utilities to the south, the highest elevations in the City are just over 12 feet and many areas are below 5 feet in the eastern part of the City. Sea level rise will reduce the capacity of available soil storage because groundwater levels also could rise in equilibrium with the salt water, reducing the distance from the surface to the water table, and the associated soil storage capacity. As a result, flooding will worsen as sea level rises because of the inability of soil to absorb the rainfall. The potential for storm surge impacts are greater because higher sea level will impede movement of stormwater out to tide. Standing tidal water may contaminate the aquifer.

Figures 3.1 and 3.2 demonstrate the problem confronting the utility with sea level rise from two modeling efforts by governmental agencies. These results show the migration of salty water inland toward the City's wellfield. The reason saltwater migrates is due to pumping of the wellfield and lowering of groundwater levels by canals. If sea level rises, there will be less unsaturated soil above the water table, which means that there will be less soil storage capacity to absorb stormwater. Sea level rise will also retard stormwater runoff capacity. Furthermore, hurricane storm surge will penetrate further inland if sea levels are elevated and be slower to drain. Adaptation to these impacts may necessitate major revisions and re-prioritizing public infrastructure projects like lock structures, reuse programs and wellfield protocols, requiring major funding. Note these model projections do not assume adaptation measures such as stacking groundwater levels behind new weir structures or impoundments, which may alleviate the migration of saltwater intrusion (Zygnerski and Langevin, 2009).

The result is a need for adaptation strategies for drinking water and wastewater infrastructure to deal with long-term sea level rise, extreme rainfall patterns, and more intense storms.

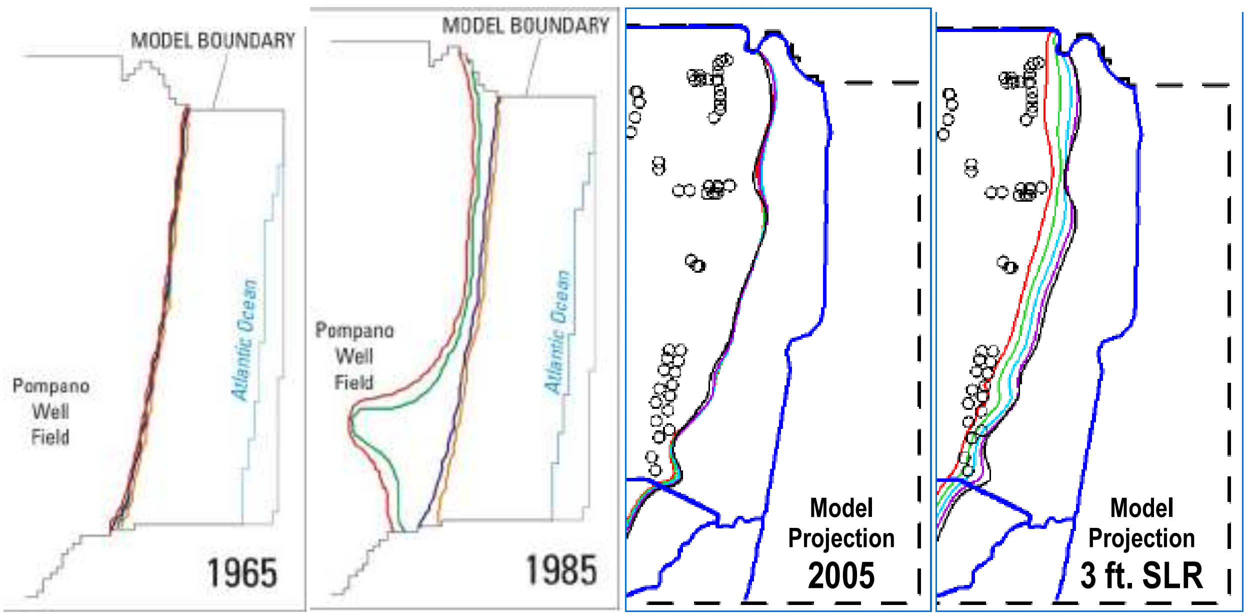

Figure 3.1 Historical modeled saltwater boundary (1965), as modeled for pumpage in the City of Pompano Beach's coastal wellfield in 1985, modeled solution for 2005 (circles show the wells), and projected change with 3 ft sea level rise, which could occur in the worst case IPCC scenarios as early as the last quarter of the 21st Century according to Table 5b of the main report (Heimlich et al, 2009).

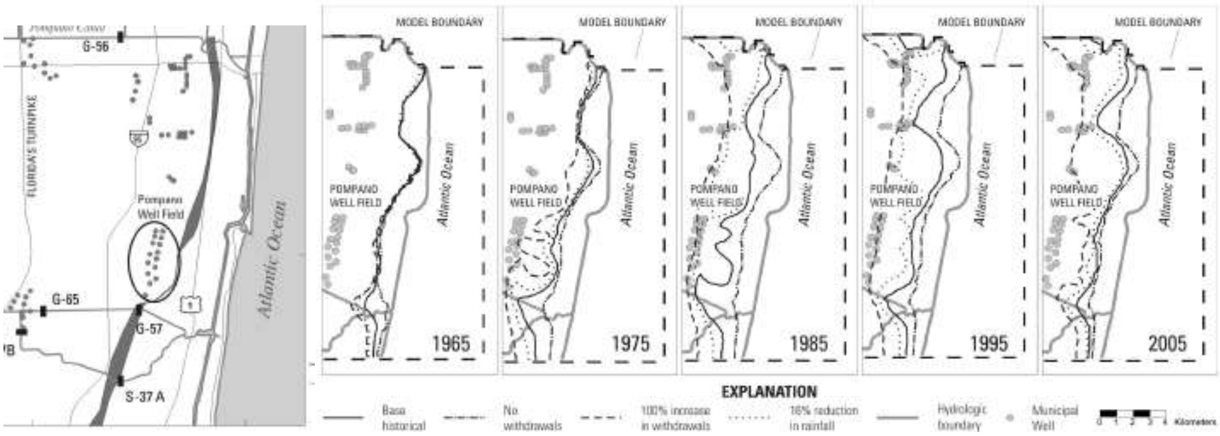

Figure 3.2 Model Boundary, showing canal system and ocean. Historical modeled saltwater boundary (1965), as modeled for pumpage in the City of Pompano Beach’s coastal wellfield in ten year increments and how the saltwater interface changes in the production zone.

3.1 System Vulnerabilities

The City of Pompano Beach has three potential vulnerabilities resulting from climate change: less rainfall, more storm activity and sea level rise. The drought issue is not significantly different from the current situation. Additional water supplies are a long-term issue for all utilities. Saltwater sources and added reuse would appear to be potential solutions to the water supply problem.

The major vulnerabilities of the City’s utility system resulting from storm events include:

- Damage to the water distribution system resulting from downed trees and vegetation
- Loss of grid power at facilities
- Catastrophic failure of equipment as a result of storm damage

A bigger long-term problem for the City is sea level rise. Based on an understanding of the City of Pompano Beach’s utility service area, the following list summarizes the system vulnerabilities as a result of encroachment from sea level rise:

- Inundation of coastal low-elevation areas with salt water
- Contamination of groundwater from sea water inundation and storm surge
- Higher water table throughout the service area resulting in less capacity to store rainfall (loss of soil storage capacity) and more runoff
- Inundated land on which septic tanks and onsite treatment and disposal systems (OSTDS) operate. Depending on location, these systems may no longer work effectively and could contaminate the groundwater as the water table rises. Fortunately, there are a limited number of septic tanks in the City.

- Increased manhole leakage and inflow (from surface flooding and saltwater intrusion)
- An associated increase in chlorides in raw wastewater requiring added treatment for reclaimed water or indirect potable reuse applications
- Saltwater migration toward eastern raw water wellfields

The common thread through all of these issues is sea level rise and reduced capacity for stormwater drainage. As a result, the City may:

- Be less able to rely on its eastern wellfield and eventually its western wellfield due to the potential for increased saltwater intrusion or inundation from storm surge
- Need to convert septic tanks and OSTDS to central sewers
- Need to harden the sewer system to prevent inflow that would be contrary to their reclaimed water goals
- Need to evaluate longer-term reclaimed water application areas with respect to potential reduced soil storage capacity
- Need to consider infrastructure for wellfield protection
- Need to consider potential pump station locations for stormwater drainage

These challenges bring opportunities for solutions and specific recommendations on action steps that the Pompano Beach utility could consider for improving the resilience of their facilities, which is the subject of Section 3.2. Of importance is the political and financial feasibility of pursing any given option. The real or perceived barriers to any option will slow its implementation, so that consideration must be addressed. These are discussed in Section 4.

3.2 Assessment of Engineered Solutions and Costs to Harden and Protect the Utility System

This section of the report is intended to provide an engineering assessment of current and alternative process technologies in order to recommend process improvements and operating strategies that would enhance the water treatment facility's resiliency against climate change impacts without compromising mandated requirements, and develop planning horizons for implementation and costs for same. For an option to be worth evaluating, it must directly address some resulting impact of climate change. In developing alternatives, the pros and cons of technical and economic factors are taken into account.

- **Damage to the water distribution system resulting from downed trees and vegetation**

  A current problem is the potential for vegetation to damage the water distribution piping system. The City should evaluate ordinances restricting the planting of vegetation in City-owned rights-of-way to minimize the potential for damage to the piping system. This is a major policy issue that may not be palatable to elected officials or residents.

- **Loss of grid power at facilities**

  The City has already installed back-up power at its water treatment facilities and has added generators for the sewer collection system to help with lift stations. The City has joined Fla-WARN which is a cooperative to share equipment during emergencies. Interconnects with adjacent utilities are also in place. The City appears to have done what is needed to address this potential concern.

- **Catastrophic failure of equipment as a result of storm damage**

  There are limited solutions to catastrophic damage to facilities at the water plant. New facilities are designed to the current building codes, but other facilities may not be designed to this standard. The City should evaluate the buildings to determine if upgrades are required.

Sea level rise is not expected to be a significant issue for any of the treatment facilities owned by the City or County due to drainage from the sites and elevation. Access to piping systems may be impacted in low lying areas (most of the pipes are under the water table at present, but access (valves, manholes, etc are not). However, since the rate of sea level rise is uncertain, the case study team decided the best way to frame the responses was by using milestone intervals for sea level rise. For example, the rise of sea level by up to 1.0 ft will likely have limited impact except in very low lying areas (elevation < 5 ft). However once the sea level increases beyond this level, the potential for water to remain in streets at locations with elevation of 3.0-3.5 ft increases, although Pompano Beach is fortunately located where much of its land area is above 5 ft NAVD (see Figure 3.3 – LIDAR data for Broward County). By the time the water rises to 2 ft above current levels, there are streets in eastern areas that will be flooded most of the time unless pumping facilities are added. By the time water levels rise to 3 ft, the western area of Broward County will have very little soil storage capacity remaining, and canals from the west will no longer flow eastward by gravity, due to their low relative elevation. A solution to this problem will require many more pumping stations than currently exist, resulting in copious amount of water (on the order of billions of gallons per day) with nowhere to be stored or and permit limitations on discharge to the ocean or the Everglades.

The following are issues that could potentially mitigate or delay certain concerns with respect to the impacts of low to moderate sea level rise (0 to 1 ft):

- **Install pumping stations in low lying areas to reduce stormwater flooding**

  This program would first identify low lying areas and then construct pumping stations to deal with increased flooding during storm events. The cost of the stations could vary from $1 to 5 million dollars each, depending on the size of the station, the area served, the time of concentration, and the flow rate expected to be pumped per storm event. Barriers to this solution include the need to acquire appropriate land to locate the pumping stations and costs to pay for their construction and operation/maintenance, but even more problematic may be obtaining environmental permits for discharge of the effluent.

Discharge to the Intracoastal Waterway has been the traditional approach, but with sea level rise, it may be more desirable to discharge further out in the ocean. The National Pollution Discharge Elimination System (NPDES) permit compliance under the Municipal Separate Storm Sewer Systems (MS4) permit of Broward County will need modification and additional monitoring. This situation works as long as the sea level rise creates only periodic or episodic inundation. The solution will likely fail for low lying areas that will be submerged most of the time.

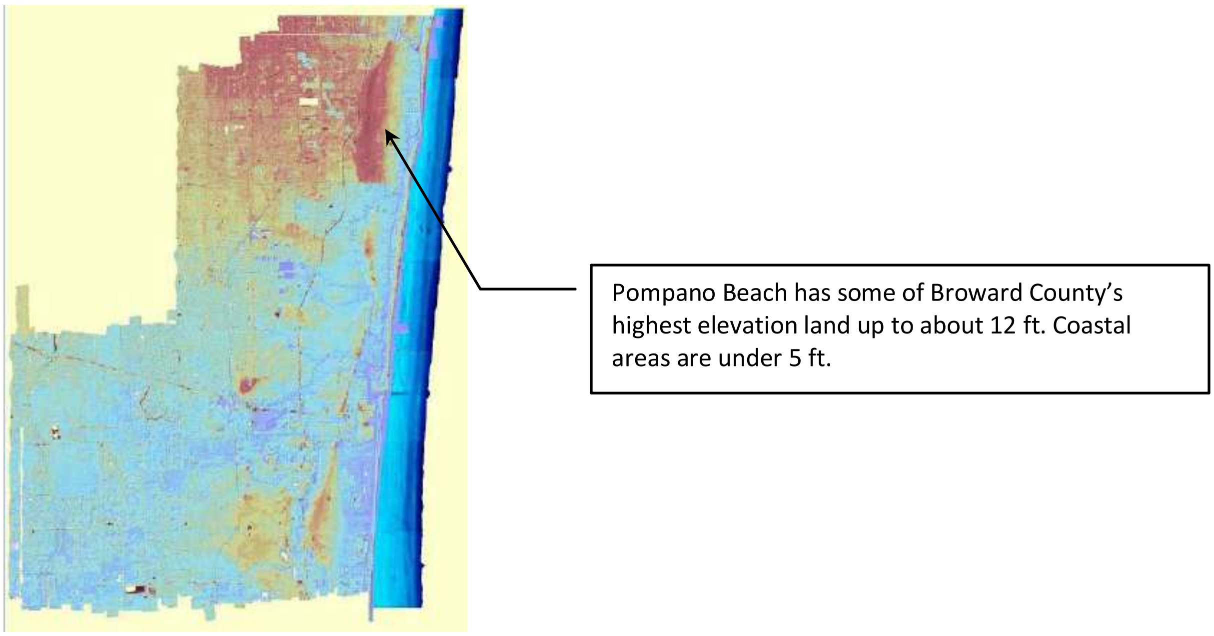

Figure 3.3 – LIDAR data map of Broward County shows areas under 5 ft NAVD in blue, , and potentially subject to more frequent flooding in the future.

- **Water conservation programs**

Water conservation, or the preferred term "water use efficiency," is used to increase the amount of water available for growth from current water supplies. To be effective, water use efficiency should be an ongoing effort since it can take years to achieve significant results. This practice is most effective where growth is limited and there is no driver for immediate reduced demand. Reducing per capita demand has the effect of reducing water consumption, allowing the utility to delay improvements for infrastructure protection and implementation of adaptation measures, in some cases for many years, saving money in present dollars. However, utility revenues are severely impacted when there is a significant drop in demands due to the imposition of water use restrictions, or when growth lags the costs for implementing new treatment and supplies.

Water conservation, or the preferred term "water use efficiency," is used to increase the availability of water for population growth from current water supplies. Water use efficiency can take years to achieve significant results and requires an ongoing effort to be effective. The intent is to modify current user practices to mitigate or delay the need to explore new supplies in the future or to delay the construction of infrastructure expansions. This practice is most effective where growth is limited. In the long-term, water conservation efforts will level off as available technologies are implemented, or until new technologies are developed. Reducing per capita demand reduces water consumption, allowing the utility to delay capacity expansion, in some cases for many years, saving money in present dollars. However, where rapid growth is occurring, gains from water conservation may not be able to match increased demand. Another advantage of conservation is that it changes use habits, reducing demand and improves safety margins during periods of drought. Reduced withdrawals from wellfields can reduce the risk of saltwater intrusion.

From the standpoint of utility economics, capacity under-utilization due to reduced demand decreases revenues that cannot be offset without cost increases, since water plants have significant fixed costs such as debt service, amortization of capital, and administrative expense. Most water plants operate with lean staffs that cannot be reduced except minimally in some cases. Therefore, effective conservation programs may require the utility to increase rates or impose surcharges on the public to meet bond covenants and legal requirements. This can create negative public response by penalizing good behavior, i.e conservation. Furthermore, capacity underutilization can cause operating problems requiring increased maintenance including flushing of lines that is contrary to the goal of conservation. These problems are diminished as population growth increases demand, capacity utilization, and revenues.

Non-emergency water conservation program tools that are commonly employed by most utilities (as a result of permit requirements) include:

- Meter reading/water billing
- Inverted block water rates (pay more for higher use)
- Leak detection and repair of faucets, toilets, pipes, etc.
- Pressure reduction to the distribution system to reduce water use
- Regional SFWMD-imposed irrigation restrictions and daytime watering bans (to reduce evaporation loss)

Other options that some utilities pursue include:

- Educational outreach programs, billing inserts, etc. with tips for how to conserve water
- Seasonal water rates
- The SFWMD offers grants up to $75,000 for water conservation. These grants are mostly for migrating away from potable water use and changing plumbing fixtures.
- Distribution system leak detection programs

Recent changes in the Florida Building Code, plumbing section, require high efficiency water fixtures and rain sensors with automatic shut-off devices in new construction and major renovations. In addition, according to the Broward County water use efficiency study (Bloetscher et al. 2009), the most cost effective programs likely to help the City of Pompano Beach (which is served in part by the County) are:

- High-efficiency clothes washer rebates
- Ultra low flush (ULF) toilet rebates

Other strategies for consideration include:

- Water-efficient landscaping (NatureScape Broward, a County Xeriscape initiative) using native drought-resistant and pest-resistant plants, irrigation evaluations, and rebates.
- Installation of rain sensors, automatic shut-off devices, soil moisture sensors, and other control devices to prevent over-irrigation.
- Rate adjustments, especially with regard to increasing the differential between the water usage billing tiers ($1.71/1000 gallons vs. $2.88/1000 gallons for the two tiers in Pompano Beach). However, as is the case for most utilities in Broward County, water use for the second tier is currently less expensive than first tier water because sewerage charges are charged based on water usage but capped at the first tier – the second tier pays no sewer charges.

The costs to implement a water conservation program vary depending on the goals and the specific strategies implemented. For example, for Pompano Beach which has about 35,000 households, a 10%/year participation in a rebate program for replacing 2 toilets per household would cost up to $3.5 million/year depending on how much of a rebate is provided, and how much follow-up is needed. Washers, irrigation modifications, and other solutions, based on the Broward County water use efficiency study (Bloetscher et al. 2009), could add up to $1.75 million per year, and public outreach programs could cost over $1 million per year. Hence there is significant investment, which should be compared to the cost of capital expansions to treatment facilities.

- **Armoring the sewer system ("G7 Program")**

Inflow reduction is important not only from the cost savings in the operation of the wastewater treatment plant, but because a portion of the collection system may be inundated as a result of sea level rise. Therefore the inflow in this case will be largely salt water, which will reduce the potential availability and beneficial uses of reclaimed wastewater because the chloride concentration will be too high for land application without reverse osmosis treatment. As a result, by pursuing an effective infiltration and inflow reduction program, the need for advanced, expensive treatment for water reclamation can be avoided initially. Both USEPA and FDEP have considered the G7 program for solving these problems. The G7 program consists of the following:

- Inspection of all sanitary sewer manholes for damage, leakage, or other problems
- Repair of benches in poor condition or exhibiting substantial leakage
- Repair of manhole walls in poor condition or exhibiting substantial leakage
- Repair/sealing of chimneys in all manholes to reduce infiltration from the street during flooding events
- Installation of dishes in all manholes to prevent infiltration
- Installation of LDL® plugs where manholes in the public right-of-way or other portion of the utility's system may be damaged
- Smoke testing of sanitary sewer system
- Identification of sewer system leaks, including those on private property (via location of smoke on private property)
- Low flow inspection events
- Documentation of all problems areas, locations, and recommended repairs
- Manhole inspection and dish replacement (for manholes where repairs have been made previously and only the inspection and dish replacement occurs)

The costs for this type of program will be on the order of $500 per manhole (a total of $2.3 million for Pompano Beach) plus repairs to at least 15% of service laterals (2,300 at a cost of up to $500 each). The program could be funded with State Revolving Funds (SRF) or other sourcing of borrowing, but ultimately should be part of on ongoing maintenance program. Repairs to pipes and laterals are estimated to add another $10 million based on experience elsewhere. These repairs should be followed-up every 5 years. The benefit of this program is that is would keep excess water out of the sewer system, especially saltwater from inundated areas. The drawback is the ongoing maintenance costs, but this program has a low initial cost and high rate of return compared to other options. If inundation of roadways occurs as a permanent issue, those affected areas would likely need to be abandoned, since there is no fail-safe way to prevent water from seeping into the sewers under these conditions.

- **Additional reclaimed water production**

Irrigation has long been a significant water use in south Florida, especially during the winter/spring dry season. Reclaimed wastewater is a useful replacement for industries (i.e. cooling tower water) needing water of lower quality compared to other users in a given basin, such as agriculture. Water supply quality for human (and ecosystem) use is higher than those demanded for industrial, agricultural, or irrigation use. Reclaimed water rules are designed to provide water to match evapotranspiration rates for a given area, so that the needs of agriculture, golf courses, residential lawns, municipal medians, etc. can be fully met with regulatory application rates. Such uses could replace irrigation wells in Pompano Beach and many other communities. In and of itself, this alone accomplishes a reduction in the competition for groundwater supplies, and is a strong reason to pursue reclaimed wastewater projects. –. Reclaimed wastewater use requires proactive regulatory encouragement to supplement or replace groundwater use for non-potable purposes in developed areas. However, SFWMD rules do not provide water credits for displacement of irrigation wells, which if offered, would increase incentives. For many years there have been ongoing discussions to allow credits to utilities for providing reuse to former large groundwater uses, but the issue remains unresolved.

The benefit in the short term is that the utilization of reclaimed water could increase available potable water supplies. The cost of implementing reclaimed water use systems is $3-5/gallon in capital costs for standard filtration, enhanced disinfection, storage, and pumping. This estimate does not include offsite piping. The cost of providing a separate distribution network to the customers is on the order of $250,000/mile. Pompano Beach has an existing reclaimed water distribution system that is used for irrigation of the municipal golf course, so extensions will be required to service new customers. The current issue is where additional reuse can be employed within the City boundaries because of an absence of potential large users to justify the enormous capital costs for network expansions. The City is also investigating the possibility of employing a fast rate infiltration trench for use of large quantities of reclaimed water as a defense against saltwater intrusion. The current water use permit requires that an additional 3 MGD of reclaimed water be delivered by 2016.

The quality of the current reclaimed wastewater is acceptable for irrigation. However it is not acceptable for either potable purposes or for indirect potable reuse, both of which are specifically identified in Chapter 62-610 FAC. The potential for indirect potable reuse projects requires full treatment under the rules. The cost for upgrades to meet the guidelines that call for reverse osmosis treatment, advanced oxidation, and other treatment processes, can approach $5-10/gallon in capital costs, and $3-5 per 1000 gallons treated beyond secondary treatment. The City anticipates another 5 MGD of treatment, which would mean that the City would need to invest over $25 million for these capital upgrades if required by Chapter 62-610, as anticipated. If the City can successfully argue that the trenches are not indirect potable reuse, these costs could be avoided.

A major issue with implementation of reclaimed water has been the cost. The cost to distribute reclaimed water to irrigation customers is significant. The costs for engineering, construction, and other services for a reclaimed water distribution network are estimated at $6000 per single family household (about $75/ft of pipe, which is the same as for a water distribution system) and the costs to filter, super-chlorinate, pump and store reclaimed water is similar to the costs for lime softening ($2/1000 gallons). On-site wells cost pennies per thousand gallons, so there is little financial incentive to convert from on-site private wells to a public reuse system. The Florida Legislature realized that there was no financial incentive to make the change to reclaimed water and recognized the potential for local utilities to take advantage of mandatory connection requirements. As a result, when the Legislature approved legislation requested by the City of Hollywood to require connection to reclaimed water, they indicated that the expectation was that the costs the City charged for reuse should be more on a par with well water, the true cost of reclaimed water.

Regarding climate change, as sea level rises, the water table elevation also increases, and the capacity of soil to store water is reduced. The loss of soil storage capacity increases flooding propensity, even with smaller rainfall amounts. Reuse could compound flooding because applying reclaimed water to saturated soils would reduce capacity for absorbing rainfall, particularly in the summer months, leading to more flooding. The result could be flooding even in areas that do not currently flood 30-70 years from now. Therefore, reuse makes sense as a near to mid-term option for the City, but one that may need to be reconsidered in light of the prospect of future sea level rise

- **Aquifer recharge/salinity barriers**

Reclaimed wastewater can also be used for aquifer recharge and/or salinity barriers, with appropriate treatment and placement. Water Factory 21 (Orange County, CA) supplies artificial recharge in this manner, and this application was investigated including a risk assessment in Hollywood, FL between 1994 and 1999. The projected costs of full treatment and potential permitting delays ended the project. The salinity barrier concept works by raising the groundwater table a small amount to increase the groundwater level gradient to slow the migration of the saltwater intrusion front. The concern is the potential to reduce soil storage and increase flooding in low lying areas. Permitting of this option could take 10 years based on prior reviews by the City of Hollywood and Miami-Dade County. Because of the City's ongoing battle with saltwater intrusion threatening its easterly wellfields, it is already planning a pilot test of the concept in cooperation with County hydrologists who are performing modeling studies. The City's approach would be to use infiltration trenches to stem the tide of saltwater intrusion.

Artificial recharge for indirect potable purposes may be viable if the salinity structures are constructed nearer to the coast and the reuse is applied directly toward capture by potable water supply wells. The cost of this option could be as much as $10/gallon ($200 million) depending on the amount of water treated by reverse osmosis. Like the reuse discussion above, reuse in any form may create more flooding in the future with sea level rise, and therefore may be only a temporary solution.

More significant steps should be considered if sea level rise rises above 2 ft. The City should review these issues early for feasibility, so that a viable implementation plan can be developed. Any plan will likely include structural changes to the canal system in south Florida, which is controlled by the SFWMD.

- **Desalination**

  Pompano Beach does not currently treat seawater or brackish water for potable water consumption purposes. However, because they possess an existing nanofiltration membrane facility and on site deep injection well capacity, there is the potential to upgrade the membrane facility to reverse osmosis to treat alternative brackish water sources in the immediate future. A Floridan aquifer production well for 1.5 MGD would cost the City about $500,000 to install. The current membrane facility could be upgraded with new membranes and more powerful pumps to treat the brackish water. Modifications to the Pompano Beach membrane plant would cost $750,000 per MGD. The benefit is that existing infrastructure is available, the water supply might be more secure, but costs to operate will be higher, on the order of $0.50/1000 gallons treated, based on increased pumping pressures, membrane cleaning, and pre-treatment. A major concern with this option would be the significant drawdowns that have already incurred in Floridan sources being used by neighboring utilities (i.e. Hollywood, Fort Lauderdale, and North Miami Beach). There is potential for water quality to degrade with time as a result of hydraulic pressure from the ocean. Since the Floridan is a confined aquifer, there is essentially no vertical recharge from the surface – so recharge can only occur horizontally. Uncertainty about the long-term viability of the Floridan aquifer is a major concern.

- **Controlling flooding west of the coastal ridge**

  Areas located west of the coastal ridge will find it more difficult to drain stormwater as sea level rises. These low lying areas currently drain because the land is 2-4 ft above mean high tide, and therefore it flows eastward by gravity via the canals. With a 3 ft sea level rise, this will no longer be the case. As a result it will be necessary to install pumping stations to move this water out of the low lying areas. Moving water east will be difficult, so pumping west, over the dike into the Everglades may become an option that receives consideration. This approach would present significant environmental regulatory hurdles due to water quality requirements in the Broward County codes and for discharges to the Everglades. Permitting would be a major challenge under the current regulatory environment. The cost of the pumping stations could vary from $1 to 5 million dollars each depending on the size of the station, the area served, and the total volume required to be pumped per storm event. Other barriers to this approach include land acquisition to locate the pumping stations and costs of construction and operation/maintenance.

  In addition to the pumping stations, the stormwater would likely require treatment for nutrient removal (phosphorus and nitrogen) and removal of other urban runoff contaminants such as petroleum hydrocarbons, litter, pesticides/herbicides, suspended solids, etc., which will be costly. Thus permitting discharges to the Everglades would be a major hurdle, but it is suggested here as a possible alternative considering that discharge to the ocean or the Intracoastal Waterway will also be more problematic as the sea rises.

Storage of water in regional reservoirs (like the proposed C51 system) could be a viable option for additional water supply as it could capture water otherwise lost to tide from the Hillsboro Canal. This concept is undergoing vigorous evaluation by a regional coalition of utilities in Broward and Palm Beach Counties and is under review by both counties and the SFWMD. There are significant technical and economic issues ($360 million), including how best to convey the water from the proposed reservoir site to the utilities. The approach being considered involves cascading the flow through Conservation Areas 1, 2, and 3. Pompano Beach, being located relatively close to the Hillsboro canal could be a significant beneficiary of the project, if it comes to fruition.

The C-9 and C-11 impoundments to capture stormwater in west Broward County are planned as part of CERP. The impoundments will virtually eliminate pumping runoff into Conservation Area 3, drastically reducing phosphorous contamination of the Everglades, and enable recharge of the aquifer by water that would otherwise be lost to tide.

- **Central sewer installation in areas with septic tanks and on-site sewage treatment and disposal systems**

  As sea level rises, operation of existing septic tanks and OSTDS will not work properly as rising water tables will submerge the drainfields. An FAU study (Meeroff et al. 2008) quantified the pollutant loading contributions with regard to nutrient and pathogen indicators from a single family residential neighborhood served by OSTDS located adjacent to coastal canals in Dania Beach, FL. Pollutant loading was compared to that in a similar residential area serviced by sanitary sewers in Hollywood, FL. Field studies of the paired sites were conducted during the seasonal high water table and seasonal low water table events. The concept is similar to what might happen with sea level rise. During the wet season, the coastal waters were impacted by OSTDS contributions, but the OSTDS appeared to work effectively during the dry season when the water table was at its lowest. This indicates that septic tanks operate properly during low water table periods, but the contributions by OSTDS to coastal pollutant loading are measurable when groundwater table elevations are relatively high. This suggests that once sea level rise reaches a certain threshold, septic tanks will no longer work properly under any conditions. Within the City of Pompano Beach, FL there are a limited number of septic tanks. The cost of transferring those properties to city sewers would average $10,000 per connection and would likely be assessed against the property owners. The total cost is estimated at under $20 million. Treatment plant capacity impacts will be negligible because the number of septic tanks in the City is minimal.

- **Closing of private irrigation wells in the Biscayne Aquifer**

  Private residential and agricultural uses exceed those of the urban uses in southeast Florida. At present time, the SFWMD does not regulate wells on private property at the present time unless they exceed 100,000 gpd. Many residents in Pompano Beach use private wells for irrigation. These wells are typically 20-30 ft deep. Water at this level is currently fresh, but if sea level rises, there is potential for saltwater intrusion, especially for wells located near the coast. The City should consider pursuing policies to prevent or otherwise limit irrigation from private wells, but will need to plan for increased demands by the citizenry for irrigation from potable or reclaimed wastewater. Politically, closing private wells is difficult to implement since operating a private well is deemed a property right by many residents and would be unpopular to impose. Furthermore, the City would not be able to acquire the water use rights for the equivalent demand.

It should be noted that where reclaimed water is available, the use of private wells is prohibited. In addition the City perceives that many of the eastern private wells are slowly becoming salty, and are being abandoned in favor of reclaimed water or potable water use. In addition, where wells become contaminated, the concept of decentralized rainwater harvesting is another option that might be pursued to replace private irrigation well water. This approach would spread out the capture of stormwater rather than construction of giant reservoirs, but this type of system would be much more difficult to control and maintain and would be more applicable to dealing with irrigation under the current regulatory environment. However, private property owners would be expected to pay the cost, which is only appropriate since they would directly benefit from such a system.

- **Relocating wellfields**

The Biscayne aquifer is located adjacent to Florida's southeast coast and is vulnerable to the effects of sea level rise. The highly managed water control system in south Florida has permanently reduced groundwater levels along the coast, which has enabled the development that exists today. During the winter months, the surficial aquifer's water level usually declines unless some form of supplemental recharge (traditionally diversions from Lake Okeechobee or unusually high winter rainfall) to prevent the aquifer from draining. Since the level of water in the Everglades is related to the water available in the Biscayne aquifer, reduced groundwater levels, combined with lessened historical flows to the Everglades result in less water standing in the Everglades during the summer (wet season) months (and dry in the winter). The net result is a reduction in available fresh water supplies during the dry season, which coincides with the increased winter population and peak irrigation season.

The City's eastern wells have potential issues with saltwater intrusion and are already under restricted use. Movement of wells to areas where water supplies are more plentiful and recharge capacity is larger should be evaluated. In the long-term, policies on Biscayne aquifer water use should be re-evaluated considering the effects of rising sea level and water table. The cost to relocate wells inland is approximately $1 million per well plus piping. For relocation of 20 MGD, this cost is likely to exceed $20 million, and may be difficult to permit under current SFWMD water availability rules. At the moment, brackish Floridan aquifer wells are a more cost effective (and easier to permit) solution (see desalination discussion above), but the long-term reliability of the water quality and quantity is uncertain since local recharge is not available. The cost for treatment of brackish water from Floridan wells significantly exceeds the cost to treat fresh water from the Biscayne aquifer wells.

The one option that has the potential to expand water supplies in the Biscayne aquifer, especially east of the salinity structures, may be horizontal wells. Horizontal wells are categorized by some state agencies as surface water sources because of their proximity to rivers and reliance on induced infiltration and must meet surface water treatment requirements. The cost of a horizontal well is $1 million per million gallons. The cost is higher than a comparable vertical well, but the potential to capture additional water is higher. It may take 5 – 10 years to implement and test this option, based on current SFWMD rules. Ongoing testing of horizontal wells is set to start in Dania Beach in 2009/2010.

- **Installation of additional salinity control structures closer to the Intracoastal Waterway**

The closest salinity structures to the coast in Pompano Beach are located west of Federal Highway, about three miles inland, none of which appear to directly affect water levels in the City. However, there are four salinity structures that might have value for modifications to increase stages. Structures G65 and G57 are on the C16 canal, and S37B and S37A are on the C14 canal (see Figure 3.4). Increasing the level of water in these areas would tend to raise the water table underneath Pompano Beach and in the surrounding areas, potentially creating flooding impacts that need further evaluation The City would likely need to participate with other entities to enact these solutions.

In addition, the City could evaluate the potential to locate a salinity structure further to the east on the C14 canal near Federal Highway. This would be of benefit to the area between Federal Highway and the City's eastern wellfield. The cost of a lock structure would be less than $5 million, but this would offer no help east of Federal Highway (US 1). A structure on the Hillsboro canal could be investigated further, but its distance from Pompano Beach makes it less beneficial than the C14 basin. This idea is likely to generate stiff resistance from property owners in the area because of the conflict between private property rights versus regional water supply needs. Furthermore, securing changes to canal stages, or constructing a lock structure might take around 20 years to implement since other agencies (permitting) and municipalities to the west of the City will be impacted.

If sea level rise increases above 2 ft by 2100, structural changes to the hydrologic cycle in south Florida will be required. Irrigation will be decreased because of the potential for flooding. Many new pump stations will be required for flood control – perhaps hundreds both along the dike and on the coastal ridge. Desalination and relocation of wellfields (or conversion to horizontal wells) would need to be evaluated. Private wells, septic tanks, and abandonment or major replacement of certain parts of the sewer system would need to have occurred at this point. Storage of water in regional reservoirs and impoundments could be an option in for increasing water supplies and as catchments for stormwater. Reuse practices will need to change. Two suggestions are:

- **Regional Wastewater Disposal Participation**

  On a more regional level, there may be a useful option to pursue. The major goal of the Comprehensive Everglades Restoration Plan (CERP) project is to retain more water in the Everglades. In addition, one of the options to improve water supplies in southeast Florida is to evaluate regional reverse osmosis plants that would treat reclaimed wastewater and send that water westward over the dike to surface waters for recharge. The concept would require participation of local utilities. As noted in the main report, this option may be more cost effective than reuse on a local level and would provide a better long-term solution that does much for the protection against saltwater intrusion from sea level rise and also Everglades Restoration. This option would require a major redirection of sanitary sewer flows, a major re-plumbing of the sewer systems throughout the area, and a major revision of current permits (water and sewer). This option would eliminate a number of eastern wastewater disposal solutions (i.e. ocean outfalls, injection wells, and/or reuse) in favor of the regional solution. The City of Pompano Beach for example, would no longer treat reclaimed water as the flows in the current outfall pipe would be redirected (and permits would need to be adjusted to reflect this participation). There is significant cost to this option and participating utilities would be expected to participate, although the costs may be embedded in rates as opposed to capital costs. The cost for the capital portion of a regional plant to Pompano Beach might be $200 million, plus sharing of operational costs. Timelines for this option are probably 30 to 70 years out. The benefit though is there would be more water in the Everglades, which would indicate that there is more recharge to the Biscayne aquifer. The quid pro quo would be to permit utilities to pump more Biscayne water in the future, which comports with the long-term needs as a result of sea level rise.

- **Aquifer storage and recovery (ASR)**

  ASR projects in Southeast Florida involve injecting freshwater into brackish water aquifers. An ASR well that recovers 40 percent of the injected water with current technology is considered successful (Bloetscher, et al 2005). Only Boynton Beach's system has been successful to date. Neither Fort Lauderdale nor Broward County's attempts at ASR have been successful for a variety of reasons, including potential casing of the appropriate injection zone. Miami-Dade County efforts have not been successful either. ASR does not seem to be a useful direction to pursue for potable water supplies.

  While potable ASR does not seem very promising, the use of ASR for impaired waters might still have value. The withdrawn water will have elevated chlorides, but there is potential to reclaim that water for irrigation or emergency purposes. The option would be to store excess reclaimed and/or stormwater that could be recovered during dry periods and treated with reverse osmosis to produce irrigation supplies or supplies to be used in the

City's proposed salinity barrier project. Major permitting hurdles must be cleared due to the potential for mixing of waters with impaired quality with potable water supplies, which is not allowed under the current rules.

Even if the waters are recovered for potable use, an argument can be made that the impaired water will need to be treated with reverse osmosis when recovered, but treating twice with reverse osmosis makes little sense. Reclaimed water ASR wells were permitted for the upper Floridan aquifer on the Gulf Coast of Florida (Englewood and Tampa, which were subsequently abandoned). FDEP requires extensive testing to demonstrate the feasibility of this option. It has potential for longer-term water supply solutions as sea level rises and reuse for irrigation is no longer practical because of loss of soil storage capacity. Costs would approach $30 million (in current dollars) for the wells and piping necessary to accomplish this option. These costs assume that reverse osmosis treatment would be available on site and that 80% recovery could be achieved.

A problem to overcome is backpressure. ASR wells have similar limitations in that injection is generally limited to 1 MGD. The density difference will cause the fresher water to rise to the surface of the formation, making withdrawal of saltwater more likely. This option would not work for significant storm events, which generate more than 1 MGD of stormwater runoff, so to store this additional water, a Class I injection well would be needed (15 MGD), which carries a significant cost ($6 million each) plus an ongoing maintenance and monitoring concern. It is important to remember that this water is not stored - it is purely a disposal option.

3.3 Other Issues

The following issues are discussed in context to the Pompano Beach case study only. As a result, they do not necessarily apply to other coastal areas because of South Florida's unique geology, hydrology, topography, ecology, and urban land use. On the other hand, there are a number of issues that do not appear to offer much relief to the City in this case study. These include:

- **Statewide ban on Phosphorous**
  This is a water quality issue rather than a water supply issue. It has little effect on utility operations, but from an ecosystem perspective, removing phosphorous from wastewater would be useful and potentially facilitate discharge of reclaimed wastewater and stormwater overflows over the dike to be used for Everglades Restoration. However, it is costly to reduce phosphorous to the levels desired by regulatory agencies for use in the canals or Everglades. The cost of such nutrient removal facilities would certainly exceed any impacts of banning phosphorous. However, the phosphate industry in Florida is very powerful and would resist such a ban.

- **Regionalization of Water Supplies**

  The Regional Water Availability Rule suggests regionalization of utilities as an alternative water supply option. Since Pompano Beach is one of the larger utilities in Broward County, it is likely be one of the eventual regional utilities. As a result, the only regionalization solution could be bulk service transfers with nearby Broward County and Fort Lauderdale utilities. The cost for the water would likely be less than expansion (under $2/1000 gallons). This approach does not address the need to develop new water resources and the challenges presented by climate change. Therefore this is not truly a solution for the City.

- **Protection of recharge areas**

  This has limited value since the City is mostly developed and has very little undeveloped land that could be used for recharge.

- **Moving wellfields west of the coast to avoid saltwater intrusion**
  This is of limited value under the current SFWMD resource allocation rules. The rules would need to be reversed in order to benefit the City. It would be useful for the SFWMD to consider such a change, since pumping more Biscayne water would serve to increase soil capacity and reduce treatment costs by avoiding the need for reverse osmosis.

- **Pumping water to the Everglades**
  This is not useful to the City since there is no direct access to the Everglades. Furthermore, the City does not have (nor is it positioned geographically to have), a wastewater plant that could be used for this purpose.

If sea level rises above 3 ft, wastewater reclamation and other programs may become unworkable. Much land will be permanently inundated and enough soil capacity will be lost that irrigation will essentially cause ponding of water. The ability to drain the area would be severely limited. Flooding from storm events could be catastrophic. Customers will likely flee the City as private property cannot be adequately protected from high water. Building an eastern dike along the coastal ridge to protect the western areas and make a New Orleans-style bathtub would appear to be cost prohibitive because the dike would need to be over 150 miles long, and wrap back to the dike west of the urban corridor.

4.0 IMPLEMENTATION

For the City of Pompano Beach, the effects of climate change were evaluated and a series of suggested alternative steps identified. Climate change effects with regard to storm events and rainfall are relatively short-lived and involve mostly flooding of streets and property. With climate change, severity of storm events will worsen current problems. Pumping stations are appropriate engineering solutions to address episodic flooding. However, because of the location of the City and its low elevation, sea level rise is likely to create more significant and more constant flood control issues, while exacerbating the need to address storm impacts. Limited impact on the water treatment plants is expected, although piping system in low lying areas are threatened. Sea level rise will diminish the amount of soil storage capacity in the City, which will directly impact the amount of rainfall that can filter into the soil. As a result, flooding will worsen as sea level rises. Smaller storms will cause ponding of water, and flooding will occur more readily. Summer rains will frequently cause floods since the stormwater will have limited ability to move to the sea or evaporate. Hence, more pumping stations will be required. A bigger question is where to discharge the stormwater so that water quality and environmental impacts are minimized. The cost to treat this water is also of concern. As a result, addressing the sea level rise issue, will by its nature, work toward solving the flooding/storm event problem.

Based on the prior section, the City has a series of options it can implement to deal with sea level rise. For the long-term, the City of Pompano Beach has a number of alternatives that it can pursue to harden its water supply infrastructure and protect its vulnerable residents from the impacts of sea level rise. However, rather than dictate a timeline (given the uncertainty with respect to predicting the timing of climate change impacts), it is more appropriate to match the implementation goals to milestone increments in sea level elevation. For purposes of this case study, there are four benchmark scenarios:

1. Minimal risk (under 1 ft)
2. Moderate risk (1-2 ft)
3. High risk (2-3 ft)
4. Extreme risk (over 3 ft)

Table 4.1 outlines the timing of the improvements, appropriate options to pursue, and the estimated costs associated for each of these scenarios. The estimated timeframes are based upon the method described in the main report in Section 4.1 and Appendix C (Heimlich et al, 2009). Estimates of sea level rise versus time and timeframes at which increments of sea level rise may occur are presented in Table 5 on page 31 of the main report.

Table 4.1
Implementation Program

Trigger	Implementation Strategy	Barriers to Implementation	Cost	Point when Action may need to be Abandoned
Immediate 0-0.5 ft Sea Level Rise (by 2030)	Prohibit/eliminate trees in rights-of-way	Political will, resident views	Millions, costs unclear	After trees fall down
	Catastrophic Failures	Costs to upgrade buildings	unknown	Failure or facility
	Install stormwater pumping stations in low lying areas to reduce storm water flooding (requires studies to identify appropriate areas, sites and priority levels	NPDES permits, cost, land acquisition	Start at $1.5 to 5 million each, number unclear without more study	When full area served is inundated (>3-5 ft SLR)
	Water conservation	Budget, staff time, cost, political will	Start at $30 million + $1 million/yr	n/a
	Armoring the sewer system (G7 program)	Budget , recurring expense	$12.5 million start, plus annual cost allocation	When area served is inundated
0.5 – 1 ft Sea Level Rise (by 2060)	Additional reclaimed water production	Budget, lack of application sites in the city; long term frustrates sea level rise protection efforts	Over $25 million depending on permit requirements	Before 3 ft SLR makes soil saturation a problem
	Aquifer recharge/salinity barriers	Regulations for indirect potable reuse, public perception	up to $200 million depending on permit requirements	Before 3 ft SLR makes soil saturation a problem
1 – 2 ft Sea Level Rise 2040-2100	Desalination	Cost, but plant and deep well are already in place	$45-50 million to convert + wells ($750,000 per MGD)	n/a

	Control flooding west of the coastal ridge	Cost, discharge location for water	Start at $1.5 to 5 million each, number unclear without more study – at least a dozen would be need - $25 million	When full area served is inundated
	Central sewer installation in OSTDS areas	Cost, assessments against property owners	$10,000 per household	When full area served is inundated
	Closing of private wells	Private property rights	Cost unknown	n/a
	Relocate Wellfields westward/horizontal wells	Cost, concern over saltwater intrusion east and west, inundation of wellfields, permitting by SFWMD	$20 million assuming locations can be permitted in Biscayne aquifer	When well is inundated
	Salinity/lock structures	SFWMD, western residents, private property rights arguments	Up to $10 million, may require ancillary stormwater pumping stations at $2-5 million each	n/a
Before 3 ft Sea Level Rise (2070-2100)	Regional desalination/aquifer recharge/Everglades	Perception, nutrients, cost	$200 million	n/a – solution to retard sea encroachment
	Aquifer storage and recovery with reclaimed water	Regulations for indirect potable reuse, public perception, assumes desalination in place	Wells are $30 million, unknown treatment requirements	n/a
3 – 4 ft Sea Level Rise (2080- >2100)	Massive groundwater dewatering, send to Everglades	Regulations for redirection of stormwater that likely has high phosphorous levels, public perception, cost	$ billions	n/a – solution to retard sea encroachment
Beyond a 4 ft Sea Level Rise (>2100)	Large areas of the city must be abandoned	Public perception - worst case scenario, likely greater than 100 years out	$ billions	n/a
	Diking	Public perception - worst case scenario, likely greater than 100 years out	$ billions	Total inundation

4.1 Minimal Risk (under 1 ft sea level rise – 20 to 50 years)

A slight increase in sea level (i.e. minimal risk, < 1.0 ft sea level rise) probably would not create significant or difficult to manage, long-term impacts to Pompano Beach, FL. Flooding in low-lying areas may increase, but localized solutions like additional storm water pumping stations can alleviate much of these concerns. Water conservation could benefit the City by reducing the amount of water needed for potable water supply purposes and delaying the need to expand water supplies to deal with growth. The likelihood of increased inflow into the sewer collection system would indicate that solutions should be implemented to protect against sea level rise involving the wastewater system infrastructure. The principal strategies at this stage include: a) the G7 program, b) added reclaimed wastewater use for irrigation to reduce demand on the Biscayne aquifer, and c) water conservation implementation, which could be pursued immediately and probably should be used to stay one step ahead of the issue. Aquifer recharge, salinity barriers, added reclaimed water capacity, and similar options would also be appropriate actions to evaluate at this stage. Once it is determined that sea level rise will reach the 1 ft stage within about the next 30 to 50 years, the City should seriously begin efforts to review the options for: a) desalination for withdrawing water supplies from the brackish Floridan aquifer and b) relocation of existing salinity structures and construction of new salinity structures.

4.2 Moderate risk (sea level rise of 1-2 ft - 30 -60 years)

As sea level rises toward 2 ft, desalination is likely to be the preferred option to address water supplies. Before sea level rise reaches 2 ft, low-lying areas east of Federal Highway and along the beach will flood more frequently, so pumping stations will need to be in place. Farther out west, people will notice that small rainstorms may create significant flooding. The problem will be exacerbated as storm intensities increase and as sea levels continue to rise. Controlling flooding west of the Coastal Ridge will become an important program, but disposal of the water will be a challenge. Installing central sewers in septic tank areas and closing private wells are issues directly involving private citizens that should be evaluated as to their potential to protect water supplies and reuse water quality.

Structurally, the City should consider moving wellfields west or better yet, consider testing, installing, and operating horizontal wells that would skim water off the freshwater lens without encouraging saltwater migration. Appropriate modeling and permitting pursued at this point. To support horizontal wells and reduce the potential for migrating saltwater, salinity/lock structures should be installed in more eastern locations. Easements and private property rights issues should be investigated. It would be beneficial to have any control structures in place before the anticipated 2 ft change in sea level from a control perspective.

4.3 High risk (sea level rise of 2-3 ft – 50-100 years)

As sea level rise increases towards 3 feet, low elevation areas of the City will flood consistently during rainstorms and many low-lying eastern roads may be continuously flooded. The seasonal high tides will exacerbate the situation. Small storms will cause much localized flooding. Pump stations will be proposed to deal with the immediate flooding problem, but pumping will also defeat efforts associated with salinity barriers and groundwater recharge. Additional pumping of the surficial aquifer will be needed to keep water levels low. Certain aquifer recharge strategies will frustrate flood control strategies, as will the use of reclaimed water during the summer months. As a result the City should consider migration away from current reuse efforts towards a reuse ASR system whereby the reuse water could be withdrawn as a raw water supply.

The future ban of ocean outfall use will have to be reconsidered, since it is likely that there will be more water than we know what to do with, and there will be very limited options for disposal in the east. Resuming use of ocean outfalls could be a potential solution. In the west, the alternative may be to treat and discharge stormwater into the Everglades. Canal saltwater structures need to have been constructed and stage adjusted by the time sea level has risen to 3 ft.

4.4 Extreme risk (sea level rise over 3 ft – not before 2085)

If sea level rise exceeds 3-4 ft, large areas of the City may have to be abandoned. Water supply issues for the City will be an extreme challenge for the remaining areas at that point. At this stage, mandatory drawdown of the upper Biscayne aquifer for flood control will be needed to sustain the southeast urban corridor or suffer the consequences of permanently flooded low-lying zones. This water can be used for water supply purposes but will likely be more than is needed (by several orders of magnitude), so the remainder must go out to tide, to deeper aquifers, or to the Everglades to retard saltwater migration up Shark Valley.

Permits and current policies of the SFWMD are also a concern for a number of options. The current policies may frustrate flood protection goals of the City in the future. Policies such as the resource allocation rules, prohibitions on Biscayne aquifer pumping, forced use of reclaimed water by local utilities, the ban on ocean outfalls, and prohibition of discharge to the Everglades would need to be revisited in light of the impacts of climate change. New policies and infrastructure, like regional wastewater solutions, evaluation of stormwater and reclaimed water storage underground, and wastewater disposal strategies are also needed. To facilitate Biscayne aquifer drawdown and stormwater pumping, bans on phosphorous and certain fertilizer practices must be in place to prevent water quality impacts on receiving waters. Likewise treatment for petroleum hydrocarbons, pesticides, and other runoff problems must be in place to prevent pollution from non-point (stormwater and agricultural) sources.

4.5 Conclusions from Discussions with City Staff

Two meetings with the City were held to discuss overall needs of the City and the solutions proposed in Table 4.1. The City identified several issues that were already a part of their long-term vision of water supply: 1) a salinity barrier, 2) reclaimed water replacing potable water for irrigation, 3) maintaining the Biscayne aquifer water supplies, and 4) regional solutions like the C51 reservoir. All of these are issues identified in Table 4.1, under the scenarios in which sea level rise remains less than 2 feet. The City staff agreed that major shifts in regulatory objectives are needed to move beyond this point.

To illustrate the point, City staff identified several issues that are important: 1) timing, 2) short-term water supply goals, 3) current operating practices, and 4) permits. The first two issues are intertwined. The planning horizon for climate change is much longer than the planning horizon for permitting water supplies and for political interests. The goals of two different planning periods may not reach the same conclusions, and may not appear complementary, especially when one has significant uncertainty associated with it (climate change). As a result, short and long term goals must be kept in mind even though they may conflict.

The City was particularly focused on reuse. The near-term and mid-term goals for reuse are most closely associated with the permitting process. These permits are required to maintain water supplies in accordance with their 20 year consumptive use permit. However, in the long-term, the potential for sea level rise conflicts with this goal. Therefore the concern is that if the decision-makers view reuse as a long-term concern of sea level rise, without a timeline associated with this impact, they may halt the current (shorter-term) efforts upon which water supplies for the next 20 years are based. This would create a major issue for planning and management of existing water resources. Hence the City staff insisted on association of the planning benchmarks with the trigger period timelines as shown in Table 1.

The uncertainty of permits is related to decision-making and planning as well. For the City, the uncertainty about the viability of the Floridan aquifer to supply long-term water supplies was noted as a concern and a reason they have not pursued that water source. At the same time, the potential for indirect potable reuse may arise as a barrier to their reuse program, as envisioned currently. Discharge of water to the coastal ocean, canals or the Everglades are perceived to have significant water quality barriers to implementation. In any case, permits are not likely to come in the short term without significant changes in regulatory perspective.

4.6 Concluding Remarks

Costs to south Florida residents are a major concern in all alternatives discussed in this case study and in discussions with the City staff. Cost and affordability of water supplies in the future are concerns. Short-term implementation of significant restrictions to water use creates major financial hardship for the utility. Therefore the utility is put in the situation of penalizing their customers for water conservation by raising their rates. This results from a misunderstanding of how the utility operates and is funded. Furthermore, it is politically difficult to explain. Water conservation needs time for the system to “grow into” the reductions, or the above concerns arise. Unfortunately the City has recent experience with needing to raise rates due to lesser demands.

Long-term, the lack of regional water supply planning and uncertainty creates concerns. Affordability of water and sewer may limit the amount of money that can be borrowed to address water supply and treatment needs. Utilities are already talking about average water bills exceeding $200 per month for the typical user within 10 years. This may fail the affordability test most banks use when loaning money. Flood and storm insurance rates would also be unaffordable for all but the wealthiest people. Lending agencies often consider 3.5 percent of the average household income to be the limit of water and sewer costs. Costs for borrowing, and the potential risk to the lending agencies, rises beyond this amount. In addition, water costs may also impact commercial and industrial business growth and the overall economy of the City, with significant adverse impacts to the local communities.

A final issue is education of the public and elected officials. The long-term plan toward the future water supply picture is incomplete as best, which causes "starts and stops" by utilities and permitting agencies as to the components of long-term plans. Untested applications that appear to offer cheaper solutions (like ASR around Lake Okeechobee) are often pursued, which has the adverse impact of putting utilities in a "holding pattern" for years and jeopardizing permits. The lack of ability to rely on permits, water use allocations, and the ecological system in southeast Florida creates more uncertainty than can be managed efficiently. As illustrated by the Pompano Beach example, solutions to the process require far more regional reliability, respect and cooperation that currently exists, especially between the regulatory agencies and the utility community.

The City of Pompano Beach is better positioned than some utilities. Its plants are located several miles form the coast, on relatively higher ground, on sandy soils which reduces the potential from storm flooding events. The plants have back-up power to cover grid failure. These systems are tested regularly. Higher temperatures will increase irrigation, which will be met through water conservation, revisions to landscaping and reuse. These measures are already in place. Rising seal levels pose a significant long-term risk to the utility, especially piping in low lying areas.

The discussions with the City revealed a number of ideas that could be pursued: 1) a better evaluation of regional water supply issues to include the appropriate use of large amounts of storm water and reclaimed water to maximize beneficial use; 2) an attempt to maintain water supply in the Biscayne aquifer, with the Floridan aquifer as a backup source; 3) as a related issue, treat water with reverse osmosis only once – preferably treat the wastewater this way and use if to recharge the Biscayne aquifer to that freshwater is treated for potable water supply purposes – the change in viewpoint could bring significant savings in the long-term projected demands for power usage in southeast Florida; 4) evaluate what population changes may bring to southeast Florida as migration may start well before 2100 – the issue is how will this alter the water supply program; and finally 5) the need for education and discussion to achieve a long term program that does not cause limited financial resources to be spent for purposes that conflict with the long term water supply goals of the region.

Ultimately the worst case scenario for significant sea level rise is a retreat scenario. There are catastrophic economic impacts of retreat, including the likelihood that the majority of businesses in South Florida would relocate outside of the State, and create a significant impact to Florida's overall economy. While addressing the economic drivers of the mass exodus scenario is beyond the scope of this evaluation, it is imperative that a long-term evaluation of solutions be conducted to prevent the expenditure of public money for alternatives that will not provide solutions to the potential climate change impacts set forth in this study.

For the most part, the WTP in Pompano Beach is not especially vulnerable to climate change per se other than risk of flooding and power failures because they have back-up power and are on higher ground, but the major concern is vulnerability of their raw water supply and the distribution pipelines, which is why the report focuses primarily on external issues like vulnerability of wellfields, distribution systems, etc. It should be noted that this evaluation is for the Pompano Beach utility only. The findings may not be applicable to many other utilities in southeast Florida and will not be applicable to utilities in other areas of the world. Because of the regional nature of many recommendations, it is suggested that local utilities and regional entities undertake a similar evaluation to determine what regional solutions could be implemented to harden utility systems for all residents.