Ocean Outfall Study

FINAL REPORT

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Executive Summary

The purpose of the study was to evaluate the status and efficacy of effluent management options for the six municipal facilities in Florida's Palm Beach, Broward and Miami-Dade Counties that discharge secondarily treated wastewater through ocean outfalls. Urban water requirements in this region are rising due to rapid population growth, while water supply problems loom due to uncertainties in the time-phasing and funding of water resources projects. Southeast Florida's natural and artificial reef resources—some located near the outfalls—provide habitat and protection for marine organisms and contribute over 61,000 jobs and $1.9 billion in yearly income for residents of the three counties. An underutilized water management option in the region is water reuse, which could help Southeast Florida meet its water requirements while decreasing or eliminating reliance on ocean outfalls. The State has a reuse capacity of 1.2 BGD and expects to reclaim and reuse 65% of all domestic wastewater by 2020, up from 40% today. The study reviewed previous work describing the effects of ocean wastewater disposal on ocean biota and human health risks as well as past examples of obstacles and successes of water reuse in Florida, the U.S. and abroad. Four alternative ocean outfall strategies—involving varying degrees of reuse, nutrient removal and ocean outfall use— were considered. The alternatives were evaluated at each wastewater treatment plant according to four performance measures: 1) amount of freshwater saved relative to a base case with no reuse, 2) reduction in nitrogen and phosphorus discharged via ocean outfalls relative to the base case, 3) public acceptance, and 4) costs. Management recommendations based on these evaluations are presented.

Current and projected flows at the six wastewater treatment plants (WWTPs) are compared to their permitted capacities in Exhibit ES-1. The 2025 wastewater influent flow exceeds the 2005 permitted capacity at each WWTP; thus all of the facilities face important decisions regarding their future wastewater management options. According to current plans of the utilities, 7% of the total wastewater handled by the facilities will be reclaimed for traditional (public access) reuse in 2025, up from 4% currently.

Exhibit ES-1. Permitted, 2005, and Projected 2025 Flows at WWTPs with Ocean Outfalls

	Boynton-Delray	**Boca Raton**	**Broward/ North**	**Hollywood**	**M-D/ North**	**M-D/ Central**	**Total**
Permitted flow (MGD)	24.0	17.5	84.0	42.0	112.5	143.0	423
2005 flow (MGD)	19	16	84	40	108	129	396
2005 reuse[1] (MGD)	3.7	5.2	2.4	2.6	0.1	0	14
2005 reuse[1] (%)	19	33	3	7	< 1	0	4
2025 flow (MGD)	27	22	94	54	126	151	474
2025 reuse[1,2] (MGD)	7.5	15.9	5.3	3.6	0.1	0	32.4
2025 reuse[1,2] (%)	28	73	6	7	0.1	0	7

[1]Excluding onsite reuse for process

[2]Based on utilities' plans extending to 2025

Several studies have been made of the impacts of the outfalls on the ocean. Surfacing plumes are present at all six WWTP outfalls throughout the year. Rapid dilution in the immediate vicinity of the outfall continues for 6 to 41 miles downstream. One of the conclusions of a US EPA relative risk assessment involving deep well injection, aquifer recharge, discharge to ocean outfalls and surface waters as disposal options was that:

> Human health risks are of some concern, both within the 400-m mixing zone and outside of it, primarily because treatment of effluent prior to discharge via ocean outfalls does not include filtration to remove *Cryptosporidium* and *Giardia*. The most probable human exposure pathways include fishermen, swimmers, and boaters who venture out into the Florida Current and experience direct contact, accidental ingestion of water, or ingest fish or shellfish exposed to effluent. Otherwise, there is a very small, but not nonzero, chance for onshore or nearshore recreational or occupational users to be exposed to effluent constituents, since there is a small (10%) chance that currents will change direction to east or west.

Natural and artificial reefs near the six ocean outfalls contribute significantly to the tourist business in South Florida. Recent studies suggest that the outfall discharge at Boynton Beach may be having an adverse effect on Lynn's Reef, but did not establish a link between pollutant discharges and the relative importance of pollutant concentrations at a specific reef. A biomarker study indicates that the reefs have been impacted in some cases. Based on δ15N analyses of macroalgae, sponges and gorgonian corals recently collected from reefs in Palm Beach and Broward counties, researchers believe that sewage nitrogen is a contributor to the nitrogen pool in the area's coastal waters. No complete report is available for this ongoing study. These recent and ongoing studies could provide valuable new insights into the extent of the cause-effect linkage between outfall discharges and impaired reefs in Southeast Florida and indicate whether or not current wastewater treatment levels are sufficient to protect water quality in general and the reefs in particular.

Spatial analysis of the consumptive permit user database in Southeast Florida indicates that large users with individual permits in Palm Beach County and northern Broward County have the highest demands for landscape irrigation. These large users are typically golf courses, parks, and other recreational areas. Miami-Dade County has the highest potential industrial demand. The Turkey Point Power Plant is an example of an industrial user not currently being supplied with reclaimed water. A case study of the area near the Broward/North WWTP indicates that reclaimed water can be cost effectively supplied to larger irrigation users within 12 metropolitan miles (measured along streets) of the reclamation facility.

Four alternative ocean outfall strategies were examined under the defined scope of this study. Under the Currently Planned Use alternative (Alt I), ocean outfalls would be used at currently planned levels. Under the Limited Use Alternative (Alt II), ocean outfall disposal would be limited to flows remaining after traditional reuse options were maximized and underground injection flows reached full 2005 permitted capacity. Under the Ocean Outfalls as Backups alternative (Alt III), ocean disposal would only be used during wet weather periods to handle flow that would otherwise go to traditional reuse. Complete elimination of ocean outfalls was considered under the No Use alternative (Alt IV). The assumption was made that permitted capacities of the ocean outfalls would be maintained at 2005 levels and that no additional ocean outfalls would be permitted. It was also assumed that Class I injection control wells for effluent disposal would be held at 2005 permitted capacities and, furthermore, that Class I injection wells for effluent disposal that were in testing or under construction during 2005 would not receive permits. Current and potential treatment requirements employed in the evaluation of ocean outfall alternatives are summarized in Exhibit ES-2

Exhibit ES-2. Current and Potential Treatment Requirements of Wastewater Management Options

	Treatment requirements	
Option	**Current**	**Potential**
Ocean outfalls	Secondary with basic-level disinfection	Intermediate or full nutrient control with basic-level disinfection
Class I injection wells	Secondary with no disinfection	Secondary with filtration and high-level disinfection
Traditional reuse	Secondary with filtration and high-level disinfection	
Groundwater recharge	Full treatment and disinfection	

The following conclusions and recommendations were reached from the present study:

- Water reuse (traditional and groundwater recharge) offers advantages to Southeast Florida—in terms of conserving water, augmenting available water resources, and reducing discharges to the ocean environment.
- Considering impending water shortages in Southeast Florida, continued use of ocean outfalls and deep injection wells for effluent disposal represents an unsustainable export of freshwater from the region.
- The weight of indirect evidence of reef damage by ocean outfalls is cause for concern and justification for additional actions to address these issues.
- The success of water reuse in large urban areas in the U.S. and abroad indicates that difficulties to reuse posed by the highly urbanized nature of Southeast Florida can be overcome.
- Satellite water reclamation facilities can effectively serve distant users of reclaimed water in regional wastewater systems and improve reclaimed water quality in collection systems impacted by saltwater intrusion.
- Traditional (public access) reuse for the Boynton-Delray and Boca Raton WWTPs could substantially reduce nutrient loads to the ocean. Substantial reduction of nutrient loads from the other four facilities can be achieved through groundwater recharge, since traditional reuse opportunities are more limited in these areas.
- Substantial reductions in nitrogen loads are achievable through intermediate and full nutrient removal technologies. Given the relatively low total phosphorus concentrations in effluents from the WWTPs, only full nutrient removal technology can reduce phosphorus loads. Substantial reductions in phosphorus load will require moving toward either traditional reuse or groundwater recharge.

- The average freshwater savings are essentially equal to traditional reuse volumes under alternatives I (currently planned use of ocean outfalls) and II (limited use of ocean outfalls) and range from 24 to 64% at the Boynton-Delray and Boca Raton WWTPs and from 1 to 18% at the other four facilities.
- Under alternatives III (use of ocean outfalls as backups) and IV (no use of ocean outfalls), average freshwater savings range from 64 to 87%.
- Public acceptance of traditional reuse is expected to be high at all of the facilities because the reclaimed water is used primarily for irrigation.
- Public acceptance of alternatives featuring large-scale groundwater recharge could be moderate or lower. However, public education programs and community involvement throughout the planning, implementation, and continued use of water reuse projects should help mitigate public concerns.
- Trends between costs and the average of percent freshwater savings and nutrient load reduction indicate that alternatives emphasizing traditional reuse and nutrient control technology are somewhat more cost effective than those emphasizing groundwater recharge. The ability to generate revenues from traditional reuse further increases the attractiveness of this approach.
- At the facilities with lesser densities of consumptive use permittees (Hollywood, Miami-Dade/North and Miami-Dade/Central), extensive groundwater recharge would be required to achieve a 50% average of freshwater savings and nutrient load reduction unless industries and residential users are added to the reclaimed water customer base.
- Over the period 2005–2025, the costs of liquid treatment, reuse and disposal to achieve a 50% average of freshwater savings and nutrient load reduction would range from $1.00/1,000 gal at the Boca Raton WWTP to $1.90/1,000 gal at the Hollywood WWTP, averaging $1.50/1,000 gal. Increasing this average to 75% would raise the average cost to $2.60/1,000 gal.

1. Introduction

The Florida Department of Environmental Protection (FL DEP) contracted with the University of Florida to conduct a study on ocean outfalls in Southeast Florida. The purpose of the study is to evaluate the status and efficacy of wastewater disposal options in Southeast Florida, where the extent of water reuse is limited. Six publicly owned wastewater treatment plants (WWTPs) with ocean outfalls are considered in this report. The names of these facilities in geographical order (north to south) are given below. Also given for each facility is a shorter name that will be used henceforth in the report.

- City of Delray Beach, South Central Regional Wastewater Treatment Plant (Boynton-Delray WWTP)
- City of Boca Raton, Glades Road Wastewater Treatment Plant (Boca Raton WWTP)
- Broward County, North Regional Wastewater Treatment Plant (Broward/North WWTP)
- City of Hollywood, Southern Regional Wastewater Treatment Plant (Hollywood WWTP)
- Miami-Dade North District Wastewater Treatment Plant (Miami-Dade/North WWTP)
- Miami-Dade Central District Wastewater Treatment Plant (Miami-Dade/Central)

The State of Florida encourages and promotes water reuse as reflected in the state reuse objectives in Sections 403.064 and 373.250, Florida Statutes. Water reuse has been considered an important component of both wastewater management and water resource management in Florida. Benefits of water reuse include:

- Reuse decreases discharges of wastewater effluent to surface waters and deep injection wells and thus reduces environmental impacts associated with these disposal methods.
- Reclaimed water provides an alternative water supply for activities that do not require potable quality water such as irrigation and toilet flushing and helps to conserve potable quality water.
- High quality reclaimed water has the ability to recharge and augment existing water supplies.

Florida's reuse capacity has increased significantly in the past 20 years. By the year 2020, Florida is expected to reclaim and reuse 65% of all domestic wastewater. Some of the greatest challenges, but also the greatest potential benefits, of reuse implementation lie in highly urbanized Southeast Florida of Palm Beach, Broward, and Miami-Dade counties. According to the 2003 Reuse Inventory published by the Florida Department of Environmental Protection, Palm Beach, Broward, and Miami-Dade counties contain almost one-third of Florida's population and generate 39% of state's domestic wastewater (FL DEP 2004). However, they account for less than 10% of all reuse capacity in the state.

Broward and Miami-Dade counties rely heavily on ocean outfalls and deep well injection for effluent disposal, sending 510 million gallons per day (MGD) of their treated effluent to the ocean or deep, non-potable aquifers. Potential limitations on nutrient discharges to the coastal ocean and growing demands for water could alter both the economic and the hydrologic feasibility of this continuing export of fresh water.

The report includes ten chapters, as outlined in the Table of Contents. Wastewater treatment plants with ocean outfalls in Southeast Florida are reviewed in Chapter 2. Information on water supply facilities in the three counties with ocean outfalls is summarized in Chapter 3. Environmental risk associated with discharge or reuse of effluents in Southeast Florida is considered in Chapter 4. The socioeconomic impacts of reefs on Southeast Florida are also mentioned. U.S. and international case studies of water reuse in large urban areas outside Southeast Florida are reviewed in Chapter 5. Information on the withdrawal and reclamation of wastewater from mid and upper reaches of sewers—a practice known as satellite treatment—is also included. Methods for estimating the costs of traditional water reuse and groundwater recharge in Southeast Florida are presented in Chapter 6. Alternative strategies for management of treated effluents are proposed in Chapter 7, whereas indicators for evaluating the outcomes of these strategies are discussed in Chapter 8. Values of the indicators under various scenarios within the wastewater management alternatives are presented and discussed in Chapter 9. Findings of the report are summarized and conclusions are drawn in Chapter 10.

Three appendices are included in the report. Appendix 1 contains detailed information on the use of CapdetWorks 2.1 software for estimating wastewater treatment costs. Appendix 2 contains schematic diagrams of wastewater treatment process trains for meeting various effluent and water reclamation standards. Appendix 3 contains a glossary of terms used in the report. The Project Database contains in their entirety all relevant reports (in PDF format) that were obtained from consulting engineers and public agencies. The database also includes a searchable listing of the reports, as well as public domain articles on the topic of water reuse.

Reference

FL DEP (2004) 2003 Reuse Inventory. Florida Department of Environmental Protection, Division of Water Resource Management, Tallahassee, Florida. July 2004.

2. Wastewater Treatment Plants with Ocean Outfalls in Southeast Florida

Summary information on ocean outfalls and their associated wastewater treatment plants is given in the present chapter. The locations of the six ocean outfalls in Florida are shown from a statewide perspective in Figure 2-1. The three Florida Counties that are home to the outfalls are shown in Figure 2-2.

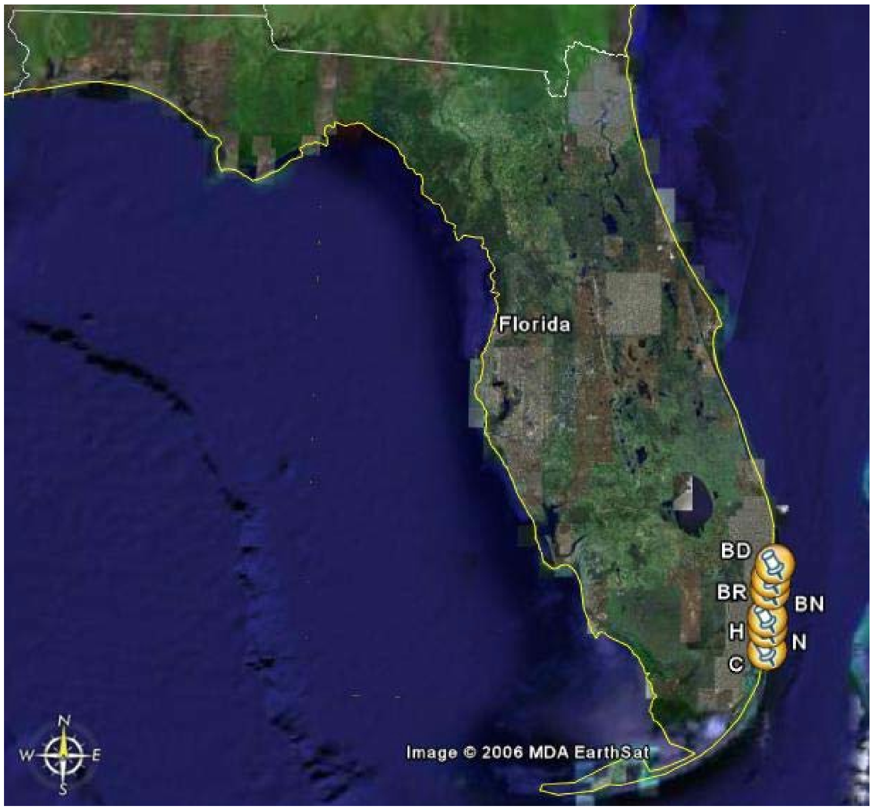

Figure 2-1. Ocean Outfalls in Florida. BD–Boyton-Delray, BR–Boca Raton, BN–Broward/North, H–Hollywood, N–Miami-Dade/North, C–Miami-Dade/Central. Photo from Google Earth (2005).

2.1 Boynton-Delray WWTP

An overview of the Boynton-Delray WWTP in Delray Beach and its associated facilities is given in Table 2-1. Included are brief descriptions of the treatment and alternative disposal methods, flows, reuse facilities, ocean outfall, and future plans. More extensive information is given below.

2.1.1 Description of Wastewater Treatment Plant

The Boynton-Delray WWTP, located at 1801 N. Congress Avenue**,** Delray Beach, was constructed in 1974 to provide wastewater treatment for the Cities of Boynton Beach and Delray Beach. The construction included two phases: Plant A with a 12 MGD design capacity was completed in 1979 with EPA grant funds and Plant B with the same design capacity was constructed in 1987. Subsequent facility improvements include conversion to fine bubble aeration, odor abatement, and installation of effluent pumping facilities. The Boynton-Delray WWTP is a complete-mix activated sludge plant. Liquid treatment facilities include screening, grit removal, flow equalization, aeration basins, clarifiers, chlorination and dechlorination. The design criteria of the aeration basins and secondary clarifiers are shown in Table 2-2. On-site solids processing includes thickening via a centrifuge or two dissolved air flotation units and lime stabilization to meet Class B criteria before being applied to land. Most of the wastewater is treated and then disposed of through an ocean outfall. A portion of the wastewater is reclaimed for water reuse. The current permitted plant capacity is 24 MGD annual average daily flow and 26.4 MGD maximum three-month average daily flow (Brown and Caldwell 1995). The plant site is constrained by housing developments on the west and by a freeway on the east (Fig. 2-3). Limited open area exists immediately south of the plant, whereas more extensive undeveloped area is located north of the WWTP.

Figure 2-2. Florida Counties with Ocean Outfalls. Photo from Google Earth (2005).

Table 2-1. Overview of Boynton-Delray WWTP, Ocean Outfall and Associated Facilities

Treatment and alternate disposal	*Method*	Completely mixed activated sludge
	Disinfection level	High level for public access reuse Basic level for ocean outfall disposal
	Other disposal options	Emergency discharge to canal
2003 Flows	*Reuse*	4.3 MGD
	Ocean outfall	12.3 MGD
	Other disposal flow	- -
	Total treated flow	16.6 MGD
Reuse facilities	*Design capacity*	10 MGD
	Current flow	4.3 MGD
	Start up	1995 design
	Applications	On site; residential irrigation; golf course irrigation
Ocean outfall	*Latitude* *Longitude*	26° 27′ 72″ N 80° 02′ 53″ W
	Discharge depth	90 ft
	Distance offshore	5,200 ft
	Inside diameter	30 inches
	Number of ports	1
	Diameter of ports	30 inches
	Port orientation	Horizontal
Future plans	*WWTP*	Could not identify
	Reuse facilities	Expand design capacity to 24 MGD

2.1.2 Historical and Projected Flows and Concentrations

The Boynton-Delray WWTP served an estimated 210,500 people within its service area in 2005. This estimate is derived from historical population data from the Boynton-Delray Wastewater Treatment and Disposal Board (Brown and Caldwell 1995) extrapolated based on projected population growth rates for Palm Beach County (GEC 2003). The population for the Boynton-Delray WWTP service area is expected to increase to 294,300 by 2025, the end of the present study period. Population projections for the study period are presented in Table 2-3.

Table 2-2. Design Criteria for the Boynton-Delray WWTP

Treatment Facility	**Value**	**Units**
Aeration Basins		
Plant A		
No. of aeration basins	6	
Basin length	65	ft
Basin width	65	ft
Sidewater depth	16	ft
Volume per basin	0.5	MG
Total aeration basin volume	3	MG
Plant B		
No. of aeration basins	4	
Basin length of basins 1, 2	66	ft
Basin length of basins 3, 4	131.5	ft
Basin width of basins 1, 2, 3, 4	65	ft
Sidewater depth of basins 1, 2, 3, 4	15.35	ft
Total aeration basin volume	3	MG
Secondary Clarifiers		
Plant A		
No. of clarifiers	3	
Diameter of clarifiers	105	ft
Sidewater depth of clarifiers	14	ft
Total surface area of clarifiers	25,980	sf
Total volume of clarifiers	2.72	MG
Plant B		
No. of clarifiers	3	
Diameter of clarifiers	105	ft
Sidewater depth of clarifiers	16	ft
Total surface area of clarifiers	25,980	sf
Total volume of clarifiers	3.2	MG

Table 2-3. Population Projections for Boynton-Delray WWTP Service Area from 2005 to 2025. Based on data from Brown and Caldwell (1995) and GEC (2003)

Year	2005	2010	2015	2020	2025
Population	210,500	231,200	252,100	273,500	294,300

Figure 2-3. Aerial photograph of the Boynton-Delray WWTP (Google Earth 2005)

Based on an historical wastewater production rate of 92 gal/capita/day in Florida (Marella 1999), the projected 2005 average daily wastewater flow rate was 19.4 MGD. The average daily wastewater flow rate is expected to increase to 27.1 MGD by 2025, based on a constant wastewater production rate of 92 gal/capita/day. Projected wastewater flow rates for the study period are presented in Table 2-4.

Table 2-4. Wastewater Flow Projections for the Boynton-Delray WWTP from 2005 to 2025. Based on data from Brown and Caldwell (1995), GEC (2003) and Marella (1999)

Year	**2005**	**2010**	**2015**	**2020**	**2025**
Wastewater flow (MGD)	19.4	21.3	23.2	25.2	27.1

A review of the flow data indicated peaking factors for maximum month average daily flow/annual average daily flow and peak hourly flow/annual average daily flow of 1.45 and 2.15 respectively (Hodges 2003).

The average influent $CBOD_5$ and TSS concentrations from January 1994 to April 1995 were 131 and 146 mg/L, respectively. The annual average $CBOD_5$ and TSS reductions were 97% and 91%, resulting in average effluent $CBOD_5$ and TSS concentrations of 4.3 and 13.6 mg/L, respectively. The historical maximum month peaking factors for $CBOD_5$ and TSS were found to be 1.31 and 1.4 and did not change over time (Brown and Caldwell 1993; Brown and Caldwell 1995). A similar analysis was carried out from October 1991 to October 1992 (Brown and Caldwell 1993). Annual average influent and effluent ammonia concentrations in 1992 were 29 and 6 mg/L, respectively, representing an 80% decrease.

The City of St. Petersburg conducted research on chloride and TDS concentrations in reclaimed water and their impact on vegetation when used for irrigation purposes. These studies reported selected species and chloride tolerances. As a result of the study, the City of St. Petersburg tries to maintain chloride concentrations in reclaimed water below 400 mg/L to protect vegetation from adverse effects of high chloride concentrations (PBS&J 1992). The average effluent chloride concentration at the Boynton-Delray WWTP from April 1994 through April 1995 was 206 mg/L, which is below the guideline. However, chloride concentrations in 1992 exceeded 400 mg/L from time to time. Most of this contribution was attributed to the high volume of infiltration/inflow from the City of Delray Beach. Collection system improvements since 1992 have improved the effluent quality (Brown and Caldwell 1995).

The effluent limitations and monitoring requirements for ocean outfall disposal in southeast Florida are summarized in Table 2-5. The quality of effluent discharged from the Boyton-Delray WWTP complies with these requirements. This can be seen from the summaries of effluent water quality that are presented in Tables 2-6 and 2-7, which cover a 15-month monitoring period (8/31/03 to 10/31/04). The average effluent concentrations of $CBOD_5$ and TSS from August 2003 through October 2004 were 11 and 9 mg/L, respectively (Table 2-6). These values are below the respective discharge limits of 25 and 30 mg/L (Table 2-5). The removals for $CBOD_5$ and TSS during this period were 95% and 96%, respectively; much higher than the 85% requirement. The average effluent concentrations for total nitrogen and phosphorus were 18.7 and 1.7 mg/L, respectively. The annual average, 90^{th} percentile, geometric mean and maximum effluent fecal coliform values were 1, 1.2, 1 and 26.5 per 100 mL, respectively, as shown in Table 2-7. These values are well below the corresponding limits of 200, 400, 200 and 800 per 100 mL. The average influent concentrations for $CBOD_5$ and TSS were 220 and 229 mg/L for the same period, as shown in Table 2-8.

Table 2-5. Permit Requirements for Ocean Outfall Disposal in Southeast Florida

			Effluent Limitations				Monitoring Requirements		
Parameter	Units	Max/ Min	Annual Average	Monthly Average	Weekly Average	Single Sample	Monitoring Frequency	Sample Type	Notes
$CBOD_5$	mg/L	Max	25 30 [2]	25 30 [2]	40 45 [2]	60	Daily	24-hr FPC [3]	5
$CBOD_5$ removal	%	Min		85					
TSS	mg/L	Max	30	30	45	60	Daily	24-hr FPC [3]	5
TSS removal	%	Min		85					
Total Nitrogen as N	mg/L and lbs/day[1]	Max	None	None	_	None	Weekly	24-hr FPC [3]	6
Total Ammonia as N	mg/L and lbs/day[1]	Max	None	None	_	None	Weekly	24-hr FPC [3]	7
Total Nitrite+Nitrate as N	mg/L and lbs/day[1]	Max	None	None	_	None	Weekly	24-hr FPC [3]	7
Total Phosphorus	mg/L and lbs/day[1]	Max	None	None	_	None	Weekly	24-hr FPC [3]	6
Fecal Coliform Bacteria	See [4]						Daily	Grab	8

Sources: (FL DEP 2000), (FL DEP 2002), (FL DEP 2003b), (FL DEP 2003a), (PBS&J 2003)

[1] mg/L (Annual Avg, Monthly Avg and Single Sample) and lbs/day (Annual Avg and Monthly Avg)

[2] Effluent limitations for Miami-Dade/North

[3] Flow proportioned composite

[4] *[62-600.440(4)c]*

- The arithmetic mean of the monthly fecal coliform values collected during an annual period shall not exceed 200 per 100 mL of effluent sample.
- The geometric mean of the fecal coliform values for a minimum of 10 samples of effluent each collected on a separate day during a period of 30 consecutive days (monthly) shall not exceed 200 per 100 mL of sample.
- No more than 10 percent of the samples collected (the 90th percentile value) during a period of 30 consecutive days shall exceed 400 fecal coliform values per 100 mL of sample.
- Any one sample shall not exceed 800 fecal coliform values per 100 mL of sample.

[5] Only Monthly Avg and Weekly Avg requirements for Miami-Dade/Central, Expansion of Hollywood WWTP includes discharge limitations for $CBOD_5$ (20 mg/L, 25 mg/L, 40 mg/L and 60 mg/L) and TSS (20 mg/L, 30 mg/L, 45 mg/L and 60 mg/L).

[6] Only mg/L and lbs/day Single Sample requirements for Broward/North, only mg/L Monthly Avg requirements for Miami-Dade/North and Miami-Dade/Central

[7] Required only for Boynton-Delray, Boca Raton and Hollywood plants

[8] Only Geometric Mean and Single Sample requirements for Miami-Dade/North and Miami-Dade/Central plants

Table 2-6. Ocean Outfall Discharge Composition of the Boynton-Delray WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

Parameter	**Average of monthly averages**	**Maximum monthly average**
TSS (mg/L)	9	12.9
$CBOD_5$ (mg/L)	11	15.6
TSS removal (%)	96	–
$CBOD_5$ removal (%)	95	–
Total N (mg-N/L)	18.7	22.2
Ammonia N (mg-N/L)	11.7	15.4
Nitrite+Nitrate N (mg-N/L)	4.1	7.1
Total P (mg-P/L)	1.7	4.0

Table 2-7. Ocean Outfall Fecal Coliform Concentrations at the Boynton-Delray WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

	Value (# /100 mL)
Average of monthly averages	1
90^{th} percentile	1.2
Geometric mean	1
Maximum	26.5

Table 2-8. Average Influent Concentrations at the Boynton-Delray WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

Parameter	**Average of monthly averages**
TSS (mg/L)	229
$CBOD_5$ (mg/L)	220

Note: The monthly averages for the TSS and $CBOD_5$ on 1/31/04 were 267 mg/L and 264 mg/L respectively, which gives the highest sum (531 mg/L) of monthly averages for TSS and $CBOD_5$.

2.1.3 Reuse Facilities

According to the 2003 Florida DEP Reuse Inventory (FL DEP 2004), the reuse system has a design capacity of 10 MGD, of which 43% (4.3 MGD) is being utilized for in-plant, residential and golf course irrigation. The reuse system was designed in 1995 and includes filtration, chlorination and storage facilities. Three Tetra deep bed downflow sand filters, with a total surface area of 1,254 ft^2 and a design capacity of 10 MGD, are being used (Brown and Caldwell 1995). The reuse system is currently being expanded.

2.1.4 Ocean Outfall

Treated effluent from the Boynton-Delray WWTP is discharged through a 30 inch pipe that extends 5,200 ft from the shoreline and reaches a depth of 90 ft. The permitted capacity of the outfall is 24 MGD annual average daily flow and 26.4 MGD maximum three-month average daily flow (FL DEP 2000). The Boynton-Delray WWTP ocean outfall was inspected by volunteer divers on October 18 and November 8, 2003 to observe effluent plume characteristics and to collect water samples. The discharge pipe was found at 26° 27′ 71.5″ N, 80° 02′ 52.5″ W, at a different location than specified on the permit, at a depth of 95 feet and inclined toward the surface at approximately 30 degrees. A buoyant, freshwater effluent was found to exit the pipe with some force and traveled toward the surface. The plume was pushed northward with the current while it moved toward the surface and formed a boil several hundred yards down-current of the discharge point (Tichenor 2004).

2.1.5 Disposal Methods in Addition to Ocean Outfalls

The City of Delray Beach has no disposal method besides its ocean outfall. The Boynton-Delray WWTP has an emergency bypass system to discharge treated effluent to the L-30 Canal (FL DEP 2000).

2.1.6 Future Plans

The reclaimed water system at the Boynton-Delray WWTP will be expanded to 24 MGD so that all of the wastewater can be reclaimed for water reuse. A reclaimed water master plan was developed for the City of Delray Beach in November 2003. The City is currently constructing the first phase (Area 1) of the reclaimed water system. In March 2005, the City applied for a permit to add additional users in Areas 2 and 3 as part of the next phase of implementation (Matthews Consulting 2003).

The first phase of the plant expansion included construction of a 2 million gallon storage tank to increase reclaimed water production for area golf courses. The cost of the Crom Corporation tank was $900,000, of which $300,000 was funded by a grant from the South Florida Water Management District. In the second phase, the filtration system and chlorine contact facility will be enlarged, reclaimed water equalization will be added before the filters, and additional pumping capability will be provided. The Board applied for $6.6 million of federal funds to pay for the work. Another grant from the South Florida Water Management District was received for the Year 2005 to continue the expansion work (Smith 2004). The cities of Boynton Beach and Delray Beach are searching for additional large users of reclaimed water and are discussing with the Florida DEP the possibility of using the ocean outfall pipeline to distribute reclaimed water to users on the barrier island (Hodges 2003).

2.2 Boca Raton WWTP

An overview of the Boca Raton WWTP in Boca Raton and its associated facilities is given in Table 2-9. Included are brief descriptions of the treatment and alternative disposal methods, flows, reuse facilities, ocean outfall, and future plans. More extensive information is given below.

2.2.1 Description of Wastewater Treatment Plant

The original WWTP in the City of Boca Raton started operation in 1974 and had a design capacity of 10 MGD. In the mid 1980s, the plant was modified to increase its design capacity to 12 MGD (Boca Raton 2005b). The Boca Raton facility provides secondary treatment and on-site biosolids processing. Liquid treatment facilities include screening and grit removal, primary clarification, an activated sludge system with mechanical and diffused aeration, final settling tanks and chlorine addition. The design criteria of the aeration basins and secondary clarifiers are shown in Table 2-10. The biosolids processing facilities include gravity belt and rotary drum thickeners, anaerobic digesters and sludge dewatering. Most of the wastewater is treated and then discharged through an ocean outfall. Some of the wastewater is reclaimed for water reuse. The plant is permitted to treat a 17.5 MGD annual average daily flow, 20 MGD maximum month average daily flow and 40 MGD peak hourly flow (Hazen and Sawyer 1997b). The Boca Raton WWTP site is constrained on the north by athletic fields and a runway, on the west and south by freeways, and on the east by the Boca Raton Water Treatment Plant (Fig. 2-4).

Table 2-9. Overview of Boca Raton WWTP, Ocean Outfall and Associated Facilities

Treatment and alternate disposal	*Method*	Conventional activated sludge
	Disinfection level	High level for public access reuse Basic level for ocean outfall disposal
	Other disposal options	None
2003 Flows	*Reuse*	5.6 MGD
	Ocean outfall	10.7 MGD
	Other disposal flow	- -
	Total treated flow	16.3 MGD
Reuse facilities	*Design capacity*	9 MGD
	Current flow	5.6 MGD
	Start up	1989 on-site; 1993 Florida Atlantic University irrigation
	Applications	On site; residential irrigation; golf course irrigation; other public access areas
	Notes	- -
Ocean outfall	*Latitude* *Longitude*	26°21′00″N 80°03′16″W
	Discharge depth	90 feet
	Distance offshore	5,166 feet
	Inside diameter	36 inches
	Number of ports	1
	Diameter of ports	36 inches
	Port orientation	Up 45° from horizontal
Future plans	*WWTP*	Could not identify
	Reuse facilities	Expand design capacity to 15 MGD

Table 2-10. Design Criteria for the Boca Raton WWTP

Treatment Facility	Value	Units
Aeration Basins		
No. of aeration basins	3	#
Basin length	255	ft.
Basin width	85	ft.
Sidewater depth	13	ft.
Volume per basin	2.11	MG
Total aeration basin volume	6.32	MG
Secondary Clarifiers		
No. of clarifiers	5	#
Diameter of clarifiers 1, 2	105	ft.
Diameter of clarifiers 3, 4, 5	110	ft.
Sidewater depth of clarifiers 1,2	12	ft.
Sidewater depth of clarifiers 3, 4, 5	14	ft.
Total surface area of clarifiers	45,829	sf
Total volume of clarifiers	4.54	MG

Figure 2-4. Aerial photograph of the Boca Raton WWTP. A portion of the Boca Raton Water Treatment Plant is visible in the lower right corner of the photo (Google Earth 2005).

2.2.2 Historical and Projected Flows and Concentrations

The Boca Raton WWTP serves an estimated 138,200 people within its service area in 2005. This estimate is derived from historical population data from the City of Boca Raton Utility Services Department (Hazen and Sawyer 1997b) extrapolated based on projected population growth rates used for the entirety of Palm Beach County issued in the United States Army Corps of Engineers Comprehensive Everglades Restoration Plan Update (GEC 2003). The population for the Boca Raton WWTP service area is expected to increase to 193,200 by the Year 2025. Population projections for the study period are presented in Table 2-11.

Table 2-11. Population Projections for the Boca Raton WWTP Service Area from 2005 to 2025. Based on data from Hazen and Sawyer (1997b) and GEC (2003)

Year	2005	2010	2015	2020	2025
Population	138,200	151,700	165,400	179,500	193,200

Based on an historical wastewater production rate of 113 gal/capita/day prepared for the United States Geological Survey study to assess wastewater discharge trends in Florida (Marella 1999), the 2005 average daily wastewater flow rate is projected at 15.6 MGD. The average daily wastewater flow rate is expected to increase to 21.8 MGD in 2025, based on a constant wastewater production rate of 113 gal/capita/day. Wastewater flow rates for the study period are presented in Table 2-12.

Table 2-12. Wastewater Flow Projections for the Boca Raton WWTP from 2005 to 2025. Based on data from Hazen and Sawyer (1997b), GEC (2003) and Marella (1999)

Year	2005	2010	2015	2020	2025
Wastewater flow (MGD)	15.6	17.1	18.7	20.2	21.8

The average influent $CBOD_5$ and TSS concentrations during 1996 were 136 and 124 mg/L, respectively. The annual average $CBOD_5$ and TSS reductions were 91% and 95%, resulting in average effluent $CBOD_5$ and TSS concentrations of 12 and 6 mg/L. This effluent quality was typically achieved utilizing two out of three aeration basins and three out of five secondary clarifiers (Hazen and Sawyer 1997b).

The average effluent concentrations for $CBOD_5$ and TSS from August 2003 through October 2004 were 3 and 6 mg/L (Table 2-13), which are below the respective discharge limits of 25 and 30 mg/L. The removals of $CBOD_5$ and TSS were 98% and 96%, respectively; much higher than the 85% requirement. The average effluent concentrations of total nitrogen and total phosphorus were 16.9 and 0.7 mg/L, respectively. The annual average, 90^{th} percentile, geometric mean and maximum effluent fecal coliform concentrations were 3, 10.1, 3.1 and 74.8 per 100 mL, respectively, as shown in Table 2-14. These values are well below the corresponding limits of 200, 400, 200 and 800 per 100 mL. The average influent concentrations for $CBOD_5$ and TSS were 190 and 185 mg/L for the same period (Table 2-15).

Table 2-13. Ocean Outfall Discharge Composition of Boca Raton WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

Parameter	Average of monthly averages	Maximum monthly average
TSS (mg/L)	6	7.9
$CBOD_5$ (mg/L)[1]	3	4.6
TSS removal (%)	96	–
$CBOD_5$ removal (%)	98	–
Total N (mg-N/L)	16.9	19.9
Ammonia N (mg-N/L)[1]	10.5	14.2
Nitrite+Nitrate N (mg-N/L)[1]	3.3	3.8
Total P (mg-P/L)	0.7	1.3

[1] Monitoring period between 2/29/04 and 10/31/04

Table 2-14. Ocean Outfall Fecal Coliform Concentrations at the Boca Raton WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

	Value (# /100 mL)
Average of monthly averages[1]	3
90^{th} percentile	10.1
Geometric mean	3.1
Maximum	74.8

[1] Monitoring period between 8/31/03 and 7/31/04 and 11/30/03 value is not reported

Table 2-15. Average Influent Concentrations at the Boca Raton WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

Parameter	Average of monthly averages
TSS (mg/L)	185
$CBOD_5$ (mg/L)	190

Note: The monthly averages for the TSS and $CBOD_5$ on 1/31/04 were 299 mg/L and 241 mg/L respectively, which gives the highest sum (540 mg/L) of monthly averages for TSS and $CBOD_5$.

2.2.3 Reuse Facilities

The Boca Raton WWTP added capability to produce a limited quantity of reclaimed water for process water and landscape irrigation onsite in 1989. Two automatic backwash filters with a total design capacity of 3 MGD were operated (CDM 1990). In 1993, Florida Atlantic University was being irrigated and Phase I of the reuse system construction was continuing to expand reclaimed water distribution to public access areas. The current reuse system includes chemical filter aid, filtration and high level disinfection. Six automatic backwash medium-depth mono-media sand filters with a total surface area of 3450 ft^2 and a design capacity of 9 MGD are being used (Brown and Caldwell 1993). According to the 2003 Florida DEP Reuse Inventory (FL DEP 2004), the reuse system has a design capacity of 9 MGD, of which 62% (5.6 MGD) is being utilized. The reuse system IRIS (In-city Reclamation Irrigation System) provides service to Boca Raton's Sabal Park/Pinelands area, Florida Atlantic University, Mizner Park and a number of commercial green spaces along Federal Highway, residential customers and golf courses (Boca Raton 2005a).

2.2.4 Ocean Outfall

The ocean outfall pipe from the Boca Raton WWTP consists of three sections with 42, 30 and 36 inch diameters. Treated effluent is discharged 5,166 ft from the shoreline at a depth of 90 ft. The permitted capacity of the wastewater effluent through the ocean outfall is 17.5 MGD annual average daily flow. In addition, the outfall is permitted to carry a 4.5 MGD annual average daily flow (7 MGD maximum daily flow) of membrane softening concentrate from the water treatment plant (FL DEP 2003b).

2.2.5 Disposal Methods in Addition to Ocean Outfalls

The City of Boca Raton has no disposal method besides its ocean outfall.

2.2.6 Future Plans

The City of Boca Raton submitted a capacity analysis report during permit renewal to the Florida DEP for a rerating of the Boca Raton WWTP's annual average daily flow from 17.5 MGD to 23 MGD, corresponding to a maximum month average daily flow of 26.5 MGD and a peak hourly flow of 46 MGD. The peaking factor for maximum month average daily flow/annual average daily flow is proposed to remain at 1.15, whereas peak hourly flow/annual average daily flow ratio is suggested to be reduced to 2.0, based on a review of historical hourly flow data from 1995 to 1996. The treatment processes limiting the rerated capacity were the primary clarifiers, return activated sludge pumping and sludge thickening. The peak flow to the outfall based on pumping capacity was estimated to be 28 MGD. The available total equalization capacity is 5.5 million gallons, consisting of a 2.5 million gallon effluent equalization tank and a 3.0 million gallon reuse system storage tank. The facilities were found to be adequate for the proposed 46 MGD peak hourly flow, considering a committed reuse flow of 2.0 MGD, 28 MGD ocean outfall and 4.0 million gallons of equalization required for a peak hourly flow rate duration of 6 hours (Hazen and Sawyer 1997b).

The reclaimed water master plan prepared by CDM for the City of Boca Raton proposed a reclaimed water system IRIS with a design capacity of 15 MGD to be completed by 2000. The service district included 2,480 acres of green space, including five large users (Florida Atlantic University and four golf courses), all public and commercial properties, multi-family condominium and rental complexes, and 12,773 single family homes. The reclaimed water system was found to reduce the annual water consumption by 25 to 30% and had the potential to eliminate the 10 MGD expansion of the water treatment plant and related water supply wells with an estimated capital cost of between 7.7 and 8.7 million dollars (CDM 1990). However, the water treatment plant was expanded in 1991, before the reclaimed water system was completed. The implementation of IRIS has been slower than planned.

2.3 Broward/North WWTP

An overview of the Broward/North WWTP in Broward County and its associated facilities is given in Table 2-16. Included are brief descriptions of the treatment and alternative disposal methods, flows, reuse facilities, ocean outfall, and future plans. More extensive information is given below.

2.3.1 Description of Wastewater Treatment Plant

The initial Broward/North WWTP, with a design capacity of 20 MGD and located at 2401 N. Powerline Road, Pompano Beach, started providing wholesale wastewater treatment service to large users in 1975. The plant underwent its first major expansion in 1980, which increased the design capacity to 66 MGD annual average daily flow. The plant reached 80 MGD annual average daily flow capacity through a second major expansion that was completed in 1992.

In 2001, a rerating was requested for the Broward/North WWTP from 80 MGD to 84 MGD and a capacity of 84 MGD annual average daily flow was permitted in 2003. The Broward County Office of Environmental Services started planning in 1995 to expand the Broward/North WWTP to 100 MGD design capacity. Sludge stabilization and dewatering improvements projects were completed in 2001 as part of the expansion (Hazen and Sawyer 2004).

The Broward/North WWTP provides secondary treatment and on-site biosolids processing. There are four individual treatment trains (Modules A, B, C, D). The liquid treatment facilities include screening, grit removal, an activated sludge system, secondary clarifiers, and chlorine contact tanks. The design criteria of the aeration basins and secondary clarifiers are shown in Table 2-17. Solids treatment facilities consist of dissolved air flotation thickeners, anaerobic digesters, and sludge dewatering. After the sludge is digested and dewatered, it is disposed of by land filling and land spreading. The sludge is rated as Class B, which is suitable for application to agricultural sites with restricted public access. Some of the wastewater is treated and then disposed of through an ocean outfall, another portion is treated and then disposed of through six Class I injection wells, and the remainder is reclaimed for water reuse (Hazen and Sawyer 2004). Some area remains open on the Broward/North WWTP site (Fig. 2-5). Commercial developments constrain the site boundaries on all four directions, although a parcel of undeveloped land extends from the northwest corner of the plant site.

Table 2-16. Overview of the Broward/North WWTP, Ocean Outfall and Associated Facilities

Treatment & alternate disposal	*Method*	Conventional activated sludge
	Disinfection level	High level for public access reuse Basic level for ocean outfall disposal
	Other disposal options	Class I injection wells
2003 Flows	*Reuse*	4.5 MGD
	Ocean outfall	36.5 MGD
	Other disposal flow	29.1 MGD
	Total treated flow	69.8 MGD
Reuse facilities	*Design capacity*	10 MGD
	Current flow	4.5 MGD
	Start up	1991
	Applications	On site; other facility; other public access
	Notes	Effluent from Modules B and C is further treated to produce reclaimed water for reuse
Ocean outfall	*Latitude* *Longitude*	26°15′00″N 80°03′45″W
	Discharge depth	107 ft
	Distance offshore	7,300 ft
	Inside diameter	54 inches
	Number of ports	1
	Diameter of ports	54 inches
	Port orientation	Horizontal
Future plans	*WWTP*	Expand to 100 MGD design capacity
	Reuse facilities	Utilize 10 MGD reuse design capacity

2.3.2 Historical and Projected Flows and Concentrations

The Broward/North WWTP serves an estimated 724,000 people within its service area in 2005, as presented by the Broward County Office of Environmental Services (Hazen and Sawyer 2004). The population for the Broward/North WWTP service area is expected to increase to 978,300 by 2025. Population projections for the study period are presented in Table 2-18.

Detailed flow data and projections for the Broward/North WWTP were available, indicating that the 2005 average daily wastewater flow rate would be 84.2 MGD (116 gal/capita/day). The average daily wastewater flow rate is expected to increase to 94.1 MGD in 2025. This flow rate reflects an anticipated reduction in wastewater production per capita from 116 gal/capita/day at the beginning of the study period to 96 gal/capita/day in 2025. The reduction in the per capita wastewater production is expected to result from increased residential population density. The increase in density per residential unit is anticipated since there is very little undeveloped land in the county, whereas migration to the area should continue. Projected wastewater flow rates over the study period are presented in Table 2-19.

Table 2-17. Design Criteria for the Broward/North WWTP

Treatment Facility	Value	Units
Aeration Basins		
No. of modules (A, B, C, D)	4	#
No. of aeration basins per module	4	#
Total no. of aeration basins	16	#
Basin length	225	ft.
Basin width	75	ft.
Sidewater depth	15.5	ft.
Volume per basin	1.96	MG
Total aeration basin volume	31.3	MG
Secondary Clarifiers		
No. of clarifiers per module	4	#
Total no. of clarifiers	16	#
Diameter of clarifiers	105	ft.
Sidewater depth of clarifiers in modules A, B, C	12	ft.
Sidewater depth of clarifiers in modules D	15	ft.
Total surface area of clarifiers	138,560	sf

Figure 2-5. Aerial photograph of the Broward/North WWTP (Google Earth 2005).

Table 2-18. Population Projections for Broward/North WWTP Service Area from 2005 to 2025 (Hazen and Sawyer 2004)

Year	**2005**	**2010**	**2015**	**2020**	**2025**
Population	724,000	790,600	856,300	919,500	978,300

Table 2-19. Wastewater Flow Projections for Broward/North WWTP from 2005 to 2025 (Hazen and Sawyer 2004)

Year	**2005**	**2010**	**2015**	**2020**	**2025**
Wastewater Flow (MGD)	84.2	88.6	90.8	92.2	94.1
Per Capita Usage (gal/day)	116	112	106	100	96

The average influent $CBOD_5$ and TSS concentrations during 2002 were 136 and 241 mg/L, respectively. The annual average $CBOD_5$ and TSS reductions were both 97%, resulting in average effluent $CBOD_5$ and TSS concentrations of 3.3 and 5.9 mg/L, respectively. This effluent quality was achieved with an average of ten out of sixteen aeration basins in service (Hazen and Sawyer 2004). The average influent $CBOD_5$ and TSS concentrations from 1997 to 2001 were 142 and 248 mg/L, respectively (Hazen and Sawyer 2002).

Additional monitoring data were summarized for the period August 2003 through October 2004. Effluent $CBOD_5$ and TSS concentrations averaged 4 and 7 mg/L, respectively as shown in Table 2-20. These values are well below the corresponding discharge limits of 25 and 30 mg/L. The removals for $CBOD_5$ and TSS were both 97%; much higher than the requirement of 85%. The average effluent concentrations of total nitrogen and phosphorus were 14.8 and 1.3 mg/L, respectively. Annual average, 90^{th} percentile, geometric mean and maximum effluent fecal coliform concentrations were 14, 25, 7 and 53 per 100 mL, respectively as shown in Table 2-21. These values are below the corresponding limits of 200, 400, 200 and 800 per 100 mL. The average influent concentrations for $CBOD_5$ and TSS were 130 and 217 mg/L, respectively, for the same period as shown in Table 2-22.

Table 2-20. Ocean Outfall Discharge Composition of Broward/North WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

Parameter	**Average of monthly averages**	**Maximum monthly average**
TSS (mg/L)	7	13
$CBOD_5$ (mg/L)	4	5
TSS removal (%)	97	–
$CBOD_5$ removal (%)	97	–
Total N (mg-N/L)	14.8	19.9
Total P (mg-P/L)	1.3	2.0

Table 2-21. Ocean Outfall Fecal Coliform Concentrations at the Broward/North WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

	Value (# /100 mL)
Average of monthly averages	14
90th percentile	25
Geometric mean	7
Maximum	53

Table 2-22. Average Influent Concentrations of the Broward/North WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

Parameter	Average of monthly averages
TSS (mg/L)	217
$CBOD_5$ (mg/L)	130

Note: The monthly averages for the TSS and $CBOD_5$ on 5/31/04 were 339 mg/L and 144 mg/L respectively, which gives the highest sum (483 mg/L) of monthly averages for TSS and $CBOD_5$.

2.3.3 Reuse Facilities

A 10 MGD reclaimed water system together with approximately 2 miles of 24 inch transmission line terminating at the North Broward County Resource Recovery Facility was placed in service at the Broward/North WWTP in 1991. The current reclaimed water system consists of a filter feed pump station, filters, a chlorine contact tank, chemical feed facilities, storage tanks, and distribution pumping systems (Hazen and Sawyer 2004). Forty Parkson Dynasand single media upflow continuous backwash filters, with a total surface area of 2000 ft^2 and a design capacity of 10 MGD, are arranged in 10 individual basins with four units per basin (Hazen and Sawyer 1992). Clarified effluent from modules B and C is diverted to the filtration system. The existing reclaimed water demand is 45% (4.5 MGD) of the current design capacity

2.3.4 Ocean Outfall

Treated effluent from the Broward/North WWTP is discharged through a 54 inch ductile iron pipe at a depth of 107 ft that extends 7,300 ft from the shoreline. The permitted capacity of the outfall is 66 MGD annual average daily flow (FL DEP 2003a).

2.3.5 Disposal Methods in Addition to Ocean Outfall

The Class I injection well system at the Broward/North WWTP that was constructed in 1990-1991 consisted of an injection well pumping station, four Class I injection wells, and two dual zone Floridan aquifer monitoring wells. In 2000-2001, two additional Class I injection wells and two monitoring wells were constructed. The combined design capacity of the ocean outfall/injection well systems with one injection well out of service is 174 MGD peak hourly flow and 87 MGD average daily flow with a peaking factor of 2.0 (Hazen and Sawyer 2002). The permitted peak hourly flow capacity for the six wells is 60 MGD (FL DEP 2003a). An average flow of 29.1 MGD was discharged to the wells during 2003 (FL DEP 2004).

Water quality issues have been encountered for one of the monitoring wells. The U.S. EPA published a draft rule change in 2000 and 2003 that requires operators of wells with questionable data to either demonstrate non-endangerment of the underground source of drinking water or provide higher levels of treatment, described as possibly filtration and high level disinfection (Hazen and Sawyer 2004). U.S. EPA published new rules governing Class I injection wells in 24 Florida Counties including Palm Beach, Broward and Miami-Dade Counties on 11/22/05. These federal rules became effective on 12/22/05.

2.3.6 Future Plans

Plans for expansion of the Broward/North WWTP to a design capacity of 100 MGD include construction of an additional treatment module (E) with 20 MGD annual average daily flow capacity, new sludge dewatering and storage facilities, expansion and improvements of preliminary treatment facilities and anaerobic digestion facilities, improvements to disinfection facilities, construction of new Class I injection wells, and updating of the plant distributed control system (Hazen and Sawyer 2004). The design criteria of the aeration basins and secondary clarifiers in Module E are shown in Table 2-23.

Broward County Office of Environmental Services has plans to utilize the 10 MGD design capacity of the reuse system. A portion of this capacity is already committed. An additional 2 MGD will be needed when the Broward/North WWTP is expanded to 100 MGD. There is an agreement with Wheelabrator Environmental Services to provide up to 2 MGD of reclaimed water and up to 2.3 MGD if the company adds boilers at the North Broward County Resource Recovery Facility. The Broward County Office of Environmental Services has started providing irrigation water for a portion of the Pompano Beach Park of Commerce, which is under development next to the plant (Hazen and Sawyer 2004).

Table 2-23. Design Criteria for Module E

Module E	Value	Units
Aeration Basins		
No. of aeration basins	4	#
Basin length	335	ft.
Basin width	52	ft.
Sidewater depth	15.5	ft.
Volume per basin	2	MG
Total aeration basin volume	8	MG
Secondary Clarifiers		
No. of clarifiers	3	#
Diameter of clarifiers	125	ft.
Sidewater depth	16	ft.
Total surface area of clarifiers	36,816	sf

The City of Pompano Beach has ongoing efforts to expand its own reclaimed water treatment design capacity and service area. This community tapped into the outfall line from the Broward North WWTP, built a filtration and high-level disinfection facility, and supplies reclaimed water within Pompano Beach. This utilization of a water resource that was previously being wasted results in an increase in the percentage of Broward/North WWTP flows that is reused (Hazen and Sawyer 2004).

Coconut Creek and the North Springs Improvement District have expressed interest in receiving reclaimed water from Broward/North WWTP for roadway median irrigation. An initiative to fund this project was introduced in 2003 by the State but was not accepted. The project was resubmitted in January 2004. If funding is obtained, the Broward County Office of Environmental Services is prepared to upgrade its facilities to meet this demand (Hazen and Sawyer 2004).

2.4 Hollywood WWTP

An overview of the Hollywood WWTP in Broward County and its associated facilities is given in Table 2-24. Included are brief descriptions of the treatment and alternative disposal methods, flows, reuse facilities, ocean outfall, and future plans. More extensive information is given below.

Table 2-24. Overview of Hollywood WWTP, Ocean Outfall and Associated Facilities

Treatment & alternate disposal	*Method*	Pure oxygen activated sludge
	Disinfection level	High level for public access reuse Basic level for ocean outfall disposal
	Other disposal options	Class I injection wells (in testing)
2003 Flows	*Reuse*	2.6 MGD
	Ocean outfall	39.5 MGD
	Other disposal flow	- -
	Total treated flow	42.1 MGD
Reuse facilities	*Design capacity*	4 MGD
	Current flow	2.6 MGD
	Start up	1994 Public access reuse
	Applications	Golf course irrigation
	Notes	- -
Ocean outfall	*Latitude* *Longitude*	26°01′04″N 80°05′04″W
	Discharge depth	93 ft
	Distance offshore	10,000 ft
	Inside diameter	60 inches
	Number of ports	1
	Diameter of ports	60 inches
	Port orientation	Horizontal
Future plans	*WWTP*	Expand to 50 MGD design capacity in two phases
	Reuse facilities	Increase reuse flow by 1.1 MGD

2.4.1 Description of Wastewater Treatment Plant

The Hollywood WWTP, located at 1621 N. 14th Avenue**,** Hollywood, has been operating since the 1940s. In 1973, trickling filters were replaced with a pure oxygen activated sludge system and the plant was expanded to 36 MGD. The design capacity was increased to 38 MGD in 1981 (Public Utility Management and Planning Services and Hazen and Sawyer 2001). The current design capacity of the plant is 45 MGD annual average daily flow as mentioned in the permit (FL DEP 2002). The permitted capacity reported in the Florida DEP (2002) permit and SFRPC (2005) are 42 and 48.75 MGD, respectively. The City started implementing a program in 1999 to expand the design capacity to 50 MGD in two phases (Hazen and Sawyer 1988; Hazen and Sawyer 1999a). The current activated sludge plant includes bar screens, grit tanks, influent pumps, oxygenation tanks, clarifiers, chlorination, effluent pumps, and post lime sludge stabilization facilities (Public Utility Management and Planning Services and Hazen and Sawyer 2001; Hollywood 2005c). The design criteria of the aeration basins and secondary clarifiers are shown in Table 2-25. Most of the wastewater is treated and then discharged through an ocean outfall. The remainder is reclaimed for water reuse. Two 24 inch Class I injection wells were constructed as part of an expansion process. The plant is sited within a golf course that is ringed with housing developments on the west, south, and east and by a recreational complex to the north (Fig. 2-6).

Table 2-25. Design Criteria for the Hollywood WWTP

Treatment Facility	Value	Units
Aeration Basins		
No. of trains (1, 2, 3, 4)	4	#
No. of aeration basins per train	4	#
Total no. of aeration basins	16	#
Basin length in trains 1, 2	58	ft.
Basin length in trains 3, 4	36	ft.
Basin width in trains 1, 2	58	ft.
Basin width in trains 3, 4	36	ft.
Sidewater depth in trains 1, 2	14	ft.
Sidewater depth in trains 3, 4	18	ft.
Volume per basins in trains 1, 2	0.35	MG
Volume per basins in trains 3, 4	0.17	MG
Total aeration basin volume	4.2	MG
Secondary Clarifiers		
Length of clarifiers no. 1-4	135	ft.
Width of clarifiers no. 1-4	135	ft.
Sidewater depth of clarifiers no. 1-4	12	ft.
Diameter of clarifiers no. 5-6	120	ft.
Sidewater depth of clarifiers no. 5-6	14	ft.
Total surface area of clarifiers	95,508	sf
Total volume of clarifiers	9.06	MG

Figure 2-6. Aerial photograph of the Hollywood WWTP (Google Earth 2005)

2.4.2 Historical and Projected Flows and Concentrations

The Hollywood WWTP serves an estimated 312,200 people within its service area in 2005. This estimate is derived from historical population data (Marella 1999) extrapolated based on projected population growth rates for Broward County presented in the United States Army Corps of Engineers Comprehensive Everglades Restoration Plan Update (GEC 2003). The population for the Hollywood WWTP service area is expected to increase to 425,600 by 2025. Population projections for the study period are presented in Table 2-26.

Based on an historical wastewater production rate of 128 gal/capita/day (Public Utility Management and Planning Services and Hazen and Sawyer 2001), the 2005 average daily wastewater flow rate was projected at 40.0 MGD. The average daily wastewater flow rate is expected to increase to 54.5 MGD in 2025, based on a constant wastewater production rate of 128 gal/capita/day. Projected wastewater flow rates for the study period are presented in Table 2-27.

The annual average influent BOD_5 and TSS concentrations from November 1985 through December 1987 were 86 and 84 mg/L. The low wastewater strength was caused by the infiltration/inflow in the Hollywood collection system (Hazen and Sawyer 1988). Effluent $CBOD_5$ concentrations for the Hollywood WWTP during high flow occurrence days in July and August 1989 were in the range of 5 to 19 mg/L (Hazen and Sawyer 1999a). The average effluent $CBOD_5$ concentration from May through October 1992 was 4 mg/L (Hazen and Sawyer 1993).

Table 2-26. Population Projections for Hollywood WWTP Service Area from 2005 to 2025. Based on data from Public Utility Management and Planning Services and Hazen and Sawyer (2001) and GEC (2003)

Year	**2005**	**2010**	**2015**	**2020**	**2025**
Population	312,200	340,100	368,400	397,500	425,600

Table 2-27. Wastewater Flow Projections for Hollywood WWTP from 2005 to 2025. Based on data from Public Utility Management and Planning Services and Hazen and Sawyer (2001), GEC (2003) and Marella (1999)

Year	**2005**	**2010**	**2015**	**2020**	**2025**
Wastewater flow (MGD)	40.0	43.5	47.2	50.9	54.5

The average effluent concentrations for $CBOD_5$ and TSS from August 2003 through October 2004 were 8 and 17 mg/L, respectively, as shown in Table 2-28. These values are below the respective discharge limits of 25 and 30 mg/L. The removals for $CBOD_5$ and TSS were 94% and 87%, respectively. The average effluent concentrations for total nitrogen and phosphorus were 16.6 and 1.1 mg/L, respectively. Several months of coliform data were missing from the data report, as explained in the footnotes to Table 2-29. Based on available data, values for the annual average, 90th percentile, geometric mean effluent fecal coliform concentrations were 7, 20.9 and 2.7, respectively, which are below the corresponding limits of 200, 400 and 200 per 100 mL. However, the maximum was 2,120 per 100 mL, which is above the limit of 800 per 100 mL. The average influent concentrations for $CBOD_5$ and TSS were 139 and 136 mg/L for the 15-month period, as shown in Table 2-30. The influent wastewater strength has increased due to infiltration/inflow reduction programs (Hazen and Sawyer 1988).

Table 2-28. Ocean Outfall Discharge Composition of the Hollywood WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

Parameter	**Average of monthly averages**	**Maximum monthly average**
TSS (mg/L)	17	26.6
$CBOD_5$ (mg/L)	8	17.9
TSS removal (%)[1]	87	–
$CBOD_5$ removal (%)[1]	94	–
Total N (mg-N/L)	16.6	21.2
Ammonia N (mg-N/L)	11.9	15
Nitrite+Nitrate N (mg-N/L)	1.2	4.8
Total P (mg-P/L)	1.1	1.4

[1] Calculated based on the given influent and effluent monthly average data

Table 2-29. Ocean Outfall Fecal Coliform Concentrations at the Hollywood WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

	Value (# /100 mL)
Average of monthly averages	7
90th percentile[1]	20.9
Geometric mean[1]	2.7
Maximum[2]	2120

[1] 11/30/03, 12/31/03, 1/31/04, 4/30/04 and 8/31/04 values were not reported

[2] 8/31/03, 11/30/03, 12/31/03, 1/31/04, 4/30/04, 8/31/04 and 9/30/04 values were not reported

Table 2-30. Average Influent Concentrations at the Hollywood WWTP from 8/31/03 to 10/31/04. Data from Florida DEP Discharge Monitoring Reports

Parameter	Average of monthly averages
TSS (mg/L)	136
$CBOD_5$ (mg/L)	139

Note: The monthly averages for the TSS and $CBOD_5$ on 5/31/04 were 158 mg/L and 162 mg/L respectively, which gives the highest sum (320 mg/L) of monthly averages for TSS and $CBOD_5$.

2.4.3 Reuse Facilities

Reclaimed water was used only for on-site processes until 1993, when process and storage facilities were installed to enable 4 MGD of public access reuse. In 1994 a transmission system was constructed to supply reclaimed water to golf courses (Public Utility Management and Planning Services and Hazen and Sawyer 2001). The current reuse system includes an 8 MGD continuous backwash tertiary filter system, high level disinfection and contact tanks, 0.5 MG of on-site reuse storage, pumping facilities and a reuse transmission and distribution system (Hollywood 2005b). The current reuse system has a permitted capacity of 4 MGD and is providing 2.6 MGD of reclaimed water to six local golf courses (FL DEP 2004). There are ongoing discussions with more users to provide an additional 1.1 MGD (FL DEP 2002).

Reuse has been found beneficial in Hollywood by reducing water withdrawals from the surficial aquifer system, helping to prevent saltwater intrusion. The City of Hollywood determined that about 4 MGD of off-site reuse was economically feasible, but it received resistance from users. The City therefore sponsored legislation to require reclaimed water to be used where it is available and reliable. Residential reuse was also considered. Capital cost for residential reuse (or dual distribution) water systems was estimated as $21 to $30 per gal/day of reuse capacity, whereas golf course irrigation was estimated as less than $2 per gal/day of reuse capacity. The City concluded that the cost of residential reuse in Hollywood was too expensive and inconvenient for single-families with small lots that utilize limited amounts of water for irrigation (Public Utility Management and Planning Services and Hazen and Sawyer 2001).

2.4.4 Ocean Outfall

The treated wastewater from the Hollywood WWTP is transported to the Atlantic Ocean through a 60 inch diameter outfall pipe that extends 10,000 ft off-shore, reaching a depth of 93 ft. The outfall pipe will be at or exceeding its recommended maximum hydraulic capacity when the plant is uprated to 50 MGD. Class I injection wells are therefore being constructed to serve as an additional disposal method (Hazen and Sawyer 1994). The City has an agreement with the Town of Davie and Cooper City to dispose of treated wastewater through the existing effluent disposal system. The permitted capacity with these flows is 46.3 MGD annual average daily flow (FL DEP 2002).

In September 1976, the 60 inch outfall pipeline failed near Michigan Street, at a point 1,200 ft off the Hollywood Beach. Repairs to the 96 ft of damaged pipe required several weeks. The Hollywood Beach was closed during this period. The failure was caused by trapped air and associated localized pressure surges (Hazen and Sawyer 1999a).

The Southeast Florida Outfall Experiment II (SEFLOE II) study characterized the minimum initial dilution properties of the outfall system at a design flow of 54 MGD. This flow was determined considering flows of 42 MGD from the Hollywood WWTP, 6.75 MGD from the Cooper City/Davie treatment plants, 2.2 MGD of reverse osmosis and membrane softening brines from the proposed water treatment plant, and 3 MGD of planned future flows. The minimum flux average dilution in the zone of initial dilution was 28.4:1, which is above the minimum of 20:1 established by regulations. The initial dilution characteristics of the Hollywood and Miami-Dade/Central outfall systems were compared. Hollywood was found to be superior to the multiport system in Miami-Dade/Central. It was therefore concluded that effluent from the Hollywood outfall undergoes rapid dilution (Hazen and Sawyer 1994).

2.4.5 Disposal Methods in Addition to Ocean Outfall

During the plant uprating process, effluent disposal options were reviewed and construction of two Class I injection wells (the Florida DEP requires a minimum of two) was chosen from among several options. Construction permits have been obtained by the City to install two 24 inch diameter Class I injection wells. Currently the two wells are under operational testing, as required to eventually obtain an operation permit. The tentative permitted capacity of the Class I injection well system is 18.6 MGD (Hazen and Sawyer 1999b).

2.4.6 Future Plans

The Hollywood WWTP is being expanded to 50 MGD (Hollywood 2005a). For upgrade to 45 MGD annual average daily flow, the following improvements were made (Public Utility Management and Planning Services and Hazen and Sawyer 2001; FL DEP 2002):

- Upgrade of influent pump station
- Installation of a third emergency generator for the influent pump station and other facilities on the south side of the WWTP
- Installation of a fourth emergency generator for the effluent and other facilities on the north side of the WWTP

- Construction of a 120 ft diameter clarifier (No. 7)
- Construction of return activated sludge pumping station (No. 4)
- Construction of a 24 inch diameter deep injection well
- Replace existing flow meter with a magnetic flow meter

Ugrading to 50 MGD annual average daily flow includes the following improvements:

- Construction of oxygenation train No. 5, consisting of four cells
- Construction of a 120 ft diameter clarifier No. 8
- Construction of second 24 inch diameter deep injection well
- Rehabilitation of oxygenation trains No. 1 and 2 and rehabilitation of clarifiers No. 1–4

The on-site storage for reclaimed water is limited during extreme storms. The possibility of using golf course ponds for additional storage during these periods is therefore being explored by the City of Hollywood. In the long term, the City is investigating the possibility of emergency discharge of reclaimed water mixed with golf course pond water to inland surface waters. The City is seeking this approach to get some relief for 5 to 10 years, but is aware of the difficulty of obtaining such a regulatory permit (Hazen and Sawyer 1999a).

2.5 Miami-Dade/North WWTP

An overview of the Miami-Dade/North WWTP in Miami-Dade County and its associated facilities is given in Table 2-31. Included are brief descriptions of the treatment and alternative disposal methods, flows, reuse facilities, ocean outfall, and future plans. More extensive information is given below.

2.5.1 Description of Wastewater Treatment Plant

The Miami-Dade/North WWTP located at 2575 N.E. 151st St., North Miami, started operation in the late 1970s. Liquid treatment facilities include bar screens, primary clarifiers, pure oxygen trains, secondary clarifiers and chlorination facilities. The design criteria of the aeration basins and secondary clarifiers are shown in Table 2-32. The sludge transfer pumping station pumps the primary sludge, waste activated sludge, and scum to the Miami-Dade/Central WWTP for biosolids treatment. Most of the treated effluent is disposed of through an ocean outfall. A portion of the wastewater is reclaimed for water reuse. Four Class I injection wells have been constructed, but a testing program must be completed before the wells may be placed in service. The maximum flow that can be discharged to the wells is 45 MGD. The plant has a rated capacity of 120 MGD annual average daily flow and is permitted to treat an annual average daily flow of 112.5 MGD (PBS&J 2003). The plant site has undeveloped land available to the north, east and south, with a freeway bounding the site on the west (Fig. 2-7).

Table 2-31. Overview of Miami-Dade/North WWTP, Ocean Outfall and Associated Facilities

Treatment & alternate disposal	*Method*	Pure oxygen activated sludge
	Disinfection level	High level for public access reuse Basic level for ocean outfall disposal
	Other disposal options	Class I injection wells (in testing)
2003 Flows	*Reuse*	2.3 MGD
	Ocean outfall	80.6 MGD
	Total treated flow	82.9 MGD
Reuse facilities	*Design capacity*	4.4 MGD
	Current flow	2.3 MGD
	Start up	1997 Florida International University irrigation
	Applications	On-site; Florida International University irrigation
	Notes	Influent from northwestern Miami with lower chloride concentrations is reclaimed for water reuse
Ocean outfall	*Latitude* *Longitude*	25°55′48″N 80°05′04″W
	Discharge depth	108 ft
	Distance offshore	11,700 ft
	Inside diameter	90 inches
	Number of ports	12
	Diameter of ports	24 inches
	Port orientation	Horizontal
Future plans	*WWTP*	Reactivate old ocean outfall for wet weather flows
	Reuse facilities	Could not identify

Table 2-32. Design Criteria for the Miami-Dade/North WWTP

Treatment Facility	Value	Units
Aeration Basins		
No. of trains	5	#
No. of aeration basins per train	4	#
Basin length	61	ft.
Basin width	61	ft.
Sidewater depth	15	ft.
Volume per basin	0.39	MG
Total aeration basin volume	7.8	MG
Secondary Clarifiers		
No. of clarifiers	12	#
Diameter of clarifiers	160	ft.
Sidewater depth of clarifiers	12	ft.
Total surface area of clarifiers	241,200	sf
Total volume of clarifiers	24.24	MG

Figure 2-7. Aerial photograph of the Miami-Dade/North WWTP (Google Earth 2005)

2.5.2 Historical and Projected Flows and Concentrations

The Miami-Dade/North WWTP serves an estimated 635,400 people within its service area in 2005. Data on population for the entire district, which includes three wastewater treatment facilities (North, Central, and South) was obtained from the Miami-Dade Water and Sewer Department for 2001 (PBS&J 2003). The population of the service area for the Miami-Dade/North WWTP was estimated by dividing the wastewater flow for the Miami-Dade/North WWTP by the total wastewater handled by all three treatment plants, and then multiplying by the total number of residents within the three service areas. Data is presented by the Miami-Dade Water and Sewer Department through the year 2015. To obtain extrapolated population data for the years 2020 and 2025, the average population increase for the previous two projection years (2010 and 2015) were averaged and the increase percent was extrapolated linearly for the final two entries of the study period. The population for the Miami-Dade/North WWTP service area is expected to increase to 777,500 by 2025. Population projections for the study period are presented in Table 2-33.

Table 2-33. Population Projections for Miami-Dade/North WWTP Service Area from 2005 to 2025. Based on data from PBS&J (2003)

Year	2005	2010	2015	2020	2025
Population	635,400	658,800	700,600	735,800	777,500

The Miami-Dade Water and Sewer Department presents wastewater flow estimates for the Miami-Dade/North WWTP for the year 2005 in their Wastewater Management Master Plan (PBS&J 2003). The wastewater flow for 2005 was estimated by the Miami-Dade Water and Sewer Department to be 107.9 MGD, or 170 gal/capita/day. The data from the Miami-Dade Water and Sewer Department extends to the Year 2015. Wastewater flow data for 2020 and 2025 were extrapolated based on the per capita wastewater generation rate and includes the decrease in per capita production reflected in the Department's data between 2010 and 2015.

The decrease was extended linearly to obtain a per capita wastewater production of 165 gal/capita/day for 2020 and 162 gal/capita/day for 2025. The average daily wastewater flow rate is expected to increase to 126.3 MGD in the Year 2025. Projected wastewater flow rates for the study period are presented in Table 2-34.

Table 2-34. Wastewater Flow Projections for Miami-Dade/North WWTP from 2005 to 2025. Based on data from PBS&J (2003)

	2005	2010	2015	2020	2025
Wastewater flow (MGD)	107.9	111.9	116.6	121.3	126.3
Per capita usage (gal/day)	170	170	166	165	162

The average influent BOD_5 and TSS concentrations during 2001 were 99 and 127 mg/L, respectively. The annual average BOD_5 and TSS reductions were 94% and 89%, resulting in average effluent BOD_5 and TSS concentrations of 5.6 and 13.6 mg/L (PBS&J 2003). The average influent BOD_5 and TSS concentrations from 1984 through 1997 were 127 and 157 mg/L, respectively. The annual average BOD_5 and TSS reductions were 89% and 88%, resulting in average effluent BOD_5 and TSS concentrations of 14 and 19 mg/L (PBS&J 1998).

The wastewater effluent quality was reviewed for a variety of constituents. The Miami-Dade/North WWTP was found to have chloride concentrations of 580 mg/L. The impacts of high chloride concentrations on public access reuse, specifically with urban and agricultural irrigation, were evaluated in the 1992 Reuse Feasibility Study (PBS&J 1992). Infiltration/inflow reduction programs in the wastewater collection and transmission system were found to be useful for reducing high chloride concentrations in reclaimed water. The Miami-Dade/North WWTP treats wastewater influents with high and low chloride concentrations in two separate trains. Influent wastewater from North Miami and Miami Beach contains chloride concentrations or 1,000 mg/L or higher, whereas influent from the northwestern portion of the county has chloride concentrations in the vicinity of 135 mg/L. Effluent from the low chloride train, which has chloride concentrations less than 400 mg/L, is reclaimed for reuse applications. Further treatment of the WWTP effluent with membrane technology or dilution to reduce chloride concentrations was considered for the case where reclaimed water from the high chloride train is used to increase reuse capacity (PBS&J 1998).

Monitoring data reported to the Florida DEP from August 2003 through July 2004 were examined. The average $CBOD_5$ and TSS effluent concentrations during this period were 6 and 10 mg/L, respectively, as shown in Table 2-35. These values are below the respective discharge limits of 30 and 30 mg/L. The removals for $CBOD_5$ and TSS were not reported and could not be calculated because the influent average monthly concentrations for $CBOD_5$ and TSS were not reported. The average effluent concentrations for total nitrogen and phosphorus were 17.5 and 1.7 mg/L, respectively. Annual average and 90^{th} percentile effluent fecal coliform values were not reported. The geometric mean and maximum concentrations were 1.2 and 67 per 100 mL, respectively, as shown in Table 2-36. These values are below the corresponding limits of 200 and 800 per 100 mL.

Table 2-35. Ocean Outfall Discharge Composition of the Miami-Dade/North WWTP from 8/31/03 to 7/31/04. Data from Florida DEP Discharge Monitoring Reports

Parameter	Average of monthly averages	Maximum monthly average
TSS (mg/L)	10	12.4
$CBOD_5$ (mg/L)	6	9.2
TSS removal (%)	–	–
$CBOD_5$ removal (%)	–	–
Total N (mg-N/L)	17.5	20.5
Total P (mg-P/L)	1.7	2.1

Table 2-36. Ocean Outfall Fecal Coliform Concentrations at the Miami-Dade/North WWTP from 8/31/03 to 7/31/04. Data from Florida DEP Discharge Monitoring Reports

	Value (# /100 mL)
Annual average	–
90^{th} percentile	–
Geometric mean	1.2
Maximum	67.3

2.5.3 Reuse Facilities

The Miami-Dade/North WWTP has an on-site reuse system that consists of filtration, chlorination and pumping facilities and reclaimed water storage tanks. Three down flow filters with a total surface area of 510 ft^2 and a design capacity of 3 MGD, two continuous backwash filters with a total surface area of 200 ft^2 and a design capacity of 1.4 MGD, a down flow deep bed filter with a total surface area of 154 ft^2 and a design capacity of 1.6 MGD, and a dual media down flow filter with a total surface area of 150 ft^2 and a design capacity of 1.1 MGD are currently in use. The reclamation system started in 1997 to provide reclaimed water to Florida International University for landscape irrigation. The reuse system capacity is 2.9 MGD for on-site and 1.5 MGD for the university's applications. During 2003, the reclaimed water flow was 2.3 MGD (FL DEP 2004). The wastewater influent from northeastern Miami contains high chloride concentrations due to the infiltration/inflow of brackish groundwater. It is therefore not reclaimed for irrigation reuse. The influent from Northwestern Miami has lower chloride concentrations and is processed in a separate train for reuse applications (PBS&J 1998).

2.5.4 Ocean Outfall

The Miami-Dade/North Outfall was constructed in 1975. It consists of a 90 inch reinforced concrete pipe that extends 11,700 ft from the shoreline and discharges effluent through 12 ports at a depth of 108 ft. The permitted capacity of the outfall is 112.5 MGD annual average daily flow (PBS&J 2003).

2.5.5 Disposal Methods in Addition to Ocean Outfall

Four Class I injection wells were constructed at the Miami-Dade/North WWTP, but a testing program must be completed before the wells are allowed to operate. The maximum flow discharge to the wells is about 45 MGD (PBS&J 2003).

2.5.6 Future Plans

The Miami-Dade Water and Sewer Department developed alternatives for Miami-Dade County to handle wastewater increases from population growth and wet-weather flows. The alternatives included two Comprehensive Everglades Restoration Plan projects. In the first project, the South District WWTP would be expanded from 112.5 MGD to 131.25 MGD and would be converted to advanced wastewater treatment such as membrane treatment to meet effluent discharge requirements for the coastal wetlands next to Biscayne Bay. In the second project, a reclaimed water plant with a design capacity of 20 MGD would be constructed at the Bird Drive Basin. The reclaimed water from this plant would be used for aquifer recharge. Among the seven alternatives considered, the chosen alternative includes the use of an abandoned ocean outfall at the Miami-Dade/North WWTP and construction of a new 120 inch ocean outfall at the Miami-Dade/Central WWTP to handle future demands (PBS&J 2003).

2.6 Miami-Dade/Central WWTP

An overview of the Miami-Dade/Central WWTP in Miami-Dade County and its associated facilities is given in Table 2-37. Included are brief descriptions of the treatment and alternative disposal methods, flows, reuse facilities, ocean outfall, and future plans. More extensive information is given below.

2.6.1 Description of Wastewater Treatment Plant

The Miami-Dade/Central WWTP is located on Virginia Key at 3989 Rickenbacker Causeway, Miami. The initial 47 MGD facility (Plant 1) started operation in 1956. The treatment capacity was increased to 70 MGD in 1974 by adding two more aeration tanks. Plant 2, a 55 MGD pure oxygen activated sludge plant, became operational in 1980. Plant 1 was down-rated to 60 MGD the same year. An upgrade of Plant 1 to pure oxygen activated sludge was completed in 1999. Plant 2 was re-rated to 83 MGD. The complete facility has a permitted capacity of 143 MGD annual average daily flow. Plants 1 and 2 are operated independently of each other.

There is no influent screening at the site, as the wastewater is screened at Pumping Stations 1 and 2. Liquid treatment facilities include aerated grit chambers, pure oxygen trains, secondary clarifiers and chlorination facilities. The design criteria of the aeration basins and secondary clarifiers are shown in Table 2-38. Biosolids treatment facilities consist of gravity sludge thickening, anaerobic digestion, centrifuge dewatering and disposal to landfills or land application sites. After chlorination, the effluents from both plants are mixed in the effluent pumping station. Most of the treated wastewater is disposed of through an ocean outfall. A small portion of the wastewater is reclaimed for water reuse (PBS&J 2003). The site of the Miami-Dade/Central WWTP is bordered by Miami Bay on the west, north and east. An undeveloped area of Virginal Key lies to the south of the plant (Fig. 2-8).

Table 2-37. Overview of Miami-Dade/Central WWTP, Ocean Outfall and Associated Facilities

Treatment and alternate disposal	*Method*	Pure oxygen activated sludge
	Disinfection level	Basic level for ocean outfall disposal
	Other disposal options	None
2003 Flows	*Reuse*	8.9 MGD
	Ocean outfall	104.6 MGD
	Other disposal flow	- -
	Total treated flow	113.5 MGD
Reuse facilities	*Design capacity*	8.5 MGD
	Current flow	8.9 MGD
	Start up	1994 Public access reuse
	Applications	On-site
	Notes	All influent has high chloride concentrations
Ocean outfall	*Latitude* *Longitude*	25°44′31″N 80°05′10″W
	Discharge depth	100 ft
	Distance offshore	18,800 ft
	Inside diameter	90 and 120 inches
	Number of ports	5
	Diameter of ports	48 inches
	Port orientation	Vertical
Future plans	*WWTP*	Construct a new 120 inch ocean outfall
	Reuse facilities	Could not identify

2.6.2 Historical and Projected Flows and Concentrations

The Miami-Dade/Central WWTP served an estimated 761,700 people within its service area in 2005. The population for the Miami-Dade/Central WWTP service area is expected to increase to 932,100 by the Year 2025. Population projections for the study period are presented in Table 2-39. Methodology for population estimates for the Miami-Dade/Central WWTP are similar to those discussed in Section 2.5.2.

The average daily wastewater flow rate is expected to increase to 151.3 MGD in the Year 2025. Projected wastewater flow rates for the study period are presented in Table 2-40. Methodology for wastewater flow projections was similar to that discussed in Section 2.5.2.

The average influent BOD_5 and TSS concentrations during 2001 were 148 and 194 mg/L, respectively. The annual average BOD_5 and TSS reductions were 95.8% and 97.4%, resulting in respective average effluent BOD_5 and TSS concentrations of 6.2 and 4.9 mg/L (PBS&J 2003). The average influent BOD_5 and TSS concentrations from 1984 through 1997 were 117 and 104 mg/L, respectively. The annual average BOD_5 and TSS reductions were 84% and 87%, resulting in respective average effluent BOD_5 and TSS concentrations of 19 and 14 mg/L (PBS&J 1998).

Table 2-38. Design Criteria for the Miami-Dade/Central WWTP

Treatment Facility	Value	Units
Aeration Basins		
Plant 1		
No. of tanks	6	#
No. of aeration channels per tank	3	#
Channel length	210	ft.
Channel width	22	ft.
Sidewater depth	13	ft.
Volume per channel	0.45	MG
Total aeration tank volume	8.1	MG
Plant 2		
No. of trains	4	#
No. of aeration stages per train	6	#
Stage length	78.33	ft.
Stage width	39.17	ft.
Sidewater depth	10.17	ft.
Volume per stage	0.24	MG
Total aeration train volume	5.8	MG
Secondary Clarifiers		
Plant 1		
No. of tanks	6	#
No. of clarifier channels per tank	3	#
Channel length	275	ft.
Channel width	18	ft.
Sidewater depth	11	ft.
Total surface area of clarifiers	89,250	sf
Total volume of clarifiers	7.32	MG
Plant 2		
No. of tanks	10	#
No. of clarifier channels per tank	3	#
Channel length	275	ft.
Channel width	18	ft.
Sidewater depth	11	ft.
Total surface area of clarifiers	148,750	sf
Total volume of clarifiers	12.2	MG

Figure 2-8. Aerial photograph of the Miami-Dade/Central WWTP (Google Earth 2005)

Table 2-39. Population Projections for Miami-Dade/Central WWTP Service Area from 2005 to 2025. Based on data from PBS&J (2003)

Year	**2005**	**2010**	**2015**	**2020**	**2025**
Population	761,700	789,800	839,900	882,000	932,100

Table 2-40. Wastewater Flow Projections for Miami-Dade/Central WWTP Service Area from 2005 to 2025. Based on data from PBS&J (2003)

Year	**2005**	**2010**	**2015**	**2020**	**2025**
Wastewater flow (MGD)	129.4	134.1	139.8	145.4	151.3
Per capita usage (gal/day)	170	170	166	165	162

An irrigation pilot study at the Miami-Dade/Central WWTP site was planned to evaluate the feasibility of using reclaimed water with high chloride concentrations for golf course irrigation. The landscape vegetation on Virginia Key and Key Biscayne was found to be naturally tolerant to high chlorides, due to the barrier island conditions (PBS&J 1992).

Influent wastewater at the Miami-Dade/Central WWTP contains high chloride levels due to the infiltration/inflow of brackish groundwater into the collection system. The combined effluent chloride concentration at the Miami-Dade/Central WWTP was 1,089 mg/L in 1994. Reclaimed water from this source was found to be unsuitable for irrigation without membrane treatment. On-site irrigation at the Miami-Dade/Central WWTP was considered because the landscape vegetation is tolerant to high chloride concentrations and most of this vegetation is turf grass, which tolerates chloride concentrations greater than 1,000 mg/L (PBS&J 1998).

Monitoring data reported to the Florida DEP from August 2003 through October 2004 were examined. The average effluent concentrations for $CBOD_5$ and TSS were 6 and 10 mg/L, respectively, as shown in Table 2-41. These values are below the respective discharge limits of 25 and 30 mg/L. The removals for $CBOD_5$ and TSS were both 95%, which is higher than the requirement of 85%. Average effluent total nitrogen and total phosphorus concentrations were 16.8 and 1.6 mg/L, respectively. The annual average and 90th percentile effluent fecal coliform values were not reported. The geometric mean and maximum concentrations were 1.3 and 19.6 per 100 mL, respectively, as shown in Table 2-42. These values are below the corresponding limits of 200 and 800 per 100 mL. The average influent concentrations of $CBOD_5$ and TSS were 131 and 201 mg/L, respectively, for the same period, as shown in Table 2-43. There were no violations of effluent quality requirements.

Table 2-41. Ocean Outfall Discharge Composition of the Miami-Dade/Central WWTP from 8/31/03 to 10/31/04[1]. Data from Florida DEP Discharge Monitoring Reports

Parameter	Average of monthly averages	Maximum monthly average
TSS (mg/L)	10	16
$CBOD_5$ (mg/L)	6	11
TSS removal (%)	95	–
$CBOD_5$ removal (%)	95	–
Total N (mg-N/L)	16.8	22.5
Total P (mg-P/L)	1.6	3.4

[1] For all the data 1/31/04, 2/29/04 and 4/30/04 values were not reported

Table 2-42. Ocean Outfall Fecal Coliform Concentrations at the Miami-Dade/Central WWTP from 8/31/03 to 10/31/04[1]. Data from Florida DEP Discharge Monitoring Reports

	Value (# /100 mL)
Average of monthly averages	–
90th percentile	–
Geometric mean	1.3
Maximum	19.6

[1] For all the data 1/31/04, 2/29/04 and 4/30/04 values were not reported

Table 2-43. Average Influent Concentrations at the Miami-Dade/Central WWTP from 8/31/03 to 10/31/04[1]. Data from Florida DEP Discharge Monitoring Reports

Parameter	**Average of monthly averages**
TSS (mg/L)	201
$CBOD_5$ (mg/L)	131

[1] For all the data 1/31/04, 2/29/04 and 4/30/04 values were not reported

Note: The monthly averages for the TSS and $CBOD_5$ on 3/31/04 were 248 mg/L and 156 mg/L respectively, which gives the highest sum (404 mg/L) of monthly averages for TSS and $CBOD_5$.

2.6.3 Reuse Facilities

The Miami-Dade/Central WWTP has on-site reuse systems for Plants 1 and 2. Each of the reuse systems includes a chlorine contact tank, reclaimed water and chlorine injector pumps, and strainers. The Plant 2 reuse system supplies reclaimed water to the sludge dewatering building, as well as the Plant 2 processes. The plant influent contains high chloride concentrations from infiltration/inflow of brackish groundwater and was found unsuitable for off-site irrigation (PBS&J 1998). The reuse system capacity and flow in 2003 were 8.5 and 8.9 MGD, respectively (FL DEP 2004).

2.6.4 Ocean Outfall

The initial ocean outfall that was placed online in 1956 included a gravity pipeline that extended 4,500 ft off-shore and discharged at a depth of 18 ft. Most of the onshore portion of the outfall pipeline consisted of 108 inch diameter reinforced concrete pipe. The offshore portion included a 90 inch diameter reinforced concrete pipe. In the 1970s, during expansion of the Miami-Dade/Central WWTP, an additional 14,296 ft of 120 inch diameter reinforced concrete pressure pipe was constructed to discharge effluent to a depth of 90 ft (Hazen and Sawyer 1997a).

The effect of Tropical Storm Gordon and Hurricane Andrew on the ocean outfall pipeline was evaluated and the pipeline was found to be hydraulically and structurally stressed (Rust Environment and Infrastructure 1995). The ocean outfall was rehabilitated in 2000. Both onshore and offshore portions of the original 108/90 inch portion of the outfall pipeline were changed. Modification of the onshore portion involved installation of 1600 ft of 120 inch pipe from the pumping station to the shoreline about 100 ft north of the existing 90 inch outfall pipe. Modification of the offshore portion included the addition of 4,442 ft of 120 inch pipe extending from shoreline to the existing 120 inch pipe (Hazen and Sawyer 1997a).

The current Miami-Dade/Central Outfall consists of parallel 120 and 90 inch pipes that connect to a single 120 inch pipe offshore. The offshore pipe extends 18,800 ft from the shoreline. The effluent is discharged through five 48 inch ports at a depth of about 100 ft. The permitted capacity of the outfall is 143 MGD annual average daily flow. The gravity flow is limited to 116 MGD by high tide conditions. An effluent pumping station is used to pump effluent through the outfall when flows exceed the maximum that can be conveyed by gravity (PBS&J 2003).

2.6.5 Disposal Methods in Addition to Ocean Outfall

The Miami-Dade/Central WWTP has no disposal method other than its ocean outfall.

2.6.6 Future Plans

Future plans for the Miami-Dade/Central WWTP were discussed in Section 2.5.6.

2.7 Summary of Flows in the Six WWTPs and Three County Area

Data collected and recorded by the United State Geological Survey, presented in Table 2-44, indicate that domestic wastewater discharged by municipal systems declined between the Years 1995 and 2000 in Broward and Miami-Dade Counties and marginally increased in Palm Beach County. These data suggest a substantial reduction in per capita usage, as much as 26% for Broward County.

Table 2-44. Wastewater Flows for the Three County Area for the Years 1995 and 2000 (Marella 1999; Marella 2004)

	1995 Average Daily Flow (MGD) (gal/capita/day)	**2000 Average Daily Flow** (MGD) (gal/capita/day)	**Percent Difference**
Palm Beach	107.7 (140)	108.1 (114)	0.3 (-18.5)
Broward	191.2 (175)	190.3 (129)	-0.5 (-26.4)
Miami-Dade	323.9 (206)	311.1 (170)	-4.0 (-17.3)

Despite the observed reduction in per capita usage, wastewater production is expected to increase over the next twenty years due to population increases, as shown in Table 2-45. Figure 2-9 depicts the projected increase in wastewater production over the study period.

Table 2-45. Summary of Six WWTP Projected Flows in MGD, 2005-2025

Year	2005	2010	2015	2020	2025
Boynton-Delray	19.4	21.3	23.2	25.2	27.1
Boca Raton	15.6	17.1	18.7	20.2	21.8
Broward/North	84.2	88.6	90.8	92.2	94.1
Hollywood	40.0	43.5	47.2	50.9	54.5
Miami-Dade/North	107.9	111.9	116.6	121.3	126.3
Miami-Dade/Central	129.4	134.1	139.8	145.4	151.3

Additional data reported by the USGS show that in 1995, the service areas of the Boynton-Delray and the Boca Raton WWTPs comprised 31% of the population and 28% of the total wastewater flow in Palm Beach County, as shown in Table 2-46. The service areas of the Broward/North and Hollywood WWTPs in Broward County accounted for 53% of both population and wastewater flow in the county during the same year, as shown in Table 2-47. The service areas of the Miami-Dade/North and Miami-Dade/Central WWTPs in Miami-

Dade County comprised 77% of the population and 71% of the total wastewater flow (Table 2-48).

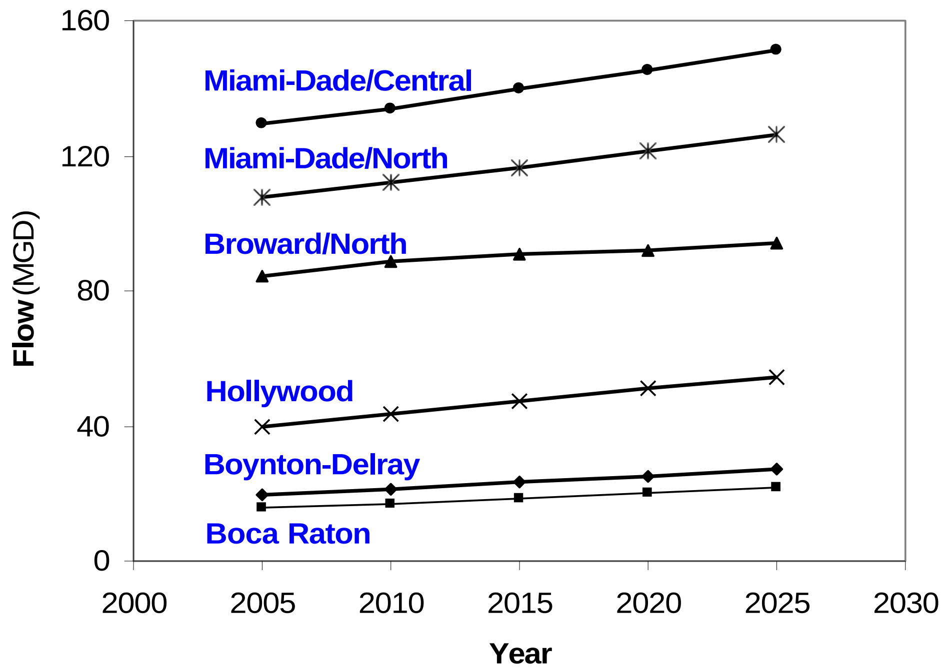

Figure 2-9. Projected Wastewater Flows for the six WWTPs with ocean outfalls from 2005–2025

Table 2-46. Palm Beach County Wastewater Flows in MGD by Service Area for the Year 1995 (Marella 1999)

	Population Served	**Permitted Capacity**	**Total**	**Ground**	**Injection Well**	**Surface**
Acme	17,000	4.8	2.4	0	2.4	0
Belle Glade	12,000	3	3.0	0	3.0	0
Boca Raton	**65,000**	**20**	**13.7**	**0**	**0**	**13.7**
Delray Beach	**175,000**	**24**	**16.6**	**0**	**0**	**16.6**
Loxahatchee	40,000	8	4.3	2.5	1.9	0
Pahokee	7,000	1.2	1.1	0	1.1	0
Palm Beach County Utilities Century	NA	1	0.4	0	0.4	0
Palm Beach County Utilities North	NA	4.5	1.5	0	1.5	0
Palm Beach County Utilities Southern	115,000	40	14.1	1.2	12.9	0
Royal Palm Beach Utilities	16,015	2.2	1.6	0	1.6	0
Seacoast Utilities	48,000	8	8.0	0	8.0	0
South Bay	4,000	1.4	0.8	0	0.8	0
U.S. Sugar Ritta Village	820	0.1	0.1	0.1	0	0
U.S. Sugar Bryant	1,300	0.1	0.1	0.1	0	0
West Palm Beach	267,000	40	40.1	0	40.1	0
United Technologies	NA	0.2	0.1	0	0.1	0
Total	768,135	158.5	107.8	3.8	73.8	30.2

Table 2-47. Broward County Wastewater Flows in MGD by Service Area for the Year 1995 (Marella 1999)

	Population Served	Permitted Capacity	Total	Ground	Injection Well	Surface
Broward County Utilities	**400,000**	**80**	**66.5**	**0**	**23**	**43.5**
Cooper City	12,600	1.3	1.3	0	0	1.3
Coral Springs	20,000	1.3	1.3	0	0	1.3
Davie	5,020	3	2.2	0	0	2.2
Ferncrest Utilities	5,500	0.6	0.3	0	0	0.3
Fort Lauderdale	224,420	43	40.7	0	40.7	0
Hollywood	**180,000**	**42**	**33.2**	**0**	**0**	**33.2**
Margate	47,279	8	8.1	0	8.1	0
Pembroke Pines	12,000	3.5	3.6	0	3.6	0
Plantation	75,184	15	12.8	0	12.8	0
Pompano Beach	NA	2.5	1.5	1.5	0	0
South Broward Utilities	5,267	0.5	0.5	0.5	0	0
Sunrise STP 1	40,000	7.5	7.1	0	7.1	0
Sunrise STP 2	14,480	3	1.5	0	1.5	0
Sunrise STP 3	50,000	8.5	7.4	0	7.4	0
Total	1,091,750	220.0	187.8	2.0	104.1	81.7

Table 2-48. Miami-Dade County Wastewater Flows in MGD by Service Area for the Year 1995 (Marella 1999)

	Population Served	Permitted Capacity	Total	Ground	Injection Well	Surface
American Village	1,000	0.2	0.6	0.6	0	0
Homestead	22,500	2	2.4	2.4	0	0
Miami-Dade/Central	**400,000**	**90**	**135.8**	**0**	**0**	**135.8**
Miami-Dade North	**800,000**	**121**	**95.2**	**0**	**0**	**95.2**
Miami-Dade South	350,000	75	90.5	0	90.5	0
TOTAL	1,573,500	288	324	3	90	231

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3. Water Supply Facilities in the Three Counties

South Florida is experiencing rapid population growth and attendant increases in water demands. The freshwater consumption rate in this region is expected to increase to 4.9 billion gallons per day by 2020, a 26% increase from 1995 (FL DEP 2002). The Everglades Comprehensive Everglades Restoration Plan (CERP) includes expansion of water supplies to restore the environment and partially meet the needs of a growing population. CERP plans to build 18 reservoirs among many innovative alternative water supplies. However, as the Florida Council of 100 (2003) notes, considerable uncertainty exists in the time-phasing and funding of these projects. Florida's water management districts are authorized to restrict water use due to water shortage conditions (Fumero 2003), thus shortfalls in water supply due to drought or delayed water infrastructure projects could lead to restriction or denial of consumptive use permits. Increased use of reclaimed water will directly reduce the increasing need for freshwater.

Summary information on sources of potable quality water, which are generally from the surficial aquifers in Southeast Florida, are noted in this chapter and past demands and population trends are utilized to develop future potable water demand projections. Information about water treatment plants (WTPs), including present capacities and plans for expansion, is also given in the present chapter.

Due to differences between potable water service areas and wastewater service areas, all of the water treatment facilities within the counties are listed. The potable water service areas that most closely cover the wastewater service areas are highlighted and summarized to develop a correspondence between water demand and wastewater production within a particular wastewater service area. It should be noted that there may be discrepancies between the actual water demand of the population within the six wastewater treatment plant (WWTP) service areas due to this lack of a clearly defined overlap between the utility service areas.

Future potable water demands are compared with design capacities to assess the potential future potable water demand that could be supplanted by reuse of reclaimed water for domestic landscape irrigation. Chapter 5 incorporates information from this chapter in the discussion of utilizing reclaimed water.

3.1 Palm Beach County

3.1.1 Water Sources and Water Demands

The population of the Palm Beach County wastewater service areas, that is, the areas served by the Boynton-Delray and Boca Raton WWTPs, relies primarily on groundwater to meet its potable water demand. In some parts of the County, the surficial aquifer is unnamed, while in other parts of the County, the surficial aquifer is the Biscayne Aquifer. These unconfined sources provide most of the raw water that is treated and distributed for the potable water service area.

Utilities in the potable water service areas have implemented water management methods to enhance their potable water supply. During times of drought, treated raw water is blended with finished water at the Boynton Beach West WTP to increase water supplies (Boynton Beach 2005a). Additionally, an aquifer storage and recovery well has been installed to store treated water for subsequent recovery when needed. Aquifer storage and recovery helps to reduce over-utilization of the shallow aquifer.

As shown in Table 3-1, the 297,000 residents within the potable water service area utilized 52.34 MGD in 1995. In 2000, the population had increased to 315,000 and the usage increased to 56.64 MGD The corresponding per capita usage was 176 gal/capita/day and 180 gal/capita/day, respectively (Brown and Caldwell 1995; Hazen and Sawyer 1997; Marella 1999; Marella 2004). In the year 2000, the Boynton-Delray wastewater service area had a per capita usage rate of 164 gal/capita/day, compared to 203 gal/capita/day in the Boca Raton wastewater service area, reflecting a higher per capita demand in the more affluent Boca Raton community.

Table 3-1. Historic Potable Water Demand for Wastewater Service Areas within the Palm Beach County Study Area. Based on data from Brown and Caldwell (1995), Hazen and Sawyer (1997), Marella (1999) and Marella (2004)

Year	**1995**	**2000**
Water usage (MGD)	52.3	56.6
Per capita usage (gal/capita/day)	176	180

As noted in Section 2.1, the population for the Palm Beach County area is expected to increase at a rate consistent with the high population influx typical for the region (GEC 2003). Table 3-2 indicates the projected potable water demand for the residents of the study area for the period from 2005 to 2025, utilizing the 2000 per capita usage of 180 gal/capita/day throughout the study period and the population projection estimated from the United States Army Corps of Engineers (GEC 2003). The potable water demand for the Palm Beach County study area is expected to increase from 62.5 MGD in 2005 to 87.4 MGD in 2025.

Table 3-2. Potable Water Demand Projections for Wastewater Service Areas within the Palm Beach County Study Area from 2005–2025. Based on data from Brown and Caldwell (1995), Hazen and Sawyer (1997), Marella (Marella 1999), Marella (2004), and GEC (2003)

Year	**2005**	**2010**	**2015**	**2020**	**2025**
Water demand (MGD)	62.5	68.7	74.9	81.2	87.4

3.1.2 Water Treatment Facilities and Future Plans

There are four WTPs in the service area within Palm Beach County. The Delray Beach, Boynton Beach East, and Boynton Beach West water treatment facilities are located within the wastewater service area of the Boynton-Delray WWTP, and the Boca Raton Glades Road WTP lies within the service area of the Boca Raton WWTP. Table 3-3 shows eight WTPs located within Palm Beach County; the WTPs that provide potable water to the population of the wastewater service areas that have WWTPs that discharge to ocean outfalls are shown in bold.

Table 3-3. Palm Beach County Water Treatment Plants (SFRPC 2005). WTPs listed in boldface type have service areas in common with the South Central Regional and Glades Road WWTPs.

Plant Name	**Plant Address/ Location**	**Design Capacity** (MGD)	**Treatment process**	**Source of water**	**Ref.**
Delray Beach WTP	**600 S.W. 2nd Ave., Delray Beach**	**26.0**	**Lime softening**	**Surficial aquifer**	**Delray Beach (2005b; 2005a)**
Boynton Beach East WTP	**1620 S. Seacrest Blvd., Boynton Beach**	**19.0**	**Lime softening**	**Surficial aquifer**	**Boynton Beach (2005b; 2005a)**
Boynton Beach West WTP	**5469 W. Boynton Beach Blvd., Boynton Beach**	**9.0**	**Membrane filtration**	**Surficial aquifer**	**Boynton Beach (2005b; 2005a)**
Glades Road WTP	**Glades Rd., Boca Raton**	**70.0**	**Lime softening & Membrane filtration**	**Biscayne Aquifer**	**(Boca Raton 2005)**
Palm Beach County WTP #2	Suburban Lake Worth	14.5	Lime softening + ozone treatment	Surficial aquifer	(Palm Beach County 2005a)
Palm Beach County WTP #3	Suburban Delray-Boynton Beach	30.0	Membrane filtration	Surficial aquifer	(Palm Beach County 2005b)
Palm Beach County WTP #8	Suburban West Palm Beach	20.0	Lime softening + ozone treatment	Surficial aquifer	(Palm Beach County 2005c)
Palm Beach County WTP #9	Suburban Boca Raton	27.0	Membrane filtration	Surficial aquifer	(Palm Beach County 2005d)

a) Delray Beach WTP. The Delray Beach WTP, located at 600 S.W. 2nd Ave., is a 26.0-MGD (design and permitted capacity) lime softening treatment facility (Delray Beach 2005b). Raw water is aerated to remove natural gases and lime is added in a clarifier for softening, color removal, and iron removal. The facility utilizes filtration, disinfection, and fluoride injection prior to distribution (Delray Beach 2005a).

b) Boynton Beach East and West WTPs. Two WTPs are operated to serve the City of Boynton Beach. The Boynton Beach East WTP, located at 1620 S. Seacrest Boulevard, was built in 1962 with a design capacity of 8 MGD and was expanded to 17.5 MGD in late 1970s (Brown and Caldwell 1993). The WTP currently has a design and permitted capacity of 19.0 MGD and uses advanced lime-softening and filtration treatment process. The Boynton Beach West WTP, located at 5469 W. Boynton Beach Blvd., Boynton Beach, started operation in 1994. This WTP utilizes membrane softening technology and has a design and permitted capacity of 9.0 MGD (Boynton Beach 2005b).

The Boynton Beach West WTP has one aquifer storage and recovery well with a permitted capacity of 6.4 MGD and is planning to install a second well in 2005 (Boynton Beach 2005a).

c) Glades Road WTP, Boca Raton. Boca Raton's first WTP was constructed in 1927 where the City Hall stands today. A new WTP was built in the northwest corner of Glades Road and Boca Raton Boulevard with a capacity of 2.0 MGD in 1956, which was subsequently replaced by a 20.0-MGD WTP in the current Utility Services Complex. The WTP design capacity was increased with a 10.0 MG storage tank to supplement the existing 7.5-MG tank. The number of filters was increased to eight by constructing a third filter building consisting of two new filters and the design capacity to expand with a ninth filter. The raw water supply was recently increased by permitting seven additional 2.0 MGD wells. An additional 40.0 MGD membrane softening water treatment facility was completed in 2004. The Glades Road WTP currently has a design and permitted capacity of 70.0 MGD (Boca Raton 2005).

3.2 Broward County

3.2.1 Water Sources and Water Demands

The public utilities within Broward County rely solely on the Biscayne Aquifer, a surficial aquifer unique to South Florida (Marella 1999).

As shown in Table 3-4, the 858,000 residents within the wastewater service areas of the Broward/North and Hollywood WWTPs utilized 138.5 MGD of potable water in 1995, increasing to 942,000 residents and 152.2 MGD in 2000. This potable water demand represents an increase of 9.9% in five years (Hazen and Sawyer 2001; Hazen and Sawyer 2004).

Table 3-4. Historic Potable Water Demand for Wastewater Service Areas within the Broward County Study Area. Based on data from Hazen and Sawyer (2001; 2004)

Year	**1995**	**2000**
Water usage (MGD)	138.5	147.2
Per capita usage (GPD)	162	162

The population within the potable water service area is expected to continue to increase in Broward County, although at a rate slightly below that of the past, decreasing from the 9.9% seen between 1995 and 2000 to an estimated 6.6% growth rate from 2020 to 2025 (Hazen and Sawyer 2001; GEC 2003; Hazen and Sawyer 2004). Table 3-5 indicates the projected water demand for the residents of the potable water service area from years 2005 to 2025, based on figures obtained from Hazen and Sawyer (2001; 2004) and a per capita usage of 162 gal/capita/day obtained from historical water demand and population values (Hazen and Sawyer 2001; GEC 2003; Hazen and Sawyer 2004). The potable water demand for the study area is projected to increase from 167.3 MGD in 2005 to 226.7 MGD in 2025.

Table 3-5. Water Demand Projections for Wastewater Service Area within the Broward County Study Area from 2005–2025. Based on data from Hazen and Sawyer (2001b; 2004) and GEC (2003)

Year	**2005**	**2010**	**2015**	**2020**	**2025**
Water demand (MGD)	167.3	182.6	197.8	212.7	226.7

The Broward County Office of Environmental Services is planning alternative technologies in case current sources of raw water prove to be inadequate. This alternative is the Floridan Aquifer, an artesian water supply located about 1,000 feet underground. Floridan Aquifer water is higher in total dissolved solids than water from the Biscayne Aquifer and thus needs to be treated with reverse osmosis membrane technology to meet regulatory requirements. The City of Hollywood and the Town of Jupiter currently use the Floridan Aquifer for a portion of their drinking water supply (Hazen and Sawyer 2004).

An integrated water resource plan will be used to develop alternative sources of raw water and innovative management methods, such as increasing water conservation, expanding reuse of reclaimed water, increasing utilization of stormwater through improved operations of the secondary canal system, and applying aquifer storage and recovery technology to meet potable water demands through 2025 (Hazen and Sawyer 2004).

3.2.2 Water Treatment Facilities and Future Plans

Table 3-6 indicates the locations of twenty eight WTPs identified in Broward County (SFRPC 2005). The WTPs that are in the service area of Broward/North WWTP are the Broward County 1A and 2A, City of Coral Springs, City of Lauderhill, and City of Tamarac Utilities West WTP; the Deerfield Beach East and West WTPs, Fiveash WTP, Hillsboro Beach WTP; North Springs Improvement District, Pompano Beach WTP, and the Springtree WTP–Sunrise #1 WTP. The WTPs that are in the service area of the Hollywood WWTP are the City of Dania Beach, City of Hallandale Beach, and Hollywood WTPs, Miramar West Water Plant, and the Pembroke Pines WTP #2.

Capacities and future plans for each WTP are shown in Table 3-7. Total permitted and design capacities for these WTPs are 415.9 and 490.7 MGD, respectively. The maximum day potable water demand is 319.0 MGD (76.7% of permitted capacity) while the annual average daily flow (AADF) is 242.0 MGD (58.2% of permitted capacity). The largest providers of potable water in the County are the Broward County, the City of Hollywood, Sunrise WTPs, and the Fiveash WTP in Fort Lauderdale. A design capacity of 37.0 MGD will be added by 2008 through expansion of eight of these WTPs (SFRPC 2005). Further information about the WTPs within the study area in Broward County is presented in the following sections.

Table 3-6. Broward County Water Treatment Plant Locations (SFRPC 2005). WTPs listed in boldface type have service areas in common with the Broward/North and Hollywood WWTPs.

Plant Permit #	FL DEP Facility ID	Plant Name	Plant Address	City
06-58-00009	**4060167**	**Broward County 1A WTP**	**3701 North State Road 7**	**Lauderdale Lakes**
06-58-00010	**4060163**	**Broward County 2A WTP**	**1390 N.E. 50th St.**	**Pompano Beach**
4060209	**4060209**	**City of Coral Springs WTP**	**3800 N.W. 85th Ave.**	**Coral Springs**
4060253	**4060253**	**City of Dania Beach WTP**	**1201 Stirling Road**	**Dania Beach**
FL4060573	**4060573**	**City of Hallandale Beach WTP**	**215 N.W. 6th Ave.**	**Hallandale Beach**
FL4060787	**4060787**	**City of Lauderhill WTP**	**2101 N.W. 49th Ave.**	**Lauderhill**
06-58-00059	4060845	City of Margate WTP	1001 West River Drive	Margate
4061429	**4061429**	**City of Tamarac Utilities West WTP**	**7805 N.W. 61st St.**	**Tamarac**
4060282	4060282	Cooper City Utilities WTP	11791 S.W. 49th St.	Cooper City
4060291	4060291	Coral Springs Improvement District WTP	10300 N.W. 11th Manor	Coral Springs
06-58-00027	4060344	Davie WTP System I	3790 S.W. 64th Ave.	Davie
06-58-00028	4060344	Davie WTP System III	3500 N.W. 76th Ave.	Hollywood
4060254	**4060254**	**Deerfield Beach East Water Plant**	**101 N.W. 2nd Ave.**	**Deerfield Beach**
4060254	**4060254**	**Deerfield Beach West Water Plant**	**290 Goolsby**	**Deerfield Beach**
4060419	4060419	Ferncrest Utilities WTP	3015 S.W. 54th Ave.	Fort Lauderdale
FL40604861-01	**4060486**	**Fiveash Water Plant – Fort Lauderdale WTP**	**1500 S. State Road 7/4321 NW 9th Ave**	**Fort Lauderdale**
4060615	**4060615**	**Hillsboro Beach Water Plant**	**925 N.E. 36th St.**	**Pompano Beach**
4060642	**4060642**	**Hollywood WTP**	**3441 Hollywood Blvd.**	**Hollywood**
W11035	**4060925**	**Miramar West Water Plant**	**2600 S.W. 66th Terrace**	**Miramar**
4064390	**4064390**	**North Springs Improvement District WTP**	**9700 N.W. 53rd Court**	**Coral Springs**
4061407	**4061407**	**Park City WTP– Sunrise #2**	**8700 S.W. 19th Place**	**Fort Lauderdale**
4061083	**4061083**	**Pembroke Pines WTP #2**	**7960 Johnson St.**	**Pembroke Pines**
4061121-01	4061121	Plantation Central WTP	400 N.W. 73rd Ave.	Plantation
4061121-02	N/A	Plantation East WTP	N/A	N/A
06-58-00078	**4061129**	**Pompano Beach WTP**	**301 N.E. 12th St.**	**Pompano Beach**
4061408	4061408	Sawgrass WTP– Sunrise #3	777 Sawgrass Corporate Parkway	Sunrise
4064326	4064326	Southwest (S. Broward) WTP	15450 Stirling Road	Davie
4061410	**4061410**	**Springtree WTP– Sunrise #1**	**4350 Springtree Drive**	**Sunrise**

Table 3-7. Broward County WTP Capacities and Future Plans (SFRPC 2005). WTPs listed in boldface type have service areas in common with the Broward/North and Hollywood WWTPs.

Plant Name	Design Capacity (MGD)	Permitted Capacity (MGD)	Peak Flow (MGD)	AADF (MGD)	Additional Capacity (MGD/yr)
Broward County 1A WTP	**60.0**	**16.0**	**9.0**	**8.3**	**NR**[1]
Broward County 2A WTP	**40.0**	**30.0**	**17.4**	**15.4**	**NR**
City of Coral Springs	**16.0**	**16.0**	**10.3**	**8.4**	**NR**
City of Dania Beach WTP	**3.0**	**4.0**	**3.4**	**2.8**	**4.5/2007**
City of Hallandale Beach	**10.0**	**10.0**	**7.0**	**5.8**	**6.0/2006**
City of Lauderhill	**16.0**	**8.1**	**8.6**	**6.9**	**NR**
City of Margate WTP	18.0	13.5	9.1	7.0	NR
City of Tamarac Utilities West	**20.0**	**8.3**	**13.1**	**6.4**	**NR**
Cooper City Utilities	7.0	7.0	5.7	2.9	NR
Coral Springs Improvement District	7.1	5.8	5.5	4.2	NR
Davie WTP System I	3.4	3.4	1.2	1.0	NR
Davie WTP System III	4.0	4.0	3.5	3.4	4.0/2006
Deerfield Beach East Water Plant	**16.8**	**16.8**	**7.9**	**2.0**	
Deerfield Beach West Water Plant	**18.0**	**18.0**	**14.9**	**12.6**	**3.5/2008**
Ferncrest Utilities	1.0	1.0	0.9	0.8	NR
Fiveash Water Plant – Fort Lauderdale	**75.0**	**67.3**	**57.1**	**42.5**	**NR**
Hillsboro Beach Water Plant	**2.0**	**1.0**	**1.3**	**1.1**	**NR**
Hollywood WTP	**61.0**	**57.5**	**32.8**	**26**	**NR**
Miramar West Water Plant	**7.5**	**7.5**	**6.5**	**5.8**	**3.0/2007**
North Springs Improvement District	**6.8**	**6.5**	**5.4**	**4.1**	**NR**
Park City WTP– Sunrise #2	**6.0**	**6.0**	**5.5**	**2.9**	**NR**
Pembroke Pines WTP #2	**18.0**	**16.2**	**15.5**	**13.5**	**6.0/2005– 2007**
Plantation Central WTP	12.0	12.0	10.6	7.0	NR
Plantation East WTP	12.0	12.0	8.2	6.8	NR
Pompano Beach WTP	**50.0**	**24.0**	**21.9**	**17.2**	**NR**
Sawgrass WTP– Sunrise #3	18.0	18.0	12.2	8.8	6.0 – 2006
Southwest (S. Broward) WTP	2.0	2.0	1.9	0.5	NR
Springtree WTP– Sunrise #1	**24.0**	**24.0**	**22.7**	**17.9**	**4.0/2006**
County Total	490.7	415.9	319.0	242.0	37.0 by 2008

[1] None Reported

a) Broward County District 1A and 2A WTPs. The Broward County Office of Environmental Services owns and operates the District 1A and 2A WTPs. The District 1A WTP, located at 3701 North State Road 7, Lauderdale Lakes, started operation in 1960 with a design capacity of 3.0 MGD. The WTP was expanded to 10.5 MGD in 1979 and achieved its current design capacity of 16.0 MGD in 1994. Upflow clarifiers and multimedia filtration are provided in conjunction with lime softening treatment of the raw water from the District 1A well field (Hazen and Sawyer 2004).

The District 2A WTP, located at 1390 N.E. 50th Street, Pompano Beach, started with a 20.0-MGD design capacity in 1972 and was brought to its current design capacity of 40.0 MGD in 1994. The permitted operating capacity is 30.0 MGD. Upflow clarifiers and multimedia filtration are provided together with lime softening treatment of the raw water from the 2A and North Regional well fields (Hazen and Sawyer 2004).

The Broward County Office of Environmental Services is working on rebuilding substantial portions of the water systems to overcome deficiencies in handling existing and projected potable water demands. The improvement projects for Districts 1, 2 and 3 are anticipated to be completed by 2008, 2010 and 2005 at estimated costs of $320 million, $167 million and $95 million, respectively (Hazen and Sawyer 2004).

b) Hollywood WTP. The Hollywood WTP, located at 3441 Hollywood Blvd., Hollywood, started operation in 1925 with a design capacity of 0.5 MGD. In 1935, a water softening system was added to the WTP to improve potable water quality. In late 1970s, the WTP was expanded with a lime softening system. The City of Hollywood decided to utilize membrane treatment in the 1980s and the WTP was upgraded with a 16.0-MGD membrane treatment facility in 1996. The membrane treatment facility has the ability to be expanded to 300 MGD. The lime softened and membrane treated waters are blended together (Hollywood 2005b). The design capacity is 61.0 MGD and the permitted capacity is 57.5 MGD (SFRPC 2005). The emergency power capabilities at the Hollywood WTP are being upgraded, a new well field is being installed, and the south well field is being rehabilitated for future demands (Hollywood 2005a).

3.3 Miami-Dade County

3.3.1 Water Sources and Water Demands

The public utilities within Miami-Dade County rely only upon the Biscayne Aquifer, a surficial aquifer unique to South Florida (Miami-Dade County 2005).

As shown in Table 3-8, the 1,282,000 residents within the service area of the Miami-Dade/North and Miami-Dade/Central District WWTPs in Miami-Dade County utilized an average of 219.3 MGD in 1995. In the year 2000, 1,343,000 residents used 229.7 MGD, an increase in water usage of 4.7% (PBS&J 2003).

Table 3-8. Historic Potable Water Demand for Wastewater Service Areas within the Miami-Dade County Study Area. (PBS&J 2003)

Year	**1995**	**2000**
Water usage (MGD)	219.3	229.7
Per capita usage (GPD)	171	171

The 1995 and 2000 values presented in PBS&J (2003) are based on per capita usage of 171 gal/capita/day. The same per capita usage was used in developing the projections shown in Table 3-9. Projected water demands for the service area increase from 238.9 MGD in 2005 to 292.4 MGD in 2025.

Table 3-9. Water Demand Projections for Wastewater Service Area within the Miami-Dade County Study Area from 2005–2025. Based on data from PBS&J (2003) and GEC (2003)

Year	**2005**	**2010**	**2015**	**2020**	**2025**
Water demand (MGD)	238.9	247.7	263.4	276.6	292.4

3.3.2 Water Treatment Facilities and Future Plans

The locations of seven WTPs that serve Miami-Dade County (SFRPC 2005) are shown in Table 3-10. The WTPs that are in the service area of the North District WWTP are the City of N. Miami Winson, Hialeah-Preston and Norwood Water Plants. There are no WTPs that lie exclusively in the service area of the Central District WWTP. The Alexander Orr WTP is on the border of the Central and South District WWTP service areas.

Detailed information and future plans for each WTP are shown in Table 3-11. Total permitted and design capacities for the WTPs are 453.8 and 500.5 MGD, respectively. The peak demand is 412.4 MGD (90.9% of permitted capacity) while the annual average daily flow (AADF) is 380.3 MGD (83.8% of permitted capacity). The largest providers in the County are the Alexander Orr and Hialeah-Preston WTPs. Additional water supply of 111.3 MGD will be completed by 2013 through expansion of five of these facilities (SFRPC 2005). The Alexander Orr and Hialeah-Preston WTPs are operated by the Miami-Dade Water and Sewer Department. Additional information about these facilities is given below.

The Alexander Orr and Hialeah-Preston WTPs include lime softening, disinfection, fluoridation, and filtration treatment. They have a common distribution system that covers most of Miami-Dade County (MDWASD 2005). The WTPs were designed for a capacity of 225.0 and 217.7 MGD, respectively, and are permitted for 199.2 and 203.1 MGD, respectively (SFRPC 2005). The Hialeah-Preston WTP, located at 1100 West 2nd Ave., Hialeah, treats water from the northwest and other nearby well fields to serve the residents north of Flagler St. The Alexander Orr WTP, located at 6800 S.W. 87th Ave., Miami, receives its water from the Alexander Orr, Snapper Creek and Southwest well fields, and serves the southern part of the county, down to SW 264th Street. Air stripping facilities were installed at the Hialeah and Preston WTPs in 1992 to restore the contaminated Hialeah and Miami Springs well fields that were out of service (PBS&J 2003).

An aquifer storage and recovery program is underway to store surplus Biscayne aquifer water in the Upper Floridan Aquifer during the wet season and retrieve this water for dry season supply. Several aquifer storage and recovery wells have been installed and others are being constructed or planned. The South Florida Water Management District (SFWMD) developed VISION 2050 for South Florida, which emphasizes development of non-traditional water sources such as reclaimed water, salt water, and deeper aquifers. In the future, the lower east coast of Florida will depend less on the regional water management system and more on local water storage, aquifer storage and recovery, water reuse, and advanced water treatment technologies. As part of this plan, a 23,000-acre freshwater lake in Northwest Miami-Dade County is proposed for water supply during the dry season (PBS&J 2003).

Table 3-10. Miami-Dade County Water Treatment Plant Locations. WTPs listed in boldface type are within the service areas of the Miami-Dade/North and Miami-Dade/Central WWTPs

Plant Permit #	FDEP Facility ID	Plant Name	Plant Address	City
13-00017-W		**Alexander Orr**	**6800 S.W. 87th Ave.**	**Miami**
13-00046-W	4130645	City of Homestead	505 N.W. 9th St.	Homestead
13-00059-W	**PWO-000017**	**City of N. Miami Winson Water Plant**[1]	**12100 N.W. 11th Ave.**	**North Miami**
13-00029-W	4130255	Florida City	461 N.W. 6th Ave.	Florida City
13-00037-W		**Hialeah-Preston**	**1100 West 2nd Ave.**	**Hialeah**
13-00060-W	**4131618**	**Norwood Water Plant – N. Miami Beach**[2]	**19150 N.W. 8th Ave.**	**Miami Gardens**
13-00040-W		South Miami-Dade WTP[3]	11800 S.W. 208th St.	Miami

[1]The City of North Miami receives 50% of its water service from WASD, while the Winson Plant provides the other 50%. The Winson Plant also provides water service to Biscayne Park and parts of Unincorporated Miami-Dade County.

[2]The City of North Miami Beach receives 50% of its water service from WASD, while the Norwood Water Plant provides water to the other 50%. The Norwood Plant also provides water service to Sunny Isles Beach, Miami Gardens, Golden Beach, and Aventura.

[3]The South Miami-Dade WTP is currently under construction. The data provided are the cumulative total for five small WTPs (Leisure City WTP, Everglades Labor Camp WTP, Newton WTP, Elevated Tank WTP, and Naranja Lakes WTP) that the County uses. These WTPs will be taken out of service after the South Miami-Dade WTP is completed.

Table 3-11. Miami-Dade County Water Treatment Plant Capacities and Future Plans

Plant Name	Design Capacity (MGD)	Permitted Capacity (MGD)	Peak Flow (MGD)	AADF (MGD)	Additional Capacity (MGD/yr)
Alexander Orr	217.7	203.1	185.5	171.9	60.3/2013
City of Homestead	16.7	11.7	10.9	8.5	5.0/2008
City of N. Miami Winson Water Plant	9.0	9.3	10.0	8.5	NR[1]
Florida City	4.03	3.51	3.6	3.0	NR
Hialeah-Preston	225.0	199.2	177.6	166.1	10.0/2005
Norwood Water Plant – N. Miami Beach	16.0	16.0	16.0	15.5	16.0/2006
South Miami-Dade WTP	12.0	10.9	8.8	6.8	20.0/2006
County Total	**500.5**	**453.8**	**412.4**	**380.3**	**111.3 by 2013**

[1] None Reported

3.4 Summary of Three County Area

Water demands for the three county area are expected to continue increasing throughout the study period, but the projected increase could be reduced by the implementation of water conservation programs and technologies. The projections given in this report provide estimates of the region's water demand that are inclusive of current water demand trends using presumed minimal water conservation efforts.

As summarized in Table 3-12, aggregate water demand for the three county area have increased from 410.2 MGD in 1995 to 468.7 MGD in 2005. Population growth in the region is expected to continue this upward trend in water demand (Fig. 3-1), resulting in an aggregate water demand of 606.5 MGD by the year 2025. The service areas for Palm Beach County are expected to see about a 40% increase in water demand between the years 2005 and 2025. The service areas for Broward and Miami-Dade Counties are anticipated to experience 36% and 22% increases in water demand, respectively, over the same period.

Table 3-12. Summary of Historical and Projected Water Demands in MGD for the Three County Area from 1995–2025

	1995	2000	2005	2010	2015	2020	2025
Palm Beach	52.3	56.6	62.5	68.7	74.9	81.2	87.4
Broward	138.5	147.2	167.3	182.6	197.8	212.7	226.7
Miami-Dade	219.3	229.7	238.9	247.7	263.4	276.6	292.4
Total	410.2	433.5	468.7	499.0	536.1	570.6	606.5

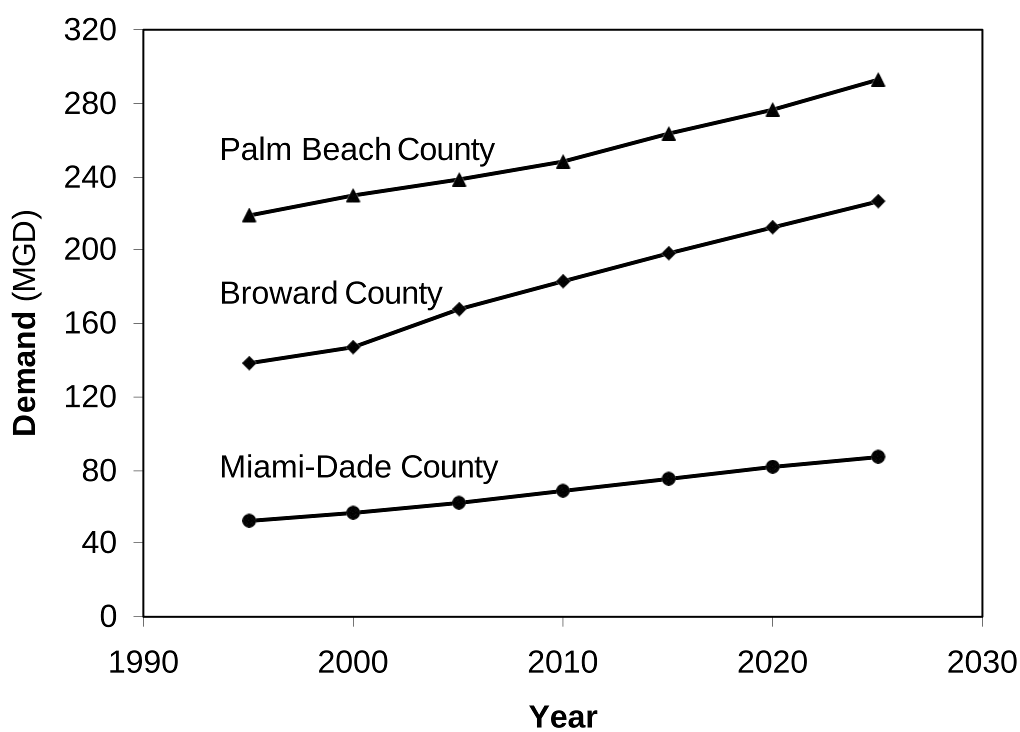

Figure 3-1. Historical and Projected Water Demands by County from 1995–2025

Each of the service areas within the three counties was analyzed to determine the future water demand in relation to the planned potable water design capacity for each of the 5-year projections. "Design capacity" indicates the amount of water that a WTP can deliver without having to incur physical modification and is preferred to the "permitted capacity", which is the amount of water that a WTP is permitted to deliver without a permit modification. In some instances where the "design capacity" is greater than the "permitted capacity", a WTP can have its "permitted capacity" increased without any physical modification to the WTP. In the case where a WTP has a "permitted capacity" less than a "design capacity", the increase in "permitted capacity" can be increased by requesting a re-rating of the WTP by the Florida Department of Environmental Protection. "New water" is the water demand in excess of the existing or planned water supply (design capacity) of the water treatment facility.

The analysis for "new water" can be used to identify WTPs where reclaimed water can be substituted for other, less available or more costly new water sources. For example, since approximately 40% of all residential potable water use is for irrigation (Heaney et al. 2000), reclaimed water can supplement current potable water supplies for landscape irrigation, potentially reducing the need for identifying new sources of potable water. Reclaimed water can be used for groundwater recharge, where applicable, or a component in an aquifer storage and recovery (ASR) systems. Additionally, reclaimed water can be utilized for make up water as part of the Comprehensive Everglades Restoration Program (CERP), a United States Army Corps of Engineers rehabilitation program that aims to improve the quality of the Everglades. Subsequent chapters of this report provide detailed information indicating the water quality standards for each of the water reuse options and the levels of treatment recommended to achieve water quality standards.

The new water analysis for Palm Beach County (Table 3-13) indicates that Palm Beach County has sufficient WTP design capacity to meet its needs until at least 2025.

Table 3-13. Summary of Projected Water Demands and WTP Design Capacities for Palm Beach County

Facility	**Design Capacity** (MGD)		**Flow projections** (MGD)				
	2005		**2005**	**2010**	**2015**	**2020**	**2025**
Boca Raton Glades Road WTP	70.0	Total	44.0	48.4	52.7	57.2	61.6
		New water*	0.0	0.0	0.0	0.0	0.0
Boynton Beach WTP	28.0	Total	15.4	16.9	18.4	20.0	21.5
		New water	0.0	0.0	0.0	0.0	0.0
Delray Beach WTP	26.0	Total	14.9	16.4	17.9	19.4	20.9
		New water	0.0	0.0	0.0	0.0	0.0
Total	124.0	Total	74.4	81.7	89.1	96.6	104.0
		New water	0.0	0.0	0.0	0.0	0.0

*Demand in excess of capacity

As depicted in Table 3-14, Broward County has 16 WTPs that provide potable water to the service areas of the Broward North and Hollywood WWTPs. The County presently has insufficient design capacity to meets its 2025 water demand. However, the water utilities within the County are planning five improvement programs during the study period to increase the design capacity by 26.9 MGD for a total of 426.8 MGD by the year 2008, which is sufficient to meet water demands throughout the study period.

Table 3-14. Summary of Projected Water Demands and WTP Design Capacities for Broward County

Facility	**Design Capacity** (MGD) **2005**		**Flow projections** (MGD) **2005**	**2010**	**2015**	**2020**	**2025**
City of Dania Beach WTP	3.0 (7.5 by 2007)	Total	3.0	3.3	3.6	3.9	4.2
		New water*	0.0	0.0	0.0	0.0	0.0
City of Lauderhill WTP	16.0	Total	7.5	8.2	8.8	9.5	10.2
		New water	0.0	0.0	0.0	0.0	0.0
City of Tamarac Utilities WTP	20.0	Total	7.0	7.6	8.3	8.9	9.6
		New water	0.0	0.0	0.0	0.0	0.0
Coral Springs WTP	16.0	Total	9.2	10.0	10.8	11.7	12.5
		New water	0.0	0.0	0.0	0.0	0.0
Deerfield Beach East WTP	16.8	Total	2.2	2.4	2.6	2.8	3.0
		New water	0.0	0.0	0.0	0.0	0.0
Deerfield Beach West WTP	18.0 (21.5 by 2008)	Total	13.8	15.0	16.2	17.5	18.8
		New water	0.0	0.0	0.0	0.0	0.0
District 1A WTP	16.0	Total	9.1	9.9	10.7	11.5	12.4
		New water	0.0	0.0	0.0	0.0	0.0
District 2A WTP	40.0	Total	16.8	18.3	19.9	21.4	22.9
		New water	0.0	0.0	0.0	0.0	0.0
Fiveash Water Plant	75.0	Total	46.4	50.6	54.8	59.1	63.3
		New water	0.0	0.0	0.0	0.0	0.0
Hallandale Beach WTP	10.0 (16.0 by 2006)	Total	6.3	6.9	7.5	8.1	8.6
		New water	0.0	0.0	0.0	0.0	0.0
Hillsboro Beach WTP	2.0	Total	1.2	1.3	1.4	1.5	1.6
		New water	0.0	0.0	0.0	0.0	0.0
Hollywood WTP	61.0	Total	28.4	30.9	33.5	36.2	38.7
		New water	0.0	0.0	0.0	0.0	0.0
Miramar Beach WTP	7.5 (10.5 by 2007)	Total	6.3	6.9	7.5	8.1	8.6
		New water	0.0	0.0	0.0	0.0	0.0
North Springs WTP	6.5	Total	4.5	4.9	5.3	5.7	6.1
		New water	0.0	0.0	0.0	0.0	0.0
Pompano Beach WTP	50.0	Total	18.8	20.5	22.2	23.9	25.6
		New water	0.0	0.0	0.0	0.0	0.0
Springtree–Sunrise #1 WTP	24.0 (28.0 by 2006)	Total	19.6	21.3	23.1	24.9	26.7
		New water	0.0	0.0	0.0	0.0	0.0
Total	399.9 (426.8 by 2008)	Total	214.9	234.1	253.5	273.6	293.0
		New water	0.0	0.0	0.0	0.0	0.0

*Demand in excess of capacity

Considerable improvements are necessary within Miami-Dade County to meet future water demands within the service area of the Miami-Dade/North and Miami-Dade/Central WWTPs (Table 3-15). The County is planning three improvement programs during the study period to increase its design capacity by 86.3 MGD for a total of 554.0 MGD by the year 2025. However, based on current plans for future improvements, the County will still need to identify sources for an additional 26.7 MGD by 2025.

Table 3-15. Summary of Projected Water Demands and WTP Design Capacities for Miami-Dade County

Facility	Design Capacity (MGD) 2005		Flow projections (MGD) 2005	2010	2015	2020	2025
Alexander Orr WTP	217.7 (278.0 in 2013)	Total	200.3	226.0	239.5	253.3	266.5
		New water*	0.0	8.3	0.0	0.0	0.0
Hialeah-Preston WTP	225.0 (235.0 in 2005)	Total	193.5	218.4	231.4	244.7	257.5
		New water	0.0	0.0	0.0	9.7	22.5
North Miami Winson WTP	9.0	Total	9.9	11.2	11.8	12.5	13.2
		New water	0.9	2.2	2.8	3.5	4.2
North Miami Beach Norwood WTP	16.0 (32.0 in 2006)	Total	18.1	20.4	21.6	22.8	24.0
		New water	2.1	0.0	0.0	0.0	0.0
Total	467.7 (554.0 by 2025)	Total	421.8	476.0	504.3	533.3	561.2
		New water	3.0	10.5	2.8	13.2	26.7

*Demand in excess of capacity

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4. Environmental Impacts of Ocean Outfalls

4.1 Introduction

The primary motivation for reducing discharges of pollutants to land and/or receiving waters is to protect water quality and avoid adverse impacts to public health, recreation, and the environment in general. Traditional indicators of water quality include dissolved oxygen (DO) levels in streams and rivers where levels below 4 or 5 mg/L under low flow conditions in the river or stream can lead to fish kills and other obvious manifestations of water quality problems. Nutrients (nitrogen and phosphorus) are other popular indicators of water quality. Excess nutrients cause algal blooms and other undesirable impacts in lakes and rivers. Florida has experienced some dramatic recent incidences lately of these impacts ranging from Lake Okeechobee to the lower St. Johns River wherein algal blooms occurred from Palatka to the mouth of the St. Johns River east of Jacksonville during the summer of 2005. Red tide outbreaks along the Gulf Coast have further heightened public awareness that human activities are having a detrimental impact on important receiving waters. In addition to DO and nutrients, bacterial water quality is used as an indicator of water quality.

The traditional concern with treated wastewater was where to dispose of it. Stricter regulations against discharge to receiving waters in Florida led to aggressive use of land disposal via effluent irrigation. In the past 25 years, there has been growing realization that this highly treated water could be reused. Thus, these land options were more properly referred to as reuse or recharge facilities.

In this study, the focus is on the six wastewater treatment plants that discharge to ocean outfalls in Southeast Florida. The following sections discuss this practice including studies of the relative risks of ocean disposal vs. other options. The relative risk approach is important to use since all disposal and reuse options have various impacts associated with them.

4.2 Description of Selected Ocean Outfall Studies

The six WWTPs in southeast Florida discharge treated effluent to the Atlantic Ocean via ocean outfalls as described in Chapter 2. Several studies have been made of the impacts of these discharges on the ocean and the associated reefs that are located near these outfalls. Summaries of these studies are presented below.

4.2.1 Southeast Florida Outfall Experiments (SEFLOE I and II)

The Southeast Florida Outfall Experiment I (SEFLOE I), initiated by utilities in Broward, Miami-Dade and Palm Beach Counties, characterized the impacts of ocean outfall wastewater disposal in Southeast Florida. Initial and subsequent dilutions were obtained through field dye and salinity data processing. The initial dilution, current meter and effluent discharge data were analyzed with dimensional analysis and regression to obtain semi-empirical relations. Dye concentration and salinity data were used to determine total physical dilutions as a function of distance from the surface boil. The Broward North and Hollywood outfall plumes were found to undergo enhanced dilution within the 100 meter range. This rapid dilution was attributed to an internal hydraulic jump. Subsequent mixing of plumes was dominated by buoyant spreading for several hundred meters from the boil. In the Miami-Dade North and Miami-Dade Central outfalls, the effluent was initially distributed over a wider area due to the multi-port diffusion. However, the dilutions were not as rapid as the Broward and Hollywood outfall plumes. Subsequent mixing of plumes was dominated by buoyant spreading and oceanic turbulence (Proni and Dammann 1989; Englehardt et al. 2001).

The SEFLOE II study was conducted between 1991 and 1994 as a cooperative effort of state, federal and local government agencies, together with Hazen and Sawyer (1994). Ocean outfalls at the North Regional and Southern Regional WWTPs in Broward County and the North and Central District WWTPs in Miami-Dade County were studied to provide site specific information. Physical, chemical, and biological data from field studies were analyzed to characterize outfall plumes and associated environmental conditions. Englehardt et al., (2001) summarize the results of the SEFLOE studies as follows:

- Bacteria—no organisms could be detected more than 800 meters from the outfall.
- Nutrients—Concentrations of ammonia, TKN, total phosphorous, and nitrate were found to reach background levels within 400 meters from the discharge points.
- Oil and grease—Visual field observations indicated no oil or grease sheens within plumes at the surface.

4.2.2 Comparative Assessment of Human and Ecological Impacts from Municipal Wastewater Disposal Methods in Southeast Florida

Englehardt et al. (2001) present a comparative assessment of the human and ecological impacts from municipal wastewater disposal in Southeast Florida. Their assessment includes ocean disposal from the six WWTPs. Ocean discharge differs from other surface water discharge due to the higher density of the saline ocean waters and the much greater dilution of the ocean. The buoyancy of the plume, marine currents and turbulence result in three distinct phases of dilution (Englehardt et al. 2001):

- Initial plume dilution takes less than two minutes from the time the effluent leaves the outfall until it reaches the ocean's surface. The freshwater-saltwater mixture creates a turbulent, rising plume with strong mixing. The mixing is further improved by the horizontal movement of the Florida Current. The plume rises to the surface downstream of the outlet by at least 10 meters. Englehardt et al. (2001) define the initial dilution as the ratio of the constituent in the effluent to the maximum concentration at the boil.
- Near-field dilution occurs after the effluent reaches the surface.
- Far-field dilution is the result of the interaction of the mixing plume and surface convective processes.

Field investigations revealed that surfacing plumes were present at all six WWTP outfalls throughout the year (Englehardt et al. 2001). All of the outfalls are in at least 28 meters of water and 2 miles offshore. They are located in the westerly boundary of the strong Florida Current, a tributary of the Gulf Stream.

Wanninkhof et al. (2006) evaluated farfield dilution of sewage outfall discharges in southeast Florida. Their studies indicate that the rapid dilution observed in the immediate vicinity of the outfall continues to occur in the 10 to 66 km downstream distances. They estimate that the dilution ratio is 212*distance (km). Thus, a unit of pollutant is diluted to 1/212 of its original value in one km. These authors do not address issues of reef impacts or pollutant control.

4.2.3 Relative Risk Assessment of Management Options for Treated Wastewater in South Florida

The 2003 US EPA relative risk assessment study involved deep well injection, aquifer recharge, discharge to ocean outfalls and surface waters as disposal options. Rapid-rate infiltration basins were chosen as the aquifer recharge option because, unlike slow-rate land application systems, they do not require back-up disposal methods, such as discharge to a storage area or to deep well injection, for wet-weather conditions (US EPA 2003).

A risk characterization was done initially for each disposal option to identify and describe the associated risks, the potential magnitude of the risks and the potential impacts on human and ecological health. The data and knowledge gaps for all disposal options were identified as part of the risk analysis. A relative risk assessment was then used to compare risks among the four wastewater disposal options. Each option had its own specific stressors, exposure pathways, receptors, and effects. A quantitative comparison was found to be infeasible because the parameters relevant to one disposal option were not necessarily relevant to the other options. The overall comparisons were presented as relative risk assessment matrices (US EPA 2003).

Treatment levels before disposal and attenuation factors, like travel distance and time, biological degradation, and adsorption, filtration through geologic media, dispersion by groundwater or ocean currents were found to control the concentrations of stressors received by the receptor. The human health risk from pathogenic microorganisms was higher for deep well injection and discharge to ocean outfalls compared to aquifer recharge and discharge to surface waters. Filtration significantly reduced the level of pathogenic protozoans in treated wastewater. Excess nutrients were found to cause ecological problems (US EPA 2003).

Human health risks from the four disposal options were low. The risk increased with less treatment or short exposure pathways. Filtration, together with high-level disinfection, reduced the risk for all options. The risk increased if there was a coincidence of the disposal location and recreational uses in surface and ocean waters. The risk also increased if harmful algal blooms occurred. The human health risks from deep well injection and aquifer recharge options included the potential impact on drinking water supplies (US EPA 2003).

Ecological health risks from deep well injection and aquifer recharge were found to be very low. The ecological risk from surface water disposal was low due to the advanced level of treatment. However, since the surface waters of South Florida are already impaired, the risk was higher. The ecological risk from ocean outfalls was low outside the mixing zones. The risk increased if harmful algal blooms or bioconcentration in food webs were caused. Risk to coral reefs would increase with the construction of new ocean outfalls (US EPA 2003).

Specific findings for ocean outfalls from this study are listed below.

- *The SEFLOE studies provide a risk assessment and a prediction that there should not be any adverse effects resulting from ocean discharge of secondarily-treated effluent. This prediction is based largely on the rapid dispersal and dilution of the effluent plumes by the Florida Current and the relatively low concentrations of stressors in the treated effluent.*
- *Prevailing directions and fast speeds of the Florida Current are major factors that decrease risk for the six ocean outfalls. Current speeds can be more than 60 or 70 cm/sec, while speeds of 20 to 40 cm/sec commonly occur. Northerly flow with the fastest speeds occurs approximately 60% of time. Southerly flow with similar or lesser speeds occurs about 30% of time. Westerly flow towards the east coast of Florida, which represents the highest risk, is estimated to occur less than approximately 4% of the time.*
- *Other factors that decrease risk are the distance of the outfalls from land. The lowest risk outfalls are farthest from land (Miami-Dade Central outfall), while the highest risk outfalls are closest to land (Boca Raton, Delray Beach).*
- *The use of multiport diffusers, compared to the use of single-port diffusers, appears to aid in dispersal of the effluent plume over a wider area, decreasing potential risk. Discharging the effluent at a fast initial speed also appears to increase the rate of dispersal and dilution of the effluent plume.*
- *Based on toxicity testing of marine organisms, there is no evidence that the diluted effluent causes acute toxic effects or short-term chronic effects.*
- *Based on nitrogen isotope studies of organic matter in sediments and nutrients in the water column, it does not appear that the nitrogen in outfall effluent is taken up in significant amounts by phytoplankton in the area. This may be because of the rapid dilution of the effluent nitrogen by the Florida Current.*
- *The State of Florida requires that Class III water quality standards be met outside a mixing zone of 400 m around the outfall. This mixing zone allows for dispersal, mixing, and dilution of the effluent plume.*
- *Concentrations of pathogens are controlled at the treatment plant through chlorination to meet water-quality standards within the required mixing zone; viruses and most bacteria are expected to be adequately inactivated by chlorine. However, there is no filtration to remove* Cryptosporidium *and* Giardia. *Lack of treatment to remove pathogenic protozoans probably constitutes the greatest human health risk posed by this wastewater management option.*
- *Pathogenic protozoans may also pose significant ecological risks related to infections of marine mammals. The effects of pathogenic protozoans on aquatic organisms need to be further investigated.*
- *The results of the SEFLOE study for metals monitoring indicates that, in general, water-quality standards are met at 400 m or 800 m.*
- *The chlorinated discharged effluent largely meets Class III water-quality standards for all regulated wastewater constituents within 400 m of the outfalls, with exceptions as noted.*
- *The lack of long-term ecological, microbial pathogen, and chemical monitoring studies makes it difficult to evaluate whether the conclusions of the SEFLOE studies will continue to hold true in the future.*

- *Human health risks are of some concern, both within the 400-m mixing zone and outside of it, primarily because treatment of effluent prior to discharge via ocean outfalls does not include filtration to remove* Cryptosporidium *and* Giardia. *The most probable human exposure pathways include fishermen, swimmers, and boaters who venture out into the Florida Current and experience direct contact, accidental ingestion of water, or ingest fish or shellfish exposed to effluent. Otherwise, there is a very small, but not nonzero, chance for onshore or nearshore recreational or occupational users to be exposed to effluent constituents, since there is a small (10%) chance that currents will change direction to east or west.*

4.3 Impacts on Coral Reefs Near Ocean Outfalls

Numerous natural and artificial reefs exist in the vicinity of the six ocean outfalls. Coral reefs represent a specific receptor that can be impaired by ocean outfall discharges. A thorough investigation of the extent of this impact would include quantification of the sources of the constituents in the water at the reefs as well as an evaluation of the impacts.

Recent studies by Tichenor (2004) suggest that the outfall discharge at Boynton Beach may be having an adverse effect on Lynn's Reef. However, the experimental design for the studies by Tichenor (2004) did not include a direct linkage of pollutant discharges and the relative importance of the concentrations of these discharges at a specific reef. Fauth et al. (2006) conducted a biomarker study that indicates that these reefs have been impacted in some cases. Lapointe et al. (2004) were able to directly link wastewater discharges in the Florida Keys with detrimental impacts to the nearby shallow seagrass and coral reef communities. This linkage was much easier to show since the discharges occurred directly offshore without the use of ocean outfalls and the extent of dilution and mixing is much less. Johns et al. (2001) present strong evidence that natural and artificial reefs are an important part of the tourist business in South Florida. A variety of initiatives are underway to foster better understanding and management of Florida's reefs. The Southeast Florida Coral Reef Initiative (SEFCRI) is described by Collier (2005). She suggests that research is needed to determine the relative importance of sewage outfall discharges on reef health. Lapointe and Risk (undated) conclude that δ15N analyses of macroalgae, sponges and gorgonian corals recently collected from reefs in Palm Beach and Broward counties, Florida indicate a significant contribution of sewage nitrogen to the nitrogen pool in the coastal waters of the area. No complete report is available for this ongoing study. These recent and ongoing studies could provide valuable new insights into the extent of the cause-effect linkage between outfall discharges and impaired reefs in Southeast Florida. If the regulatory agencies feel that current wastewater treatment levels are insufficient to protect water quality in general and the reefs in particular, then more stringent regulations such as additional treatment requirements may be imposed in the future. The costs of added treatment are estimated elsewhere in this report.

4.4 Offshore Impacts of Wastewater Discharges in the Florida Keys

The land-based nutrient pollution in shallow seagrass and coral reef communities between the Content Keys (southern Florida Bay) and Looe Key (south of Big Pine Key) in the Lower Florida Keys were studied by LaPointe et al. (2004). The impacts of physical forcing (rainfall, wind and tides) and water management on mainland South Florida on the nutrient enrichment and blooms of phytoplankton, macroalgae, and seagrass epiphytes were evaluated (Lapointe et al. 2004). Phase I of the study included daily sampling in 1996 at three stations (inshore, nearshore, offshore) between Big Pine Key and Looe Key for dissolved inorganic nitrogen (DIN) and soluble reactive phosphorus (SRP) concentrations in the water column and phytoplankton biomass (chlorophyll a) before, during, and following episodic physical forcing events. Phase II of the study involved sampling of macroalgae for stable nitrogen isotope ratios from Content Keys to Big Pine Key in the summer (wet season) of 2000 and the spring (dry season) of 2001 (Lapointe et al. 2004). The Florida Keys National Marine Sanctuary (FKNMS) was found to be affected by sewage pollution. Contaminated groundwater with high DIN and SRP from the on site sewage disposal systems entered the ocean waters through submarine groundwater discharges (Lapointe et al. 2004). Land-based nutrient enrichment was found to be the primary factor in the seasonal development of phytoplankton, macroalgae, and seagrass epiphyte blooms in the inshore, nearshore, and offshore waters of the FKNMS. Chronic nutrient enrichment of coastal waters from local (sewage) and regional (agricultural) land-based sources were responsible for the elevated ammonia and SRP concentrations which caused eutrophication and macroalgal harmful algal blooms (Lapointe et al. 2004).

4.5 Socioeconomic Importance of Reefs

Johns et al. (2001) presented the results of a major study of the benefits of reefs in Southeast Florida. Over 6,000 surveys were given to residents, boat owners, and tourists regarding the economic value of natural and artificial reefs. This study did not address water quality directly. They estimate that visitors and residents spent 22.8 million person days using artificial and natural reefs in the three counties between June 2000 and May 2001. About two thirds of these visits were to natural reefs. About one half of these visits were for fishing and most of the balance was for snorkeling and scuba diving. Their results indicate that the residents and visitors to the three counties are willing to spend $24.51 million per year in additional fees to maintain the reefs in their present condition. This study does quantify the overall economic importance of reefs. However, it does not address the relative importance of the reefs that might be affected by the six ocean outfalls.

4.6 Summary and Conclusions

Several studies have been made of the impacts of the outfalls on the ocean. Surfacing plumes are present at all six WWTP outfalls throughout the year (Englehardt et al. 2001). Rapid dilution in the immediate vicinity of the outfall continues for 6 to 41 miles downstream (2006). Existing evidence suggests that the human and ecological risks from the six ocean outfalls are generally low because the wastewater is treated to reduce the contaminants and the rapid mixing and dilution reduces residual pollutant concentrations to very low levels (US EPA 2003). One concern cited by the US EPA (2003) was the risk posed to both humans and marine mammals by *Cryptosporidium* and *Giardia* in the unfiltered wastewater effluent.

Natural and artificial reefs near the six ocean outfalls contribute significantly to the tourist business in South Florida (2001). Recent studies by Tichenor (2004a; 2004b) suggest that the outfall discharge at Boynton Beach may be having an adverse effect on Lynn’s Reef, but did not establish a link between pollutant discharges and the relative importance of pollutant concentrations at a specific reef. A biomarker study by Fauth et al. (2006) indicates that the reefs have been impacted in some cases. Offshore wastewater discharges with limited dilution and mixing in the Florida Keys were linked to detrimental impacts to the nearby shallow seagrass and coral reef communities (2004). Based on δ15N analyses of macroalgae, sponges and gorgonian corals recently collected from reefs in Palm Beach and Broward counties, Lapointe and Risk (undated) believe that sewage nitrogen is a significant contributor to the nitrogen pool in the area's coastal waters. No complete report is available for this ongoing study. These recent and ongoing studies could provide valuable new insights into the extent of the cause-effect linkage between outfall discharges and impaired reefs in Southeast Florida and indicate whether or not current wastewater treatment levels are sufficient to protect water quality in general and the reefs in particular.

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5. Water Reuse Options, Experience, and Potential

The greatest use of reclaimed water has been in regions suffering water scarcity or severe restrictions on disposal of treated effluents. Water utilities facing these difficulties have devised and implemented a variety of innovative approaches that utilize reclaimed water to help meet their communities' needs. Case studies of these projects have been summarized in several excellent reviews published over the last few years, e.g., Crook (2004), Radcliffe (2004), and Law (2003), as well as in journal papers, reports and Web sites prepared by water and wastewater utilities. A sampling of the experiences of some of the larger utilities is given in the present chapter. The current status of satellite water reclamation systems is also reviewed. These systems could reduce distribution costs for reclaimed water and also alleviate salinity problems of waters reclaimed from sewers in low-lying coastal areas such as Southeast Florida. The chapter ends with an analysis of the potential for traditional water reuse in Southeast Florida. The analysis sets up a new approach in identifying large users that are well-suited for traditional reuse. The methods introduced will be further used in a case study in Chapter 6 to produce feasible traditional reuse demand flow values that can alleviate the flows currently going to ocean outfalls. Traditional reuse demand flows are projected for the six wastewater treatment plants of interest and used in the evaluation of alternatives to ocean outfalls in Chapter 7 by using the methods presented in this chapter.

5.1 Experience of Large Utilities in the U.S.

The water reuse industry in the U.S. has experienced rapid growth in recent years. The State of Florida, which publishes a yearly Reuse Inventory, is a well-documented example of the increasing significance of water reuse in water management. Over the 18 year period from 1986 to 2004, both reuse flow and capacity in Florida have increased by more than 300% (Fig. 5-1), reaching 630 MGD and 1,270 MGD, respectively, in 2004 (FL DEP 2005a). California has seen its deliveries of reclaimed water increase from 150 MGD in 1970 to over 500 MGD in 2002 (DWR 2003). Statistics such as these firmly establish the feasibility of water reuse and its expanding role in water resources management.

While California, Arizona and Florida have practiced water reuse for many years, other states such as Texas are implementing their own programs as they recognize the value of water reuse as an integral component of water resources management. In this section, case studies from across the U.S. are described, emphasizing those operated by large municipal utilities. General locations of the case studies are shown in Figure 5-2.

5.1.1 Green Acres Project

a) Service area. The Green Acres Project serves users in the Los Angeles area, including Fountain Valley, Huntington Beach, Costa Mesa, Newport Beach, and Santa Ana, California (Fig. 5-3).

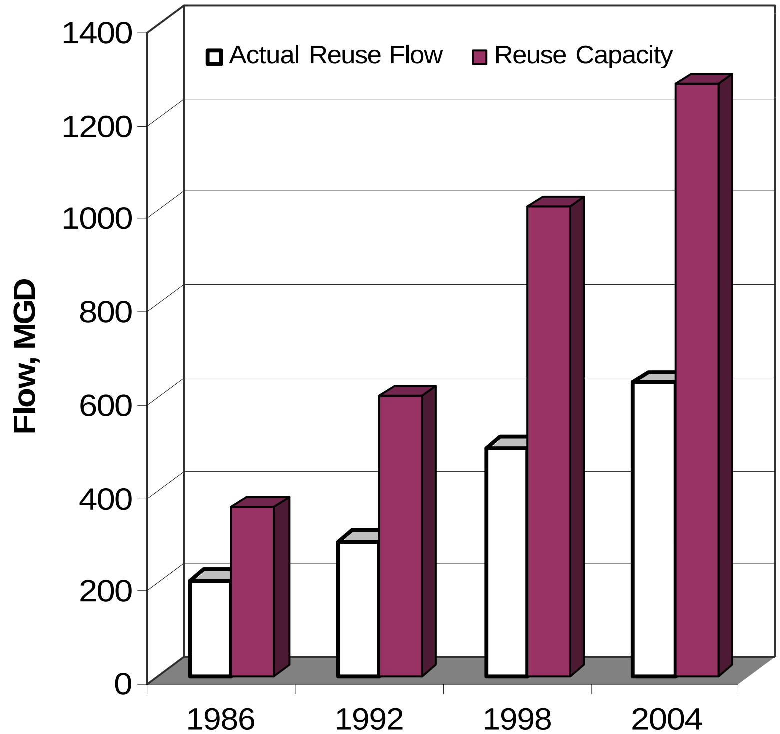

Figure 5-1. Growth of Water Reuse in Florida (FL DEP 2005a)

Figure 5-2. Selected Sites of Water Reuse in the USA. Photo from Google Earth.

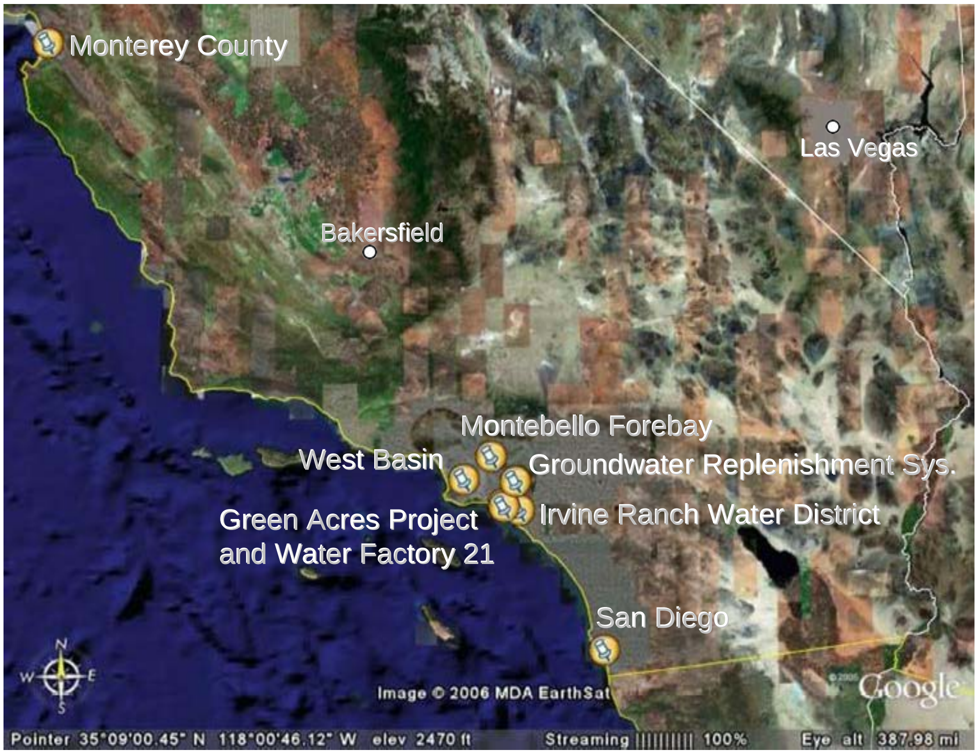

Figure 5-3. Selected Sites of Water Reuse in California. Photo from Google Earth.

b) Reclaimed water quality control. Reclaimed water is obtained from the Green Acres Project water reclamation plant during the summer months. During the winter months, the Green Acres Project plant is taken out of service and reclaimed water is obtained from the 15 MGD Irvine Ranch Water District's Michelson Water Reclamation Plant. Municipal wastewater undergoes filtration and disinfection in addition to secondary treatment at each facility. The water meets the disinfected tertiary recycled water requirements of California Title 22, which include a weekly median total coliform concentration no higher than 2.2/100 mL, a single sample maximum total coliform concentration of 23/100 mL, and an average daily turbidity no higher than 2 nephlometric turbidity units (NTU). Maximum limits also are specified in Title 22.

c) Reclaimed water distribution and customers. More than 6 MGD of reclaimed water, on the average, is delivered through 32 miles of pipelines to users in Fountain Valley, Huntington Beach, Costa Mesa, Newport Beach, and Santa Ana. Pipeline sizes range from 6 to 42 inches in diameter. A potential extension into central Huntington Beach would add 0.9 MGD of flow. The reclaimed water is used for landscape irrigation (parks, schools, golf courses, etc.) and industrial purposes such as cooling and process washdown.

d) Problem encountered. A carpet dyer found that the reclaimed water caused occasional spotting of dyed carpets and discontinued its use of the water. The Orange County Water District is exploring means to resolve the water quality issues involved.

e) Project costs. Capital cost of the project, including assistance for end-user retrofits, was $49M. Annual operations and maintenance costs are $0.9M. The Orange County Water District wholesales the reclaimed water to various water agencies.

f) Information sources. Information for this case study was taken from OCWD (2001) and Crook (2004).

5.1.2 Irvine Ranch Water District

a) Service area. The Irvine Ranch Water District is located in Orange County, California, and includes the City of Irvine (Fig. 5-3). The District serves a population of 316,000 and has a service area of 133 square miles. Reclaimed water makes up 20% of the Irvine Ranch Water District water supply.

b) Reclaimed water quality control. Reclaimed water is provided by the 15 MGD Michelson Water Reclamation Plant (WRP) and the 5.5 MGD Los Alisos WRP. Water drawn from the open reservoirs in the distribution system may be further treated before introduction to the transmission and distribution pipelines. Treatment operations that may be applied include straining, pressure filtration, and disinfection. The water meets the advanced tertiary standards of California Title 22 requirements, which include weekly median total coliform concentrations no higher than 2.2/100 mL and daily average turbidity no higher than 2 NTU.

c) Reclaimed water distribution and customers. A yearly average of 11 MGD is supplied to 1,750 customers. Most of the service area has access to a reclaimed water distribution system, which consists of 300 miles of reclaimed water pipelines. Some of the reclaimed water distribution lines were retrofitted. In new developments, distribution lines for reclaimed water are installed along with lines for domestic water and sewer. Reclaimed water is stored in winter months. The supply system is interconnected with that of the Orange County Water District to provide the opportunity for shut-down for maintenance.

There are over 3,400 metered connections to the reclaimed water distribution system. The combined capacity of the reclaimed water storage reservoirs is 656 MG. Two of the reservoirs are open, whereas the others are closed concrete or steel tanks. A total of 15 pump stations are located throughout the reclaimed water distribution system.

The primary use of reclaimed water is landscape irrigation, with 80% of all business and public area landscaping (parks, school grounds, golf courses, a cemetery, freeway landscapes, city-maintained streetscapes, common areas managed by homeowner associations, front and back yards at individual residential dwellings) irrigated with this water source. Additional uses include food crop irrigation, toilet and urinal flushing in 12 dual-plumbed office buildings, and commercial office cooling towers. Use of reclaimed water is mandated for high-rise buildings. The additional cost of providing a dual system in new buildings over seven stories adds only 9% to the cost of plumbing.

d) Problems overcome. More frequent reservoir tank cleaning, increased control valve maintenance, and potential damage to mainline valve body seats from higher chlorine levels are noted in the reclaimed water distribution system, in comparison to potable water distribution systems. The Irvine Ranch Water District now specifies a type of valve seat that has higher resistance to chlorine. Possible cross connections are checked for once a year. Leaks or spills are routed wherever possible to the sanitary sewer system instead of storm drains, or may be collected and trucked back to the plant. Salinity is an ongoing challenge. A significant source of total dissolved solids is self-generating water softeners. These were prohibited for many years by a City of Irvine ordinance. However, such bans by water agencies elsewhere in California were overturned by a court decision in 1997. The District is seeking legislation that would restore its ability to control salinity.

e) Education and outreach. The District uses brochures, videos, workshops, and other means to educate and involve the public about water reuse. Tours of the WRPs and water quality laboratory are held on a regular basis. The need for conserving water is taught at all grade levels. In addition, the concept of water reuse is introduced in the fifth grade.

f) Project costs and rate structure. Annual operations and maintenance costs in fiscal year 2002–2003 were $6.6M. The base reclaimed water rate is $0.82/1000 gal, which is 90% of the base domestic water rate. The District penalizes excess usage of reclaimed water with an ascending block rate.

g) *Future plans*. Conversion of an existing open reservoir will add 813 MG of seasonal storage of reclaimed water. The Irvine Desalter Project, currently in the planning stage, will treat water from a plume of trichloroethylene-contaminated groundwater using reverse osmosis, air stripping with activated carbon filters, and disinfection. The product water will be added to the reclaimed water system, providing an additional 1.6 MGD of flow. Plans call for the capacity of the Michelson WRP to be increased to 33 MGD by 2025 and eventual expansion of the Los Alisos plant to 7.8 MGD.

h) Information sources. Information for this case study was taken from Anderson (Anderson 2003), Crook (2004), Mantovani et al. (2001), Radcliffe (2004) and US EPA (2005).

5.1.3 Montebello Forebay Groundwater Recharge Project

a) Service area. Reclaimed water from three satellite water reclamation plants (WRPs) is used to recharge groundwater for the Central Basin, which is the main groundwater basin underlying the greater Los Angeles metropolitan area (Fig. 5-3). Additional reclaimed water from these facilities is used by the County Sanitation Districts of Los Angeles County for nonpotable applications such as landscape and agricultural irrigation, industrial process water, recreational impoundments, and wildlife habitat. The management of the WRPs and responsibility for monitoring reclaimed water quality is borne by the County Sanitation Districts of Los Angeles County. Management of the recharge facilities, including the river conveyance and spreading basins, is assumed by the Los Angeles Department of Public Works. Overall management of the groundwater basin, including groundwater monitoring, is the responsibility of the Water Replenishment District.

b) Reclaimed water quality control. The treatment plants are the Whittier Narrows WRP, the 100 MGD San Jose Creek WRP and the 13 MGD Pomona WRP. Each of these facilities provides biological nitrogen removal, filtration and disinfection in addition to secondary treatment. The biosolids generated at the plants are returned to one of the major trunk sewers and are subsequently treated at the Joint Water Pollution Control Plant near the coast in Carson. This decreases the complexity of the facilities and reduces both capital and operations and maintenance costs.

Reclaimed water produced by the WRPs meets primary drinking water standards and contains no more than 2.2 total coliforms/100 mL and 2 NTU of turbidity. Extensive sampling of the reclaimed water for viruses and parasites has shown it to be essentially free of measurable levels of pathogens.

c) Method of addition to natural waters. Reclaimed water from the San Jose Creek and Whittier Narrows WRPs is spread in an unconfined region of the Central Basin known as the Montebello Forebay. Available reclaimed water from the Pomona WRP is discharged to San Jose Creek, a tributary of the San Gabriel River, and ultimately becomes a source of recharge in the Montebello Forebay. Up to 60,000 acre-ft of reclaimed water in a single year or up to a running three-year average of 50,000 acre-ft/yr may be applied. Stormwater runoff and imported surface water are used along with reclaimed water for recharge. The running three-year percentage of reclaimed water in this mix should not exceed 35% of total recharge.

The total area available for spreading recharge water is 698 acres. Additionally, percolation occurs over 133 acres of the unlined San Gabriel River. Batteries of spreading basins are normally operated on a 21-day cycle, consisting of 7 days each of filling, emptying (through percolation), and drying. The vadose zone underlying the basins is generally 10 ft or more in thickness.

d) Health effects studies. Four different heath effects studies, the latest in 1999, have concluded that there is no evidence that populations consuming groundwater—estimated to contain as much as 31% reclaimed water in the Montebello Forebay—had a higher risk of cancer, mortality, infectious disease, or adverse birth outcomes than those using other water sources.

e) Project benefits. The Montebello Forebay Groundwater Project has helped reduce the cumulative groundwater overdraft in the Central Basin. It provides a new water supply that meets the demand of 250,000 persons. Use of reclaimed water in lieu of imported water saves the Districts $12M/yr.

f) Information sources. Information for the present case study was taken from Crook (2004).

5.1.4 Monterey County Water Recycling Project

a) Service area. Reclaimed water is distributed within the Salinas Valley, which lies in the northern part of Monterey County, California (Fig. 5-3). The water reaches 222 parcels of farmland in the 12,000 acre service area.

b) Reclaimed water quality control. A 30 MGD regional wastewater recycling facility was constructed adjacent to the regional secondary treatment plant to provide tertiary treated, reclaimed water for agricultural applications. The tertiary treatment includes flocculation, dual media filtration and chlorine disinfection. The facility delivers 20 MGD of reclaimed water.

c) Distribution system and customers. The reclaimed water distribution system includes 46 miles of water transmission and distribution pipelines, 22 supplemental wells to augment reclaimed water flows at times of peak demand and 111 flow-metered connections. Equalization storage is provided to smooth diurnal inflow variations. Three booster pump stations maintain pressure in the system. Crops irrigated include lettuce, celery, broccoli, cauliflower, artichokes, and strawberries.

d) Problems overcome. Minor problems have included the need to flush construction debris from the system, excessive sand in the water extracted from wells, and a few pipeline breaks. The system is run by a three-person crew on a continuous basis. No adverse effects to the crops, soil or field workers have been noticed. Salinity control is an ongoing challenge. The reclaimed water has a sodium absorption ratio of 4.7, compared to the ratio of 1.7 for good quality well water. The blend of reclaimed and well water used for irrigation typically has a sodium absorption ratio somewhat above 3.0, which is the maximum desired by the growers. Soils irrigated with the blend of reclaimed and well water have a higher sodium absorption ratio and exchangeable sodium percentage than soils irrigated with well water. The Monterey Regional Water Pollution Agency is currently focusing on source control as a means of limiting salt concentration in reclaimed water.

e) Education and outreach. A Water Quality and Operations Committee was formed early in the project to gain input from users. A proactive education plan was developed in 1977 to address perception issues.

f) Project costs and rate structure. Construction cost of the project was $75 million. The total cost to treat and deliver recycled water to agricultural areas is $0.90/1000 gallons. This amount excludes secondary treatment costs, but includes debt service from loans and operations and maintenance for tertiary treatment and distribution. Revenue is provided from land assessments ($233/acre/yr) and a water delivery charge of $0.05/1000 gal.

g) Information sources. Information for the present case study was taken from Crook (2004) and Sheikh (2004).

5.1.5 Water Factory 21 and Groundwater Replenishment System

a) Service area. The Orange County Water District has operated Water Factory 21, an advanced water reclamation facility, since 1976. The Orange County Water District began construction in 2003 of the Groundwater Replenishment System, which will provide 70,000 acre-ft/yr (62.5 MGD) of reclaimed water (Fig. 5-3).

b) Reclaimed water quality control. The treatment train of the 15 MGD Water Factor 21 includes secondary treatment (provided by an adjacent wastewater treatment plant operated by the Orange County Sanitation District), lime clarification, filtration, reverse osmosis, and UV/hydrogen peroxide disinfection/advanced oxidation. The reverse osmosis units were found to remove sufficient nitrogen from the reclaimed water, so the air stripping towers were removed from service in 1986. The treatment train for the Groundwater Replenishment System, located in Fountain Valley, will include secondary treatment, microfiltration, reverse osmosis, and hydrogen peroxide/UV advanced oxidation/disinfection.

c) Method of addition to natural water body. After treatment by reverse osmosis and activated carbon, reclaimed water from Water Factor 21 is mixed with deep well water and injected into four aquifers prone to seawater intrusion using multi-point injection wells. Most of the injected water flows inland to augment groundwater used as a potable supply source. Reclaimed water for the Groundwater Replenishment System will be pumped through a 14 mile long, 78 inch force main to deep spreading basins near Anaheim. Depending on the time of year, 15 to 40 MGD of the water will be diverted to an expanded Talbert Gap Seawater Intrusion barrier currently served by Water Factory 21. Some of the reclaimed water could be made available for irrigation, industrial process water, or other approved uses by connections to the conveyance pipeline.

d) Health effects studies. No evidence of significant risks from this practice has emerged.

e) *Outreach.* Water user telephone surveys, mailings, print and cable television advertising, and meetings with community groups, businesses, hospitals, and elected officials have been used to inform water users on the need for the project and the water quality.

f) Project costs, rate structure and benefits. Both of the Orange County groundwater recharge systems protect coastal aquifers against seawater intrusion and replenish the groundwater. The Groundwater Replenishment System is estimated to cost $454M with an annual operations and maintenance budget of $22M. Funding has been provided by several agencies, including $92.5M in federal and state grants and a State Revolving Fund loan of $145M.

g) Information sources. Information for the present case study was taken from Crook (2004) and GRS (2004).

5.1.6 San Diego, California

a) Service area. Reclaimed water is distributed from the North City WRP (Fig. 5-3). The North City Distribution System extends from the coast to the City of Poway and provides service to Mira Mesa, Miramar Ranch North, Scripps Ranch, University City, and Torrey Pines. The South Bay Distribution System will eventually connect to facilities being constructed by the Otay Water District. The system also delivers reclaimed water to the adjacent International Boundary and Water Commission Wastewater Treatment Plant.

b) Reclaimed water quality control. The treatment sequence at the 30 MGD North City WRP includes primary settling, activated sludge with anoxic selectors to control filamentous bacteria and anthracite coal filters. A portion of the filtrate is demineralized using electrodialysis reversal process in order to decrease the salinity of the reclaimed water. The demineralized stream is combined with filtrate prior to chlorine disinfection. The quality level of the reclaimed water is suitable for irrigation of food crops, parks, playgrounds, etc. Control of the North City plant is transferred to the utility's communications center in

Kearny Mesa from 12:30 am to 5:30 am each night, with an operator on call in the event of an emergency. The North City WRP currently treats 22.5 MGD.

The 15 MGD South Bay WRP has a similar sequence of treatment processes as described above. Disinfection is accomplished through ultraviolet irradiation and there is no process for demineralization. The facility is staffed from 6:00 am to 4:00 pm Monday through Friday. Plant control is accomplished from the utility's communications center outside these hours. The facility currently discharges up to 9 MGD of secondarily treated wastewater that is disposed of via an ocean outfall.

c) Reclaimed water distribution and customers. Reclaimed water from the North City WRP is distributed through 79 miles of pipeline, two storage tanks and two pump stations. There are 356 metered connections, including a single metered connection with the City of Poway, which serves an additional 193 customers. The single largest use of reclaimed water is landscape irrigation. Additional uses include industrial processes, cooling towers, soil compaction, dust suppression, circuit board washing and urinal flushing. Customers include General Atomics, Motorola, CalTrans, University of California at San Diego, Torrey Pines Municipal Golf Course, Nissan Design, Burnham Institute, Metro Biosolids, Miramar Landfill and the City Poway. The City has a guaranteed water program that exempts research and development or industrial manufacturing firms from mandatory water restrictions during periods of drought in exchange for participation in daily water conservation programs that include use of reclaimed water.

The South Bay Distribution System currently consists of a pipeline along Dairy Mart Road. It will eventually tie in with facilities being constructed by the Otay Water District.

d) Education and outreach. Businesses, public agencies, homeowners' associations and academic institutions with proximity to the optimized system are being contacted to retrofit their properties and receive education on the use of reclaimed water.

e) Project costs and rate structure. The cost for reclaimed water started at $1.34 per hundred cubic feet of water ($1.79/1000 gal) in 1997. This was lowered by the San Diego City Council to $0.80 per hundred cubic feet ($1.07/1000 gal) in 2001 to encourage use of reclaimed water. This rate is 57% less than the current potable water rate of $1.87 per hundred cubic feet ($2.50/1000 gal).

f) Future plans. A pricing structure that covers the actual cost of producing reclaimed water will be considered by the City Council in 2006.

g) Information sources. Information for this case study was taken from the City of San Diego (City of San Diego 2005; City of San Diego undated-e; City of San Diego undated-b; City of San Diego undated-d).

5.1.7 West Basin Municipal Water District, California

a) Service area. The West Basin Municipal Water District is a public agency that wholesales water to local cities, mutual water companies, private companies and investor-owned utilities in a 200-square mile area of southwest Los Angeles County. It obtains secondarily treated wastewater from the Hyperion Wastewater Treatment Plant in Los Angeles and pumps it through five miles of 60 inch force main to the District reclamation facility in El Segundo (Fig. 5-3).

b) Reclaimed water quality control and customers. The El Segundo WRP provides filtration and disinfection in addition to secondary treatment and meets California Title 22 standards for tertiary quality reclaimed water. About 2.5 MGD of this water is used for irrigation through the Water Replenishment District. The El Segundo WRP also feeds three satellite plants, each of which polishes the water for a specific industrial user. One satellite plant provides nitrification and disinfection for a flow of 7.4 MGD that is used for industrial cooling makeup water. A second satellite plant applies lime treatment, reverse osmosis, and disinfection to a flow of 6.5 MGD, producing drinking quality water that is used for recharge of groundwater to provide a barrier to seawater intrusion as part of the West Coat Basin Barrier Project. The third satellite plant provides microfiltration, reverse osmosis, and disinfection to a flow of 5.8 MGD that is used for low pressure boiler feed water. Another 2.4 MGD of reclaimed water from the third satellite plant is passed through the reverse osmosis process a second time and then used as high pressure boiler feed water. The reject water (concentrate) from the reverse osmosis units is returned to the Hyperion Wastewater Treatment Plant for disposal by ocean outfall.

c) Education and outreach. An extensive ongoing public outreach program is maintained by the West Basin Municipal Water District, including a children's education program, reclaimed water marketing and school education.

d) Project cost and rate structure. The selling price of the reclaimed water is 20 to 40% less than imported water. (Imported water sells for $510/acre-ft.) Nitrified water sells for 20% less than imported water. Reclaimed water receiving reverse osmosis treatment is sold at the same rate or slightly higher than imported water.

e) Plans for expansion of services. The West Basin Municipal Water District has begun a 10 MGD expansion of Title 22 water production. A 5 MGD expansion of Barrier water production is also underway. The increased flow of Barrier water will shift the proportions of reclaimed water and natural water used for groundwater recharge from 50:50 to 75:25.

f) Information sources. Information for the present case study was taken from Crook (2004) and Miller (2003).

5.1.8 Phoenix

a) Reclaimed water production and customers. Situated in an arid desert, the City of Phoenix, Arizona has practiced water reuse since the turn of the century. Water reclamation facilities are co-located with the City's wastewater treatment plants. The total wastewater treated is 140,000 acre-ft/yr (125 MGD), of which nearly 80,000 acre-ft/yr (71 MGD) is reused. The ratio of reclaimed water use to wastewater treated (57%) is one of the highest reuse ratios among large municipalities in the U.S.

i) 23rd Avenue WWTP. Up to 30,000 acre-ft annually (27 MGD) of reclaimed water is produced for delivery to farms in the nearby Roosevelt Irrigation District. In return, the District sends groundwater to the Salt River Project—a canal bringing water to the Phoenix area from a series of reservoirs on the Salt River—for use as raw water for the City's surface water treatment plants. Delivery of reclaimed water in excess of exchanged groundwater is credited to the City as groundwater recharge, giving the City flexibility to pump more groundwater during drought or for specific projects.

ii) *91st Avenue WWTP*. The Palo Verde Nuclear Generation Plant is contracted to receive as much as 105,000 acre-ft per year (94 MGD) of reclaimed water from the 91st Avenue WWTP. Actual usage for the Palo Verde plant has been 70,000 acre-ft/yr (62 MGD).

iii) Cave Creek Water Reclamation Facility. Golf courses and other turf users in the northern portions of Phoenix are served by the Cave Creek Water Reclamation Facility, which has a capacity of 8 MGD.

b) Future plans. Several innovative projects are underway to help assure dependable water availability in the future. Realization of these projects would enable Phoenix to reclaim more than 90% of its wastewater, totaling over 200,000 acre-ft/yr (179 MGD).

i) Tres Rivers Demonstration Project. A pilot study involving 12 acres of free-water-surface wetlands is underway at the convergence of the Salt, Gila and Agua Fria rivers. The Tres Rios Demonstration Project is developing design criteria for a wetlands system that could meet upcoming effluent quality standards.

ii) Agua Fria Linear Recharge Project. A conceptual plan was developed for groundwater recharge along the Agua Fria River using a portion of the reclaimed water from the 91st Avenue WWTP. The project involves discharging water into the dry riverbed at several locations and allowing the water to percolate into the aquifer. As much as 60,000 acre-ft/yr (54 MGD) of reclaimed water could be applied in this project, generating pumping credits available to all owners of the 91st Avenue WWTP. Phoenix and its partners would develop strategies for recovering the water, which in some instances would be treated for potable use.

iii) *The Market Resource Center.* A recommendation of the 25-yr Master Plan for the 91st Avenue WWTP was to treat available wastewater (remaining after commitments) to the highest water quality standards. This new source of water would be offered to identify future markets.

c) Information sources. Information for the present case study was obtained from Gritzuk and Conway (2004).

5.1.9 San Antonio

a) Reclaimed water quality control. Four major water recycling centers (WRCs) are operated by the San Antonio Water System (Fig. 5-2). The combined output of these plants is 116

MGD. The facilities provide treatment to meet Texas regulations for Type I reclaimed water, which applies to water that is likely to come into contact with humans. These regulations specify BOD_5 and turbidity should be no higher than 5 mg/L and 3 NTU, respectively, on a 30-day average basis. The geometric mean for fecal coliforms must be no higher than 20 CFU/100 mL, while the maximum concentration of fecal coliforms in any grab sample must not exceed 75 CFU/100 mL.

b) Distribution system and customers. Downstream water rights are allocated 49% of San Antonio Water System reclaimed water. The Dos Rio WRC discharges treated reclaimed water to the San Antonio River, from which the City's municipally-owned electric generating facility withdraws up to 36 MGD of reclaimed water to cooling water lakes. The electric generating facility pays the San Antonio Water System $0.153/1000 gal for use of this water. A reclaimed water distribution system containing 75 miles of pipeline was recently completed to provide up to 31 MGD to additional water users. The Salado Creek and Leon Creek WRCs currently feed the system, providing more than 14 MGD to 45 customers that include industrial cooling water, river maintenance, golf courses, schools and commercial sites. The overall transmission and distribution system includes 11 operational pump and storage facilities.

c) Problems overcome. One of the problems encountered was water quality degradation during startup of the distribution system, due to microbial growth in supply lines and tanks. This was attributed to stagnation of water in the system associated with low flows. Chlorination points were installed within the distribution system to maintain a chlorine residual of at least 1 mg/L throughout the system. Additionally, storage tanks are drained and cleaned of sediment periodically. Another problem in the first few years of operation was a series of pipeline failures. Two of the incidents involved joint failures in the main transmission lines. Concern was expressed that high levels of dissolved salts, particularly chlorides, could adversely affect vegetation. In response, the San Antonio Water System included assurances in the reclaimed water agreement that total dissolved solids would be no higher than 1500 mg/L and that the sodium absorption ratio would not exceed 5.0.

In 2002, a cross-connection between the non-potable and potable water system at a golf course was discovered. To preclude further incidents, the San Antonio Water System now provides training for customer workers involved in routine system operation before reclaimed water service begins. A five-step process is followed to ensure complete separation between the reclaimed and potable water systems. After initiation of reclaimed water service, the San Antonio Water System staff rechecks and tests the reclaimed water system.

d) Project costs and rate structure. The price of reclaimed water in the San Antonio Water System is $0.98/1000 gal, which is 49% of the potable water rate. The rates vary somewhat based on season and amount of water used. A lower amount ($0.25/1000 gal) is charged to customers who trade pumping withdrawal rights to the local aquifer in return for reclaimed water.

e) Information sources. Information for the present case study was taken from Coker (2004), Crook (2004) and Fletcher (2006).

5.1.10 Pinellas County

a) Service area. Pinellas County is located in the west central region of Florida, bounded by the Gulf of Mexico on the west and by Tampa Bay to the south and east (Fig. 5-4).

b) Reclaimed water quality control. Pinellas County Utilities operates two regional water reclamation facilities (WRFs). The William E. Dunn WRF, located in the northern part of the county, has a capacity of 9.0 MGD and produces 6.5 MGD of reclaimed water on the average. Wastewater undergoes nitrogen and phosphorus removal, filtration and high-level disinfection in addition to secondary treatment. All of the reclaimed water from the Dunn WRF is sent to the reclaimed water distribution system. In addition, up to 0.8 MGD of reclaimed water is purchased from the City of Oldsmar and up to 3 MGD is purchased from the City of Clearwater. The South Cross Bayou WRF in the southern part of the county has a capacity of 33 MGD and produces an average of 26 MGD of treated effluent. On the average, 7.4 MGD is reclaimed for water reuse. The remaining reclaimed water is discharged to a tidal creek. Like the Dunn WRF, the wastewater receives nitrogen and phosphorous removal and high-level disinfection in addition to secondary treatment.

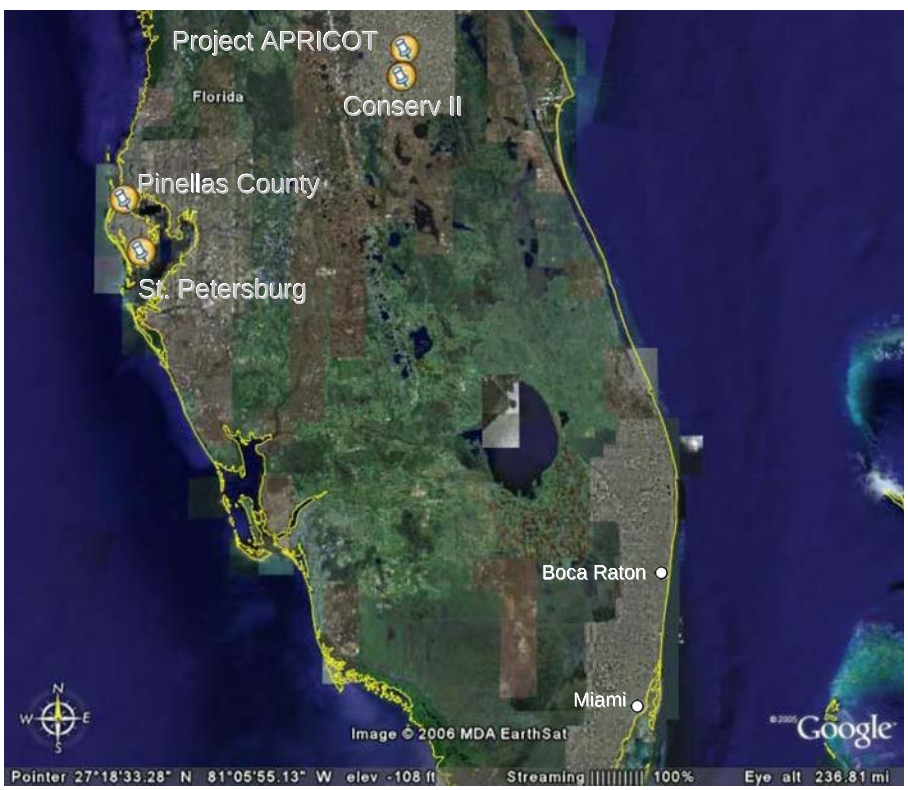

Figure 5-4. Selected Sites of Water Reuse in Florida. Photo from Google Earth.

c) Distribution system and customers. The Dunn WRF includes a 63 MG storage pond and 17 MG reject pond. Strainers are installed in the outlet line of the storage pond to remove particulate material that could clog irrigation systems. In 2002, Pinellas County had 10,400 users of reclaimed water who were supplied with an average of 14.7 MGD. Types of use included golf courses, parks, playgrounds, schools and residences.

d) Problems overcome. One problem encountered was algae growth in pipelines, due to stagnant conditions that resulted from delays in connecting to the system. This was corrected by a flushing program. Connection procedures were changed to remedy the root cause of the problem.

e) Project costs and rate structure. Reclaimed water use by residential customers is not metered. An availability charge of $7/month is mandatory and irrigation customers pay an additional $2/month for unrestricted use. Multi-family and nonresidential customers pay the availability charge plus $0.29/1000 gal.

f) Information sources. Information for the present case study was taken from Crook (2004).

5.1.11 Project APRICOT

a) Service area. Project APRICOT (A Prototype Realistic Innovative Community of Today) is located in Altamonte Springs, Florida (Fig. 5-4).

b) Reclaimed water quality control. Reclaimed water is produced by activated sludge treatment with anoxic and aerated zones for nitrogen removal, followed by alum addition, flocculation, and deep bed denitrifying filters for additional nitrogen removal. The water is then re-aerated and disinfected with chlorine prior to distribution. The capacity of this reuse system is 14.6 MGD and about 5.9 MGD of reclaimed water was reused in 2004.

c) Distribution system and customers. A dual distribution was installed throughout the city, consisting of 83 miles of 4 inch through 30 inch transmission mains, with 6,000 residential service connections and several hundred commercial connections. One elevated 0.5 MG storage tank and a surface storage/augmentation facility are included in the system in addition to two 3 MG storage tanks at the reclamation facility. Commercial and multi-family dwellings are required to connect to the system, as well as all new single-family houses constructed after January 1989. The system involves extensive efforts to get reclaimed water into existing residential subdivisions. Reclaimed water is used for household irrigation, fire mains, ornamental fountains and ponds and for toilet flushing in commercial buildings. Interestingly, one of the commercial customers is a car wash. Vegetable growing is allowed, provided that they are peeled, skinned, cooked or thermally processed before consumption, or that a drip irrigation system is used. Aboveground outside taps at individual households are prohibited, whereas belowground taps in lockable boxes are allowed. Hoses must be disconnected after use.

d) Challenges. Shortages occur in hot weather, requiring importation of sewage from other utilities for treatment to meet the demand. The City is actively managing demand by enforcing mandatory watering restrictions.

e) Education and outreach. The City has engaged in a detailed communication program with its residents. A full-time information liaison position was created within the Public Works

Department. This person issued press releases, coordinated with homeowners and condominium associations, and generally acted as a spokesperson for APRICOT. Two videos and several brochures discussing water quality issues were produced by the City.

f) Project costs and rate structure. The distribution network was constructed over a 15 year period at a cost of $40 million, all of which was funded locally. Reclaimed water supplied to commercial buildings and multi-unit dwellings is metered, whereas reclaimed water supplied to single family houses is not. Commercial users and condominiums were charged $0.82/1000 gal in 1997 (40% of potable water rates). Single family dwellings paid a flat fee of $10/month.

g) Information sources. Information for the present case study was taken from Altamonte Springs (1997), FDEP (2005b; 2005a), (Helgeson 2004; 2005b), Mantovani et al. (2001), Radcliffe (2004), York (2005) and Williams (1996).

5.1.12 St. Petersburg

a) Service area. St. Petersburg is located in the west central part of Florida (Fig. 5-4). The city is largely confined to a peninsula bounded to the west by the Gulf of Mexico and Boca Ciega Bay and to the south and east by Tampa Bay.

b) Reclaimed water quality control. Wastewater from the City of St. Petersburg is treated in four regional water reclamation facilities (WRFs) that provide coagulation, filtration and high-level disinfection in addition to secondary treatment. The total outflow from the four WRFs in 2002 was 42 MGD, of which 21 MGD was reused. The remaining water was disposed of through deep well injection into a nonpotable aquifer.

c) Distribution system and customers. Reclaimed water is distributed to more than 10,500 customers through more than 200 miles of pipelines, including 100 miles of trunk and transmission mains and 190 miles of small diameter distribution pipe. Residences using the water for landscape irrigation account for 10,000 of the customers. Other customers include six golf courses, 95 parks, 64 schools and 335 commercial areas. Reclaimed water provides fire protection via more than 300 reclaimed water hydrants.

Covered storage tanks are included in the system at each of the WRFs. Five City-owned and four privately owned booster pump stations maintain pressure in the system for all applications. Top loading, double check valve, backflow prevention assemblies are used to protect potable water services at residences. Backflow prevention provisions for commercial users are specified according to the level of risk posed by the users' activities.

d) Problems overcome. Problems that cropped up during the early years of operation of the reclaimed water system included water heater pressure relief valves, high chloride concentrations and inadequate supply. Backflow assemblies installed on residential services caused problems in plumbing systems when pressure built up by the hot water heater caused a discharge at the heater's temperature and pressure relief valve. The City overcame this problem by providing to property owners pressure relief regulating devices that fit on the water heater's external spigot and directed discharges outside rather than inside the homes.

Alternative solutions were to install expansion tanks or flushometers on the toilets. Irrigation with reclaimed water containing chloride concentrations in excess of 400 mg/L was found to damage chloride-sensitive plants. The high chlorides were due to seawater infiltration into sewers near the coast. Programs were successfully implemented to decrease chloride levels. These included an infiltration/inflow correction program, mixing high-chloride reclaimed water with low-chloride reclaimed water, and diverting reclaimed water containing very high chloride concentrations to the deep injection wells. Shortages of reclaimed water occurred during the dry spring months when wastewater flows tended to be low, whereas irrigation demands were highest. Installation of more storage has been marginally successful in alleviating this problem.

e) Education and outreach. Public forums that address water quality issues, booklets and videos on water conservation, taped television messages broadcast weekly, a Web site with links to water conservation information, annual public recognition awards, and community events promoting water reuse and conservation have been used for adult education. Programs for youth education on water conservation have been created for use in schools and youth agencies.

f) Project costs and rate structure. A voluntary assessment program allows residential customers pay for the cost of extending distribution lines to serve them. This cost typically ranges from $500 to $1,200 per customer. The connection fees for a residence consist of a $180 tapping fee and $115 for a backflow prevention device on the potable water line. A charge of $11.36 is made for the first acre-ft/month ($0.035/1000 gal), with $6.51/acre-ft ($0.02/1000 gal) charged for additional water use in the same month. Not all commercial customers are metered. Metered commercial customers pay $0.33/1000 gal.

g) Information sources. Information for the present case study was taken from Crook (2004).

5.1.13 Water Conserv II

a) Service area. The Water Conserv II project consists of a network of rapid infiltration basins and irrigated agricultural land 20 miles west of Orlando, Florida (Fig. 5-4).

b) Reclaimed water quality control. Reclaimed water is provided by the City of Orlando Water Conserv II Water Reclamation Facility and the Orange County South Regional Water Reclamation Facility. They provide secondary treatment, nitrogen removal, filtration, and high level disinfection. Reclaimed water total suspended solids cannot exceed 5.0 mg/L in a single sample. The high level disinfection standard mandates no detectable fecal coliforms in at least 75% of samples in any 30-day period and no more than 25 fecal coliforms/100 mL at any time.

c) Distribution system and customers. The distribution system consists of 21 miles of transmission piping that links two water reclamation facilities to a distribution center. Reclaimed water is transported from the distribution center to 76 agricultural and commercial customers through a 49 mile pipeline network that can handle up to 75 MGD. The reclaimed water that is not used for irrigation is distributed to rapid infiltration basins for groundwater recharge. The rapid infiltration basin system consists of eight sites with 72 basins, taking up

3,725 acres. The project reuse capacity is 68 MGD, with the rapid infiltration basins accounting for 22 MGD. About 20 MGD of reclaimed water was used for irrigation and 16.7 MGD was used for groundwater recharge in 2003. The irrigated land includes 10,035 acres of citrus, 7 foliage and landscape nurseries, 2 tree farms, 3 ferneries, and the Orange County National Golf Center.

d) Problems overcome. The project began operations in 1986. Severe freezes in the 1980s put several growers out of business and encouraged others to move, decreasing the acreage of orange groves served. Research carried out in parallel with the project has shown that total juice production from the oranges grown on project land is as high as oranges from conventionally irrigated land, tree condition is at least as good as in groves irrigated with well water, and soil pH is maintained in a favorable range without lime addition, as required in groves irrigated with well water.

e) Project costs and rate structure. The capital costs of the reuse distribution system total $278M and the current annual operating budget is $4.8M. The U.S. EPA provided $100M, with the rest coming from the City of Orlando and Orange County, Florida. Reclaimed water is provided at no cost to orange growers. This provision—extending for 20 years from the project startup—was included in the original project agreement to encourage participation by growers. Charges to residential and commercial users are $0.84 and $0.70 per 1000 gal, respectively. Residential users also pay $3.14 monthly per connection.

f) Future plans. The project reuse capacity is slated to expand to 81 MGD, of which 53 MGD is planned for irrigation and the balance for groundwater recharge. New commercial customers are anticipated to include a large sand mining operation, an additional golf course, residential irrigation, and a major regional/municipal interconnect for landscape irrigation.

g) Information sources. Information for the present case study was taken from Crook (2004), Cross (Cross undated), and FDEP (2005b).

5.2 Experience of Large Utilities outside the U.S.

Worldwide, water reuse is becoming an increasingly common component of water resources planning due to due to limited opportunities for conventional water supply development and increasing costs of wastewater disposal (Williams 1996). The greatest water reuse occurs in regions suffering water scarcity, such as the Middle East and Australia, or in densely populated regions with severe restrictions on disposal of treated wastewater effluents, such as England and Germany (Marsalek et al. 2002) and Japan (Ogoshi et al. 2001). In this section, case studies of water reuse in Australia and Singapore are presented, providing examples of nonpotable and indirect potable reuse.

5.2.1 Rouse Hill, Australia

a) Service area. The Rouse Hill Development Area northwest of Sidney will eventually accommodate some 300,000 people (Fig. 5-5). The development incorporates a dual distribution system that supplies flush water for indoor toilets as well as water for landscape irrigation. Reclaimed water is also used for fire protection, allowing the potable water mains to be reduced in size. The number of homes serviced as of 2004 was 12,000.

Figure 5-5. Selected Sites of Water Reuse outside the U.S. Photo from Google Earth.

b) Reclaimed water quality control. Reclaimed water is supplied by the Rouse Hill Sewage Treatment Plant, which can treat 4.4ML/d (1.2 MGD) for reuse by a treatment train consisting of activated sludge with biological nitrogen and phosphorus removal, coagulation and flocculation with alum addition, tertiary settling, filtration, ozonation, strainers, microfiltration and superchlorination. Microbiological water quality limits for reclaimed water are 1 fecal coliform/100 mL, 25 total coliforms/100 mL, 2 viruses/50 L, and 1 parasite/50 L. Limits are also placed on turbidity (2 NTU geometric mean; 5 NTU in 95% of samples) and color (15 TCU).

c) Distribution system and customers. The reclaimed water is pumped from the sewage treatment plant to three 2 ML (0.5 MG) elevated reservoirs, from which it flows through 34 km (21 miles) of distribution network to the homes. Each reservoir is equipped with dechlorination facilities to ensure that the chlorine residual at the consumers does not exceed 0.5 mg/L.

d) Problems overcome. The ozonation process has been unreliable. Consequently, microfiltration is relied upon for parasite removal and superchlorination is used to back up the ozonation process. Many errors were detected in the plumbing work done by private contractors between the Sydney Water main and the final house fittings. Training programs have been developed to assist plumbers and sales staff understand their roles in relation to public health. It is recognized that an ongoing effort will be needed at Rouse Hill to educate customers, as well as plumbers, about cross connection control. Complicating this issue are numerous differences between the National Plumbing and Drainage Code and State-based regulations.

e) Education and outreach. Research indicates that residents are proud of the Rouse Hill system and feel that they are helping to pave the way of future water management.

f) Project costs and rate structure. The capital cost for Stage 1 infrastructure was $285M (Australian), of which $35M was associated with the sewage treatment plant and $22M with the reclaimed water distribution system. Charges for reclaimed water in Australian currency are $0.28/kL, compared to $0.98/kL for potable water. The modest charge for reclaimed water has encouraged consumption. In the summers between January 2001 and December 2002, Rouse Hill total consumption was 20% above the Sidney average. The production cost for reclaimed water is estimated at $3–4/kL when the Rouse Hill system is fully operational.

g) Information sources. Information for the present case study was taken from Law (1996) and Radcliffe (2004).

5.2.2 Singapore

a) Reclaimed water quality control. A demonstration facility was operated at the Bedok Sewage Treatment Plant for two years, beginning in the year 2000 (Fig. 5-5). The demonstration facility included two parallel 5 ML/d (MGD) reverse osmosis trains, each fitted with thin film aromatic polyamide composite membranes configured for 80-85% recovery in a three-stage array. The UV system at this plant consisted of three UV units in series. Experience from the 24-month sampling, analytical testing and monitoring program showed that high turbidity (> 10 NTU) in secondary effluent has a deleterious impact on the performance of microfiltration. Inflows of tidal seawater into the sewer system through leakage ultimately resulted in reduced performance of the reverse osmosis component of the plant. Biological fouling of the reverse osmosis membranes reduced their effectiveness, but free chlorine could not be used to combat fouling because of deleterious effect on the membranes. In general, biological and other forms of fouling increased operating pressures and the required frequency of cleaning.

Three water reclamation plants are in use. These are the Bedok and Kranji Water Reclamation Plants, which were commissioned at the end of 2002, and the Seletar Water Reclamation Plant was commissioned in January 2004. The total capacity of the three water reclamation facilites is 92,000 m^3/d (20 MGD).

Effluent from secondary treatment is processed by microfiltration, reverse osmosis and UV disinfection. The reclaimed water meets all U.S. EPA and WHO primary and secondary standards for drinking water. It has better clarity, lower color, and lower particle content than Singapore's raw water sources (rivers and reservoirs) and is equivalent in these quality parameters to the tap water currently supplied in the city. The dissolved organic matter concentration in the reclaimed water is substantially lower that that in the tap water. Typical water quality parameter values for the reclaimed water are at or below 5 NTU turbidity, 100 mg/L total dissolved solids, and 5 Hazen units of color. Total coliforms and enterovirus are undetectable.

b) Nonpotable and indirect potable reuse. Reclaimed water from the Bedok and Kranji Water Reclamation Plants is supplied to wafer fabrication plants at Woodlands and Tampines/Pasir Ris and to other industries for nonpotable use. The Seletar Water Reclamation Plant supplies reclaimed water to a wafer fabrication plant at Ang Mo Kio. Singapore's goal is to increase use of reclaimed water for nonpotable applications to at least 15% of the total water demand by the year 2010.

The Public Utilities Board has begun adding 3 MGD of reclaimed water (1% of total daily water consumption) to the raw water reservoirs. The Board has a goal of increasing this amount to 2.5% of daily water consumption by 2011.

c) Studies. A review of the two-year demonstration study was carried out by an expert panel. It found that the plant operated at 80-82% recovery, required 0.7-0.9 kWh/m^3 of electrical energy, and achieved over 7 log (99.99999%) reduction of microorganisms. The panel concluded that the reclaimed water is suitable for human consumption and can be reliably produced. It recommended that the Singapore Government consider use of the reclaimed water to supplement the existing water supply. A health effects study was ongoing at the time the expert panel report was written. The study seeks to evaluate short and long term health effects on mice and fish. In addition, the effect of the reclaimed water on reproduction and development of the fish is being investigated. Preliminary results indicate the absence of a carcinogenic effect on the mice and fish and absence of reproductive and developmental effects on the fish.

d) Outreach. The Public Utilities Board coined the term "NEWater" for the high quality reclaimed water that is produced and built a NEWater Visitor Center at the site of the demonstration facility to inform the public about the need for water reuse, the rigorous treatment sequence applied for water reclamation, and the excellent quality of the product. Interactive computer, video and electronic presentations are emphasized in order to appeal to young Singaporeans.

e) Information sources. Information for the present case study was taken from Macpherson (2003), Ong (2002), PUB (undated) and Radcliffe (2004).

5.3 Comparisons between Case Studies

Key characteristics of the nonpotable reuse applications discussed in this chapter are compared in Table 5-1. The case studies are from California, Texas, Florida, Australia and Singapore. Six of the systems have in excess of 3,000 connections. The size of the distribution systems ranges from 5 to 300 miles and delivered flow ranges from 6 to 118 MGD. None of the nonpotable reuse applications has reported public health impacts. Challenges in system management include more frequent system cleaning relative to potable water distribution systems and high salinity relative to crop tolerances. Shortages of reclaimed water during warm weather were cited in several cases, attesting to the popularity of the delivered product. Every system has invested efforts at public education, both in the planning stages and continuing after the system is placed online.

Key characteristics of the systems for groundwater recharge to potable aquifers and indirect potable reuse that were discussed in this chapter are summarized in Table 5-2. The water reclamation sequence for groundwater recharge by direct injection and indirect potable reuse by supplementation of surface water supplies includes secondary treatment, lime clarification and filtration or membrane filtration, reverse osmosis, and UV disinfection. In the California systems, advanced oxidation is included at the disinfection stage. A sequence consisting of secondary treatment, nitrogen removal, filtration and high-level disinfection is applied for reclamation of water that is subsequently allowed to percolate through the vadose zone to underlying groundwater in the Montebello Forebay. All health effects studies have concluded that ingesting reclaimed water poses no additional risk to consumers. Controlling concentrations of chemicals of concern in reclaimed water was the main problem cited in these systems.

5.4 Satellite Water Reclamation Systems in the U.S. and Australia

5.4.1 Introduction

Regional wastewater management systems have become the norm in the cities of industrialized countries due to their success in protecting public health (Fane and Fane 2005). Regional systems also tend to be more cost-effective than distributed systems due to economies of scale when reuse is not included. However, regional systems may be more expensive if reuse is included because the reclaimed water needs to be returned to the original source areas over longer distances. The treatment plant in a regional collection system is typically located at the lower end of the system, far removed from many potential users of reclaimed water. Reclaimed water distribution costs can be reduced by integrating satellite facilities for water reclamation into regional systems (Butler and MacCormick 1996). Satellite facilities withdraw wastewater from a sewer, reclaim the liquid portion, and return the solids to the sewer (Okun 2000). They maintain economies of scale for biosolids management, since the biosolids are still processed in a regional facility. Satellite facilities lessen the hydraulic load on the regional treatment plant, thus delaying or ameliorating the need for capacity upgrades. They can also achieve higher qualities of reclaimed water. For example, wastewater chloride concentrations in coastal areas impacted by seawater intrusion tend to be high because of infiltration and inflow of salty groundwater. Wastewater from upper portions of the sewerage, where local groundwater is less impacted by saltwater intrusion, can serve as a better starting point for water reclamation.

A typical satellite facility is shown in Figure 5-6. Wastewater is withdrawn from the sewer and is treated by a series of unit processes to achieve requisite water quality, including biological treatment through a suspended growth process such as activated sludge. Primary settling is generally included to decrease aeration requirements and reduce the size of the biological treatment unit. After separation of activated sludge from mixed liquor in a final settling tank, the effluent is coagulated, filtered and disinfected. Chlorine may be added upstream of the filter in order to prevent attached growth in the filter media. Particulate matter removed in the treatment process, including primary and waste activated sludge, is returned to the sewer. The reclaimed water produced by the indicated sequence of treatment processes would meet the standards for unrestricted public access reuse.

Table 5-1. Comparison of Nonpotable Reuse Case Studies

Project	**Locale**	**Flow** (MGD)	**Dist. sys. size** (miles)	**No. of connections**	**Status**	**Costs/Rate structure**
Green Acres	Calif.	6.9	32	Wholesale provider	Demand to increase to 7.9 MGD	$49M project cost / $0.9M annual operations and maintenance
Irvine Ranch Water District	Calif.	11	300	3,400	Expanding storage and treatment capacity	$6.6M annual operations and maintenance / Base reclaimed water rate is $0.82/1000 gal (90% of domestic water rate)
Monterey County	Calif.	20	46	111	Aquifer storage and recovery to be added	$75M construction cost / $0.90/1000 gal delivery cost / revenue obtained from land assessments ($233/acre/yr) and delivery charge ($0.05/1000 gal)
San Diego	Calif.	22.5	79	549	South Bay Distribution System awaiting connections to customers	Reclaimed water price is $0.80/hundred cubic feet / Increase in price projected for 2006
West Basin Water Management District	Calif.	118	5	3+	Adding 10 MGD	Price charged is 20–40% less than imported water, which sells for $510/acre-ft
Phoenix	Ariz.	71	- -	- -	Planning increase to 179 MGD	- -
San Antonio Water System	Texas	50	75	45	67 MGD cap committed	$124M capital cost / Price charged is $0.98/1000 gal (49% of potable water rate) / $0.25/1000 gal charged if withdrawal rights to local aquifer are given up

Table 5-1 (continued)

Project	Locale	Flow (MGD)	Dist. sys. size (miles)	No. of connections	Status	Costs/Rate structure
Altamonte Springs	Florida	5.7	83	6,000+	Actively managing demand with mandatory watering restrictions	$40M capital cost for distribution system / $0.82/1000 gal charged to commercial users and condominiums / Single family dwellings pay $10/mo
Pinellas County	Florida	14.7	- -	10,400	Expanding	Fees include an availability charge of $7/mo / Multifamily and nonresidential customers pay an additional $0.29/1000 gal
Project APRICOT	Florida	5.9	83	6,000+	Shortages occurring in warm weather	$40 capital cost / Commercial users and multi-unit dwelling paid $0.82/1000 gal in 1997 (40% of potable water rates) / Single family dwellings paid $10/month
St. Petersburg	Florida	21	200	10,500	Need to develop additional potable water supply has been postponed	Metered commercial customers pay $0.33/1000 gal / Residential customers pay $0.035/1000 gal for the first acre-ft and $0.02/1000 gal thereafter / $500–1,200 connection fee
Water Conserv II	Florida	37	70	76	Reuse capacity to expand from 68 to 81 MGD	$278M capital cost and $4.8M annual operating budget / Growers currently pay no fee / Residential users pay $0.84/1000 gal plus $3.14/connection/mo / Commercial users pay $0.70/1000 gal

Table 5-1 (continued)

Project	Locale	Flow (MGD)	Dist. sys. size (miles)	No. of connections	Status	Costs/Rate structure
Rouse Hill	Sydney, Australia	1.2 (current capacity)	21	12,000	Will eventually serve 300,000 people	\$22M (Aus) capital cost for reclaimed water distribution system / Users pay \$0.28/kL (29% of potable water fee)
Singapore	- -	- -	- -	3+	Intend to supply at least 15% (45 MGD) of total water demand by 2010	- -

Table 5-2. Comparison of Groundwater Recharge and Indirect Potable Reuse Case Studies

Project	Loca-tion	Flow (MGD)	Treatment	Appli-cation method	Comments	Project Costs/Benefits
Montebello Forebay	Calif.	6	Secondary, nitrogen removal, filtration, disinfection	Infiltra-tion	4 studies concluded no adverse health effects	Provides new water supply equivalent to demands of 250,000 persons / Saves $12M/yr in water purchases
Orange County Water Factory 21	Calif.	15	Secondary, lime clarification, filtration, reverse osmosis, H_2O_2/UV oxidation/disinfection	Injection to potable aquifer	NDMA reduced to acceptable levels by applying RO plus UV/advanced oxidation	Both of the Orange County groundwater recharge systems protect against seawater intrusion and replenish groundwater
Orange Country Groundwater Replenish-ment System	Calif.	62.5	Secondary, membrane filtration, reverse osmosis, H_2O_2/UV oxidation/disinfection	Injection to potable aquifer	Under construction	$454M capital cost and $22M/yr operations and maintenance / Partial funding from $92.5M in grants and $145M in loans
Singapore	- -	3	Secondary, microfiltration, reverse osmosis, UV disinfection	Add to raw water reservoirs	2-yr water quality demonstration completed; parallel epidemiological study in progress	0.7-0.9 kWh/m^3

The potential for substituting compact membrane bioreactors for the aeration basin, final settling tank and filter as shown above has generated considerable interest on the part of water and wastewater utilities (Farmhand Foundation 2004; Wallis-Lage et al. 2004; Cupps and Morris 2005). The small footprint, automation capability, and "double" disinfection (once by the membrane and once by the disinfection unit) of such facilities make them a viable candidate for neighborhood scale water reclamation (Butler and MacCormick 1996; Fane and Fane 2005)

As the present review shows, satellite water reclamation facilities are well established, having been in use for over four decades. The facilities are diverse in size, with the largest producing 35 MGD of reclaimed water and the smallest treating 0.01 MGD. Examples are drawn from systems in the U.S. and Australia, where interest in this technology is highest.

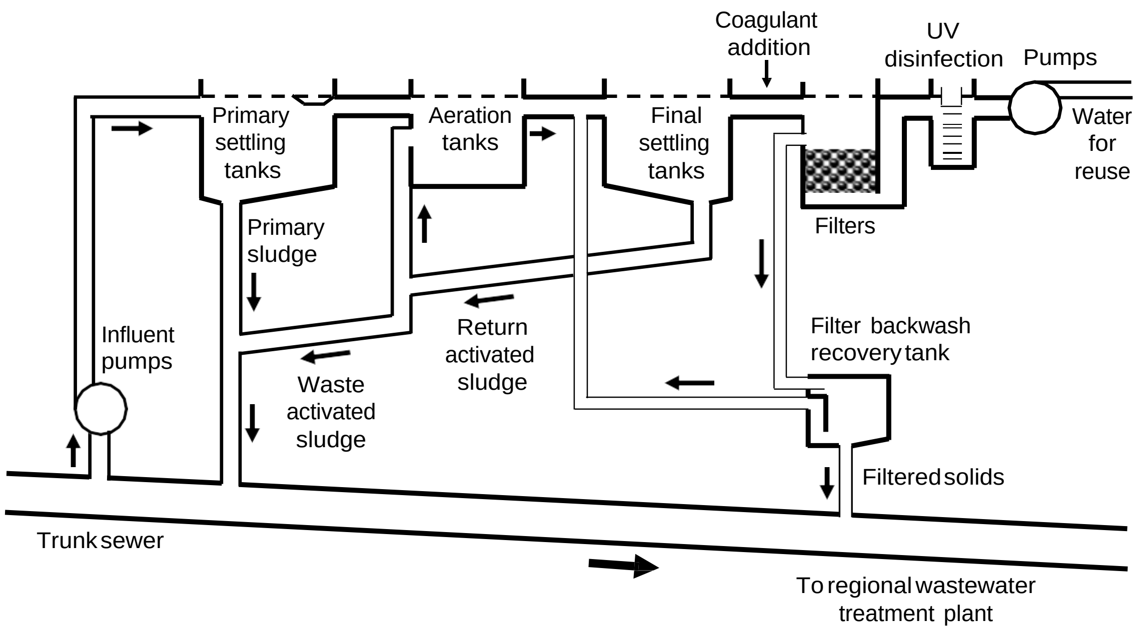

Figure 5-6. Profile of an Illustrative Satellite Water Reclamation Facility. Redrawn and modified from LACSD (undated)

5.4.2 Los Angeles and Orange Counties

Four satellite water reclamation systems are located in Los Angeles County and Orange County, California (Fig. 5-7). Two are operated by the Sanitation Districts of Los Angeles County, one by the City of Los Angeles, and one by the Irvine Ranch Water District in conjunction with the Orange County Sanitation District.

a) Sanitation Districts of Los Angeles County. The largest system of satellite water reclamation systems belongs to the Sanitation Districts of Los Angeles. It includes eight satellite facilities that together produce an average 73 MGD of reclaimed water (LACSD undated). The system spans a distance of 42 miles from the Joint Water Pollution Control Plant to the La Canada Water Reclamation Plant (WRP). Wastewater solids returned to the sewer from each of the satellite plants travel to the Joint Water Pollution Control Plant. Here, the solids are removed from the wastewater, anaerobically digested and dewatered.

Methane from anaerobic sludge digestion fuels a combined cycle power plant (gas turbines followed by boilers and a steam turbine) that provides enough electricity to make the plant self sufficient with respect to energy requirements.

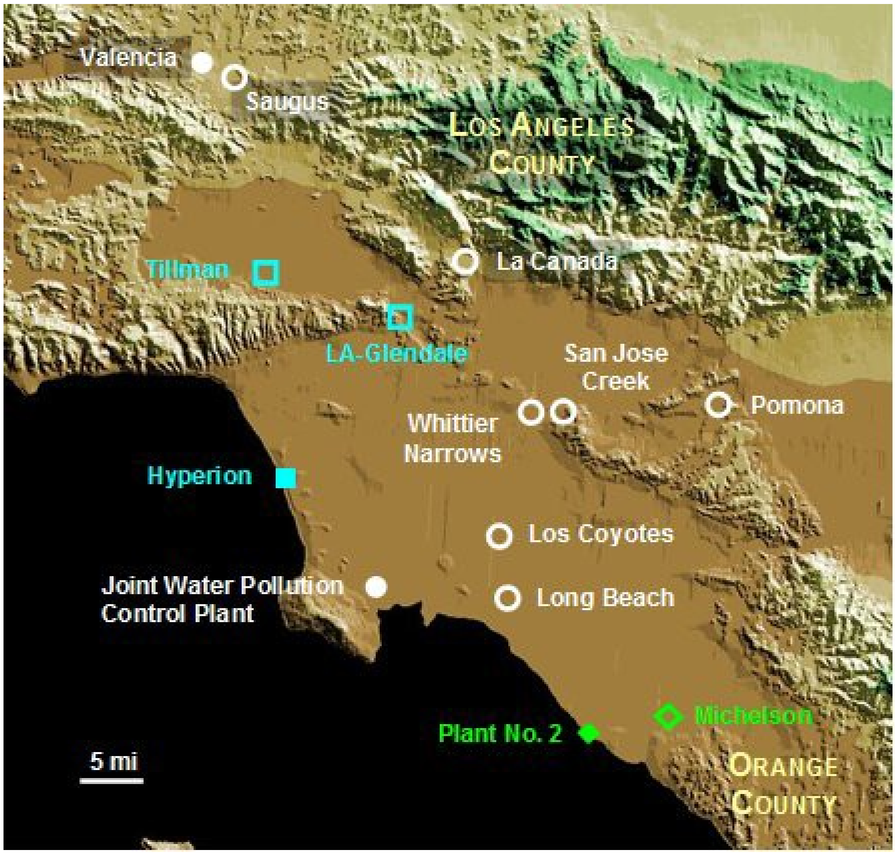

Figure 5-7. Satellite Water Reclamation Systems in Los Angeles County and Orange County, California (IRWD 2006; City of Los Angeles undated; LACSD undated). Open points denote satellite facilities and solid points represent regional treatment plants. Facilities operated by the Los Angeles County Sanitation Districts are represented by circles and facilities operated by the City of Los Angeles are represented by squares. The Michelson Water Reclamation Plant is operated by the Irvine Ranch Water District and Treatment Plant No. 2 is operated by the Orange County Sanitation District. Facility locations are shown on a digital relief map of California (USGS 2002).

The system includes the Whittier Narrows WRP, which is the pioneering satellite facility in the U.S., beginning operations in 1962. The facility currently produces 15 MGD of reclaimed water for groundwater recharge into the Rio Hondo and San Gabriel Spreading Grounds as part of the Montebellow Forebay Project. Reclaimed water is also used for irrigation at an adjacent nursery. The process train of the Whittier Narrows WRP is typical of the satellite facilities operated by the Sanitation Districts of Los Angeles County, consisting of primary settling with optional coagulation, activated sludge with polymer addition to the final settling tanks if needed, alum coagulation and filtration, and chlorination before and after filtration, with 90 minutes of chlorine contact time after filtration (CMHC 2006; LACSD undated). Wastewater solids, including primary sludge, waste activated sludge, and filtered solids are returned to the sewer. Reclaimed water that will be discharged to surface water is dechlorinated before leaving the plant.

Two additional satellite facilities produce reclaimed water for groundwater recharge as part of the Montebellow Forebay Project. The San Jose Creek WRP is the largest of the satellite facilities, with a capacity of 100 MGD. It produces 35 MGD of reclaimed water for reuse at 17 different sites, including irrigation of parks, schools and greenbelts, as well as groundwater recharge. The Pomona WRP produces 8 MGD of reclaimed water that is reused at over 90 different sites. The remainder of the reclaimed water is discharged into the San Jose Creek channel, where it makes its way to the unlined portion of the San Gabriel River and percolates into the groundwater.

The 5 MGD Los Coyotes WRP, along with the San Jose Creek WRP, provide reclaimed water for the Century and Rio Hondo Reclaimed Water Distribution Systems. These systems comprise a looped network of 65 miles of dedicated pipelines that distributes water to a number of municipal and private water purveyors. The reuse distribution system was developed by the Central Basin Municipal Water District in cooperation with the Sanitation Districts of Los Angeles County and 29 other public agencies and private entities, and delivers up to 22,000 acre-ft (20 MG) annually.

The La Canada WRP produces 0.2 MGD of reclaimed water for golf course irrigation. The Long Beach WRP, which treats a total flow of 25 MGD, produces 5 MGD of reclaimed water for reuse at over 40 sites, including repressurization of oil-bearing strata, as well as irrigation of schools, golf courses, parks and greenfields.

The second satellite water reclamation system operated by the Sanitation Districts of Los Angeles County is located in the northern part of the county and consists of the Saugus WRP, a satellite facility, and the Valencia WRP. The Saugus WRP incorporates biological nitrogen removal in its process train. Primary sludge from the Saugus WRP is returned to the sewer and flows 3 miles to the Valencia WRP, where it is removed, anaerobically digested, and thickened. Waste activated sludge from the Saugus WRP is pumped through a force main to air flotation tanks at the Valencia WRP for thickening prior to anaerobic digestion. Methane produced by sludge digestion is used as for plant fuel.

The Saugus WRP produces 7 MGD of reclaimed water for reuse applications. Water not reused is dechlorinated and discharged to the Santa Clara River.

b) City of Los Angeles. The City of Los Angeles operates two satellite water reclamation facilities (City of Los Angeles undated). The Donald C. Tillman WRP, northernmost of the two facilities, has a capacity of 80 MGD. Its sequence of unit processes includes primary settling, activated sludge with nitrification and denitrification, coagulation and filtration, and chlorination. Grit, screenings, primary and waste activated sludge, and filter backwash are returned to the sewer and travel 29 miles to the Hyperion Treatment Plant. Sludge is removed and anaerobically digested at the Hyperion Treatment Plant. Methane from digestion is piped to a nearby power plant in exchange for reduced electricity rates.

Landscaped Japanese gardens adjacent to the Tillman WRP are irrigated with reclaimed water from the plant. The reuse demand totals 26 MGD and includes in-plant applications and many users in the San Fernando Valley in addition to the gardens. The remainder of the reclaimed water is discharged to the Los Angeles River.

The southernmost satellite facility in the City of Los Angeles system is the LA-Glendale WRP, which treats 20 MGD of wastewater using a process train similar to that at the Tillman WRP. Solids removed in the treatment process are returned to the sewer and flow to the Hyperion Treatment Plant. Reclaimed water from the LA-Glendale WRP totaling 4.5 MGD is used for landscape irrigation, cooling water makeup, and irrigation of parks, freeway landscaping, local cemeteries and nearby golf courses. The plant is highly automated and staff can control processes from remote locations.

c) Irvine Ranch Water District/Orange County Sanitation District. The Michelson WRP is operated by the Irvine Ranch Water District and produces 11 MGD of reclaimed water (IRWD 2006). Its treatment train includes primary settling, activated sludge with nitrification and denitrification, dual media filtration, and chlorine disinfection. Primary and waste activated sludge are returned to the sewer and flow 7 miles to the Orange County Sanitation District Treatment Plant No. 2. Sludge is removed from the wastewater by primary settling at Treatment Plant No. 2, anaerobically digested, and dewatered. Methane recovered from the digesters is used to generate electricity for plant use.

Reclaimed water from the Michelson WRP is distributed through 250 miles of reclaimed water pipelines for use in landscape and agricultural irrigation as well as other applications. Excess reclaimed water is stored in several reclaimed water reservoirs and is supplied to the Orange County Sanitation District's Green Acres Project.

5.4.3 San Diego County

Two satellite water reclamation systems are operated by the Metropolitan Wastewater Department of San Diego (Fig. 5-8). The North City WRP currently treats 22.5 MGD of wastewater and has a capacity of 30 MGD (City of San Diego undated-b). The capacity for reclaimed water production is effectively 24 MGD when partial demineralization is practiced. The process train includes primary settling, activated sludge with anoxic selectors to control filamentous bacteria and anthracite coal filters. A portion of the filtrate is demineralized using an electrodialysis reversal process in order to decrease the salinity of the reclaimed water. The demineralized stream is combined with filtrate prior to chlorine disinfection. Primary and waste activated sludge are pumped 5 miles to the Metro Biosolids Center, where they are thickened, anaerobically digested, and dewatered. Methane collected from the digesters is burned at a co-generation facility that provides electricity and steam for the Metro Biosolids Center and the North City WRP. Control of the North City plant is transferred to the utility's communications center in Kearny Mesa from 12:30 am to 5:30 am each night, with an operator on call in the event of an emergency.

An average reclaimed water flow rate of 6 MGD from the North City WRP is distributed through 79 miles of pipeline, two storage tanks and two pump stations. There are 356 metered connections, including a single metered connection with the City of Poway, which serves an additional 193 customers. The single largest use of reclaimed water is landscape irrigation. Additional uses include industrial processes, cooling towers, soil compaction, dust suppression, circuit board washing and urinal flushing. Excess reclaimed water is conveyed to the Point Loma Wastewater Treatment Plant for disposal through ocean outfall.

Figure 5-8. Satellite Water Reclamation Systems in San Diego County, California (City of San Diego undated-b; City of San Diego undated-e; City of San Diego undated-c; City of San Diego undated-a). Open points denote satellite facilities and solid points represent regional treatment plants. Facility locations are shown on a digital relief map of California (USGS 2002).

The treatment sequence of the South Bay WRP is a similar to that of the North City WRP, except that disinfection is accomplished through ultraviolet irradiation instead of chlorination and there is no process for demineralization. Primary and waste activated sludge is returned to the sewer and flows 22 miles to the Point Loma Wastewater Treatment Plant, where the sludge is removed, anaerobically digested, and then pumped 17 miles to the Metro Biosolids Center for dewatering.

The South Bay WRP has a capacity of 15 MGD and treats 5–6 MGD. Currently, 1.2 MGD of reclaimed water is applied for beneficial reuse, including 0.7 MGD supplied to the adjacent International Boundary and Water Commission Wastewater Treatment Plant. Total planned reuse with completion of ongoing projects is 7 MGD. Excess reclaimed water is piped to the ocean outfall at the Point Loma WWTP. The South Bay WRP is staffed from 6:00 am to 4:00 pm Monday through Friday. Plant control is accomplished from the utility's communications center outside these hours.

5.4.4 Thurston County

The Cities of Lacey, Olympia and Tumwater, Washington, together with Thurston County, formed the LOTT Alliance to plan for water and wastewater management (Cupps and Morris

2005). The Alliance's plan calls for three satellite water reclamation facilities to be completed over a 30-year period (Fig. 5-9). Construction of the first satellite facility, the Martin Way Reclaimed Water Plant (RWP), began in 2004 and startup is scheduled for mid-2006. Its treatment sequence includes grit removal, a membrane bioreactor using hollow fiber membranes, and chlorine disinfection (DE 2006). The quality of water produced will meet Class A standards, which include limits of 2 NTU for the monthly average operating turbidity, 5 NTU for the maximum turbidity at any time, 2.2 per 100 mL for the 7-day median total coliform concentration, and 23 per 100 mL for a single sample concentration of total coliforms. In addition, nitrate N and nitrite N are limited to 10 mg/L and 1 mg/L, respectively, for groundwater recharge.

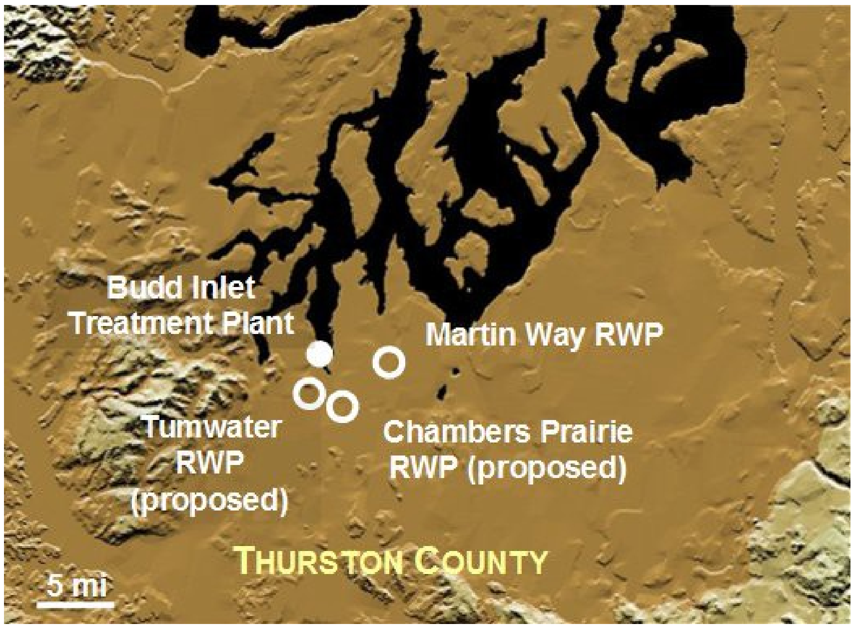

Figure 5-9. Satellite Water Reclamation Systems in Thurston County, Washington (LOTT Alliance 2005). Open points denote satellite facilities and the solid point represents the regional treatment plant. Facility locations are shown on a digital relief map of Washington State (USGS 2002).

The plant has an initial capacity is 2.0 MGD and is expandable to 5 MGD. Waste activated sludge will be returned to the Martin Way Pump Station and pumped 5 miles to the Budd Inlet Wastewater Treatment Plant, where it will be removed, thickened, anaerobically digested, and dewatered. Methane gas collected from the digesters is used as fuel for an engine generator that produces electricity and heat for the plant.

The $18.5 Martin Way RWP is designed to blend in with its neighborhood. Much of the plant equipment will be placed below a ground-level, flat roof that is covered with soil and native vegetation. Reclaimed water will be piped 3 miles to the $6.2 million Hawks Prairie Reclaimed Water Park, also under construction. The park includes 20 acres of constructed wetlands and groundwater recharge basins. Some of the reclaimed water will be used to irrigate parks and to supply commercial and industrial customers in the city of Lacey. The total cost of the satellite water reclamation facility, reclaimed water pipeline, and water park is $30 million (Dodge 2005).

The LOTT Alliance is currently acquiring land for groundwater recharge sites associated with two more satellite water reclamation facilities, one to be constructed in the Chambers Prairie area beginning in 2023 and the other to be constructed in Tumwater sometime after 2025. Each of these plants would have an initial capacity of 1 MGD and be capable of expansion to 5 MGD.

5.4.5 Clark County

Two satellite water reclamation systems are located in the Las Vegas area (Fig. 5-10). The Desert Breeze Water Resource Center (WRC) is a satellite facility operated by Clark County (Grinnell 2006; Clark County Water Reclamation District undated), which is responsible for treating wastewater from unincorporated parts of Clark County within the Las Vegas Valley, including most of the Las Vegas Strip. The capacity of the satellite facility is 5 MGD, expandable to 10 MGD. Available wastewater in the area limits reclaimed water production to 4.3 MGD.

The process train includes equalization, activated sludge with nitrification, final settling tanks, automatic backwash filters, UV disinfection, and hypochlorite addition for reclaimed water distribution. The tanks and most of the equipment are below ground, making the site unobtrusive to the neighborhood (Fig. 5-11). The reclaimed water meets a total coliform limit of 2.2 CFU per 100 mL on a 30-day average basis. Waste activated sludge is returned to the sewer and flows 14 miles to the Main Facility, where it is removed by primary settling, thickened, dewatered, and disposed of by landfilling.

The Desert Breeze WRC provides reclaimed water to four 18 hole golf courses and one 27 hole golf course, as well as 2 parks and 2 schools. The 2005 demand was 3.8 MGD, of which 2.7 MGD was satisfied using reclaimed water. The remainder was met using water extracted from a potable aquifer.

The City of Las Vegas operates two satellite facilities (City of Las Vegas 2005; Grinnell 2006). The larger of the two is the $37 million Durango Hills WRC, which has a capacity of 10 MGD. The process train is similar to that of the Desert Breeze WRC, with all treatment processes underground or under cover. Waste activated sludge is returned to the sewer and flows 18 miles to the Water Pollution Control Facility, where it is removed by primary settling, thickened, anaerobically digested, and dewatered. Methane collected from the anaerobic digesters is burned to heat the digesters and power some equipment, including blowers that supply air to the activated sludge process.

Reclaimed water from the Durango Hills WRC is supplied to 11 golf courses through a distribution system comprising one main pump station, a 2 MG storage reservoir, 17 miles of pipelines, two remote booster pumping stations, and four recharge wells. Reclaimed water production is limited by available wastewater flows, averaging 3.2 MGD in 2005, since the collection system is not yet built out. Excess reclaimed water is discharged to a storm drain during low demand periods.

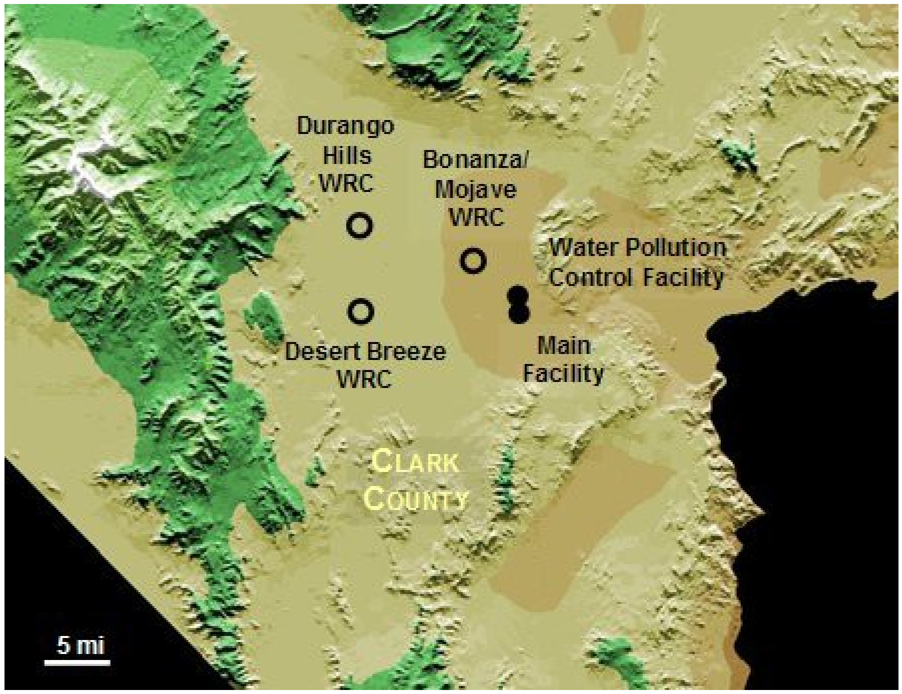

Figure 5-10. Satellite Water Reclamation Systems in Clark County, Nevada (City of Las Vegas 2005; Grinnell 2006; Clark County Water Reclamation District undated). Open points denote satellite facilities and the solid point represents the regional treatment plant. Facility locations are shown on a digital relief map of Nevada (USGS 2002).

Figure 5-11. Desert Breeze Water Resource Center (Clark County Water Reclamation District undated)

The Bonanza/Mojave WRC provides reclaimed water to a single 18 hole golf course. The facility's capacity is 1.1 MGD. The 2005 reclaimed water production averaged 0.2 MGD.

Waste activated sludge from this facility is returned to the sewer and is pumped 11 miles to the Water Pollution Control Facility.

5.4.6 Maricopa County

The Kyrene Water Reclamation Facility in Tempe, Arizona has recently been expanded to 9 MGD capacity and retrofitted with membrane technology (Zenon 2004; Nichols 2006). The facility is expected to resume operations in spring 2006. The flow treated before the upgrade was 4.5 MGD. The treatment sequence includes screening and grit removal, aerated equalization, activated sludge with nitrification and denitrification, a membrane system for separation of activated sludge from treated effluent, and UV disinfection (City of Tempe 2005). The entire process is located underground. Residual solids are returned to the sewer and flow to the 91st Avenue Wastewater Treatment Plant in Phoenix, where they are removed by primary settling, anaerobically digested, and spread on drying beds (PCA undated).

The completed Kyrene WRF will produce very high quality A+ reclaimed water suitable for a wide range of non-potable water uses in Tempe. Up to now, applications included cooling at the Salt River Project Kyrene Electrical Generating Station (1.2 MGD in 2004), irrigation use at the Tempe Ken McDonald Golf Course, and a small amount for groundwater recharge at the golf course. Excess reclaimed water is discharged to the Salt River. Reclaimed water reuse at the power plant and the golf course allow Tempe to receive surface water from the Salt River Project in exchange for reclaimed water deliveries to these sites. More extensive water reuse alternatives are being considered for the city’s Reclaimed Water Master Plan, including possible replenishment of the Tempe Town Lake (Kamienski 2004).

5.4.7 Melbourne, Australia

The locations of satellite water reclamation facilities around Port Phillip Bay, Australia that are in operation or have been evaluated are shown in Figure 5-12. A 1,300 kL/d (0.34 MGD) facility on the eastern side of the bay has been in operation since 1974 (Farmhand Foundation 2004). All flow is used for irrigation. The solids removed during treatment are returned to the sewer and flow to the Eastern Treatment Plant (Melbourne Water undated).

A 30 L/d (0.01 MGD) membrane bioreactor was demonstrated at Kings Domain Gardens, 150 m from the South Yarra Main Sewer north of the bay (Mallia et al. 2003; Farmhand Foundation 2004). This unit, which was housed in a portable shipping container, has a process train consisting of a submersible grinder pump mounted directly in the channel beneath a manhole, screens with 3 mm apertures, Zenon Membrane Bioreactor containing hollow fiber membranes having a 0.04 micron nominal pore size, reverse osmosis unit containing Dow low-fouling membranes designed for brackish water, and calcium hypochlorite dosing. Solids removed during treatment were returned to the sewer and flowed to the Western Treatment Plant (Melbourne Water undated).

The unit was operated for three months. Class A water quality, which allows virtually unrestricted use of water for garden watering, closed toilet flushing, etc., was achieved even before hypochlorite dosing. A seed irrigation trial carried out in parallel with the demonstration showed no effect of the product water on the tested species.

A 35 kL/d (0.01 MGD) system that provides localized filtration of wastewater without need for biological digestion was demonstrated at Flemington Race Course in the northern bay area (Borton 2003; Waste Technologies of Australia 2006; WME 2006). The system is one-half the size of a portable shipping container (Fig. 5-13). Its process train consists of a 200 micron screen, chlorination of screened influent, microfiltration, reverse osmosis, and chlorination of reclaimed water. Solids removed in the treatment processes were returned to the sewer and flowed to the Western Treatment Plant (Melbourne Water undated).

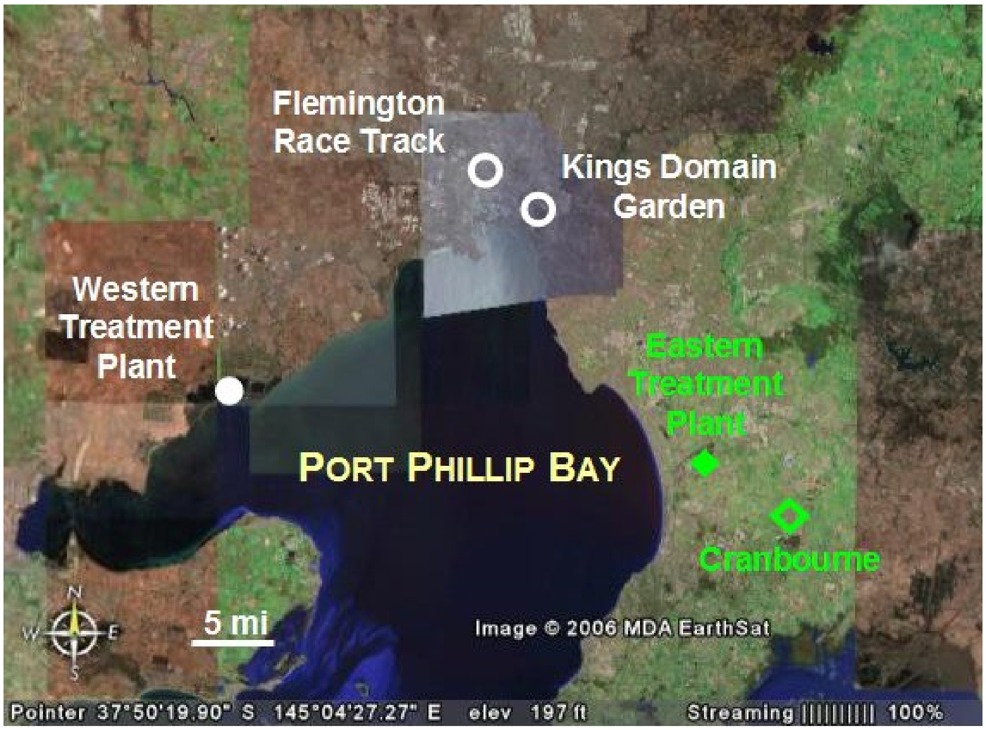

Figure 5-12. Satellite Water Reclamation Systems in Melbourne, Australia (Mallia et al. 2003; Farmhand Foundation 2004; WME 2006; Melbourne Water undated). Open points denote satellite facilities and the solid points represent regional wastewater treatment plants. Photo from Google Earth.

The membrane system produces Class A water and achieves a 7 log reduction in viruses and 6 log reduction in protozoan parasites. Cost of the water produced was estimated at $1 (Au) per 1000 L, with 20% of the cost due to energy requirements. Water from the unit was used to irrigate roses and other plants.

5.4.8 Canberra, Australia

A 300 kL/d (0.08 MGD) satellite water reclamation facility has been in operation in Southwell Park in the city of Canberra since 1995 (Butler and MacCormick 1996; Farmhand Foundation 2004; ActewAGL 2006). Reclaimed water produced by the unit is used to irrigate Southwell Park. The $2.4 million (Au) facility is housed in an odor-controlled building with a footprint of 180 sq m (1,900 sq ft) and has a process train consisting of lime assisted primary settling, fixed film reactor biological treatment with nitrification, microfiltration and hypochlorite dosing for disinfection. Its annual operating budget is

$100,000 (Au). The solids removed during treatment are returned to the sewer and flow to the Lower Molonglo Water Quality Control Centre.

Figure 5-13. Flemington Racecourse Satellite Water Reclamation Facility (Waste Technologies of Australia 2006).

5.4.9 Summary

Satellite water reclamation facilities have been integrated into regional wastewater management systems since 1962. Most of the facilities use conventional process trains that include preliminary treatment to remove screenable materials and grit, primary settling, activated sludge, filtration, and disinfection with chlorine or UV. A few facilities with membrane bioreactors substituting for activated sludge and filtration are in operation, ranging in size from a 9 MGD plant in Tempe, Arizona to 0.01 MGD units demonstrated in Melbourne, Australia. Satellite water reclamation facilities greatly expand the potential for supplying reclaimed water to users throughout the sewer collection system at reasonable distribution costs. They also allow the continued use of regional biosolids management facilities and can improve the quality of reclaimed water over that produced at a regional water reclamation plant.

5.5 Potential for Traditional Water Reuse in Southeast Florida

Consumptive Use Permit data was obtained from the South Florida Water Management District and was used to determine the larger irrigation users who have separate permits for their water use. Attention was focused on the Consumptive Use Permit holders that are located in or near the service areas of the six wastewater districts that discharge to ocean outfalls. Analysis of data from the Consumptive Use Permits enables effective identification of such users.

All Consumptive Use Permit users were first arranged by land use. Six types of land uses were initially analyzed from the South Florida Water Management District data: golf courses, landscaped areas, agricultural areas, aquaculture areas, nurseries, and industrial uses. This study focused on golf courses and landscaped areas that constitute a relatively large proportion of the Consumptive Use Permits and tend to be located closer in distance to the wastewater treatment plants than other water-demanding activities. Industrial users, such as the Turkey Point Power Plant located in Princeton, are also attractive in the development of a reuse network. The potential industrial demand is concentrated in the two Miami-Dade wastewater districts as Consumptive Use Permit data indicate a demand of approximately 33 MGD, of which 17 MGD is located within 12 miles of the two WWTPs. However, industrial users need to be evaluated on a case by case basis due to their diverse needs and widely varied demand flow data as reported in the Consumptive Use Permit Database. Furthermore, the majority of the demand (12 MGD) is in the service area of the Miami-Dade/Central WWTP, which has saline inflow. The remaining golf and landscape areas were arranged by daily allocation. For the purposes of this study, a golf course or landscaped area was considered a “large user” if its demand was 0.05 MGD or higher. Urban users with unit demands of 0.05 MGD or more comprise 80-90% of the total Consumptive Use Permit demand.

The large users were entered into a GIS database along with the service areas of the six wastewater treatment plants that use ocean outfalls, and can be seen in Figures 5-14 through Figures 5-16. The service areas were described in reuse feasibility studies for the Boynton-Delray WWTP in Delray Beach (Brown and Caldwell 1995), the Boca Raton WWTP (Brown and Caldwell 1993), the Broward/North WWTP (Hazen and Sawyer 2004), the Hollywood WWTP (Public Utility Management and Planning Services and Hazen and Sawyer 2001), and the Miami-Dade/North and Miami-Dade/Central WWTPs (PBS&J 1992).

The large users were categorized according to their location. The first category includes users that are located within the service areas of one of the six WWTPs under consideration, with two exceptions. The Town of Davie and Cooper City in Broward County were considered part of the Hollywood WWTP service area. According to FL DEP (2002), these two areas send wastewater to the Hollywood WWTP. Similarly, Boynton Beach in Palm Beach County was included as part of the Boynton-Delray WWTP (Brown and Caldwell 1995).

The next category of large users included those lying outside these boundaries, but still within areas that could be served by traditional water reuse. Most of these outlying areas are now served by wells, but upcoming legislation could limit the availability of this water source. An area was considered as a possible annexation target for traditional water reuse provided that it did not lie within the service area of another wastewater treatment plant. The expanded service areas can be seen as part of Figures 5-14 through 5-16. Palm Beach County has several users in this outlying area that are candidates to receive reclaimed water. Broward County has fewer expansion candidates because there are several other wastewater treatment plants in this area. The service areas of Miami-Dade/North and Miami-Dade/Central WWTPs encompassed all large users.

Large users occupy 18% of the area of the Broward/North WWTP reuse district in Broward County, which consists of the defined WWTP service area plus the expanded area. Palm Beach County has the second largest proportion of large users; 13% of the reuse districts of the Boynton-Delray and Boca Raton WWTPs are occupied by large users. In contrast, only 5% of the reuse district of the Hollywood WWTP is occupied by large users. The reuse districts of the two WWTPs in Miami-Dade County that are under consideration have the lowest proportion of large users (2%).

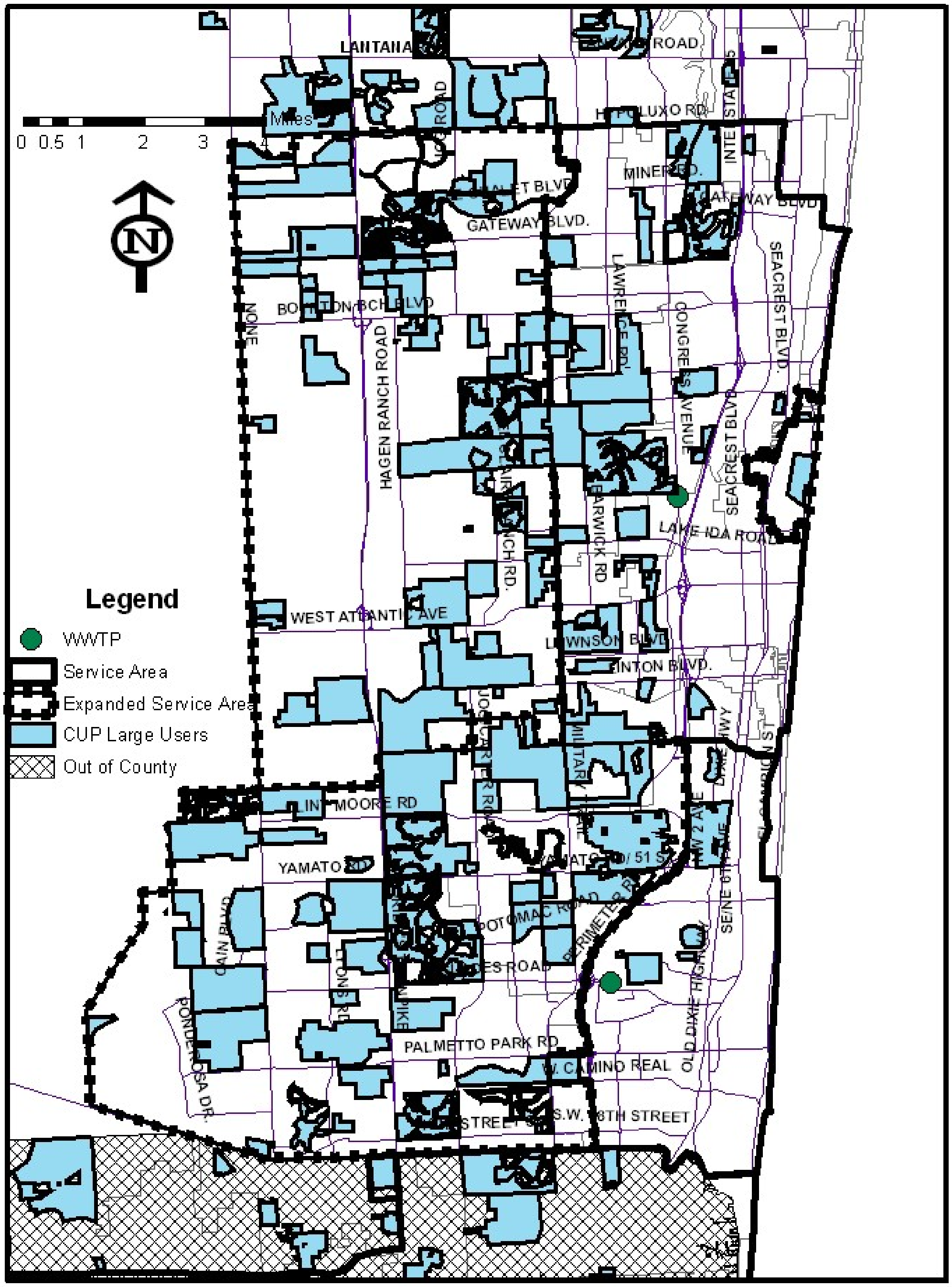

Figure 5-14. Palm Beach County Large Water Users with Separate Permits

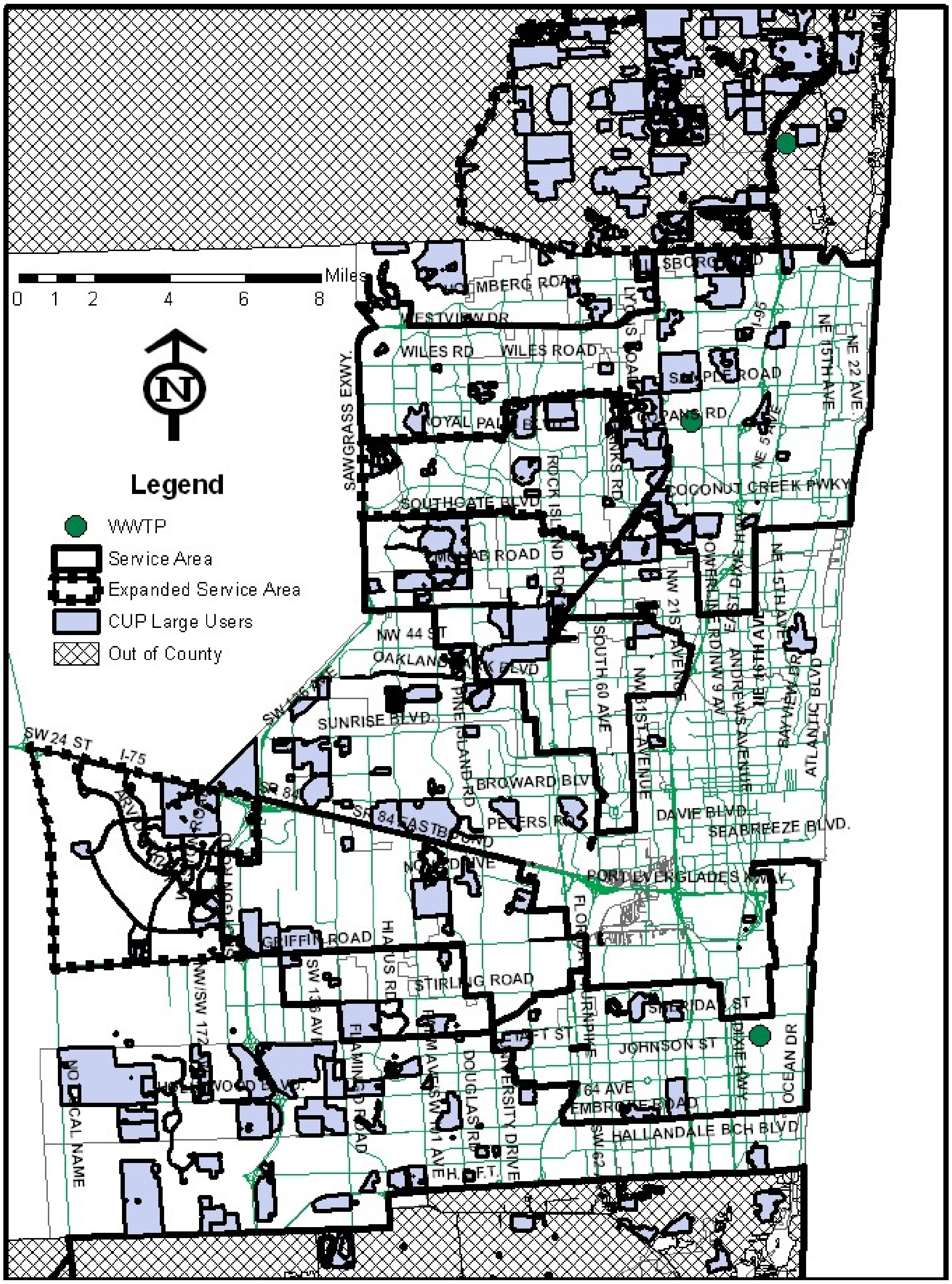

Figure 5-15. Broward County Large Water Users with Separate Permits

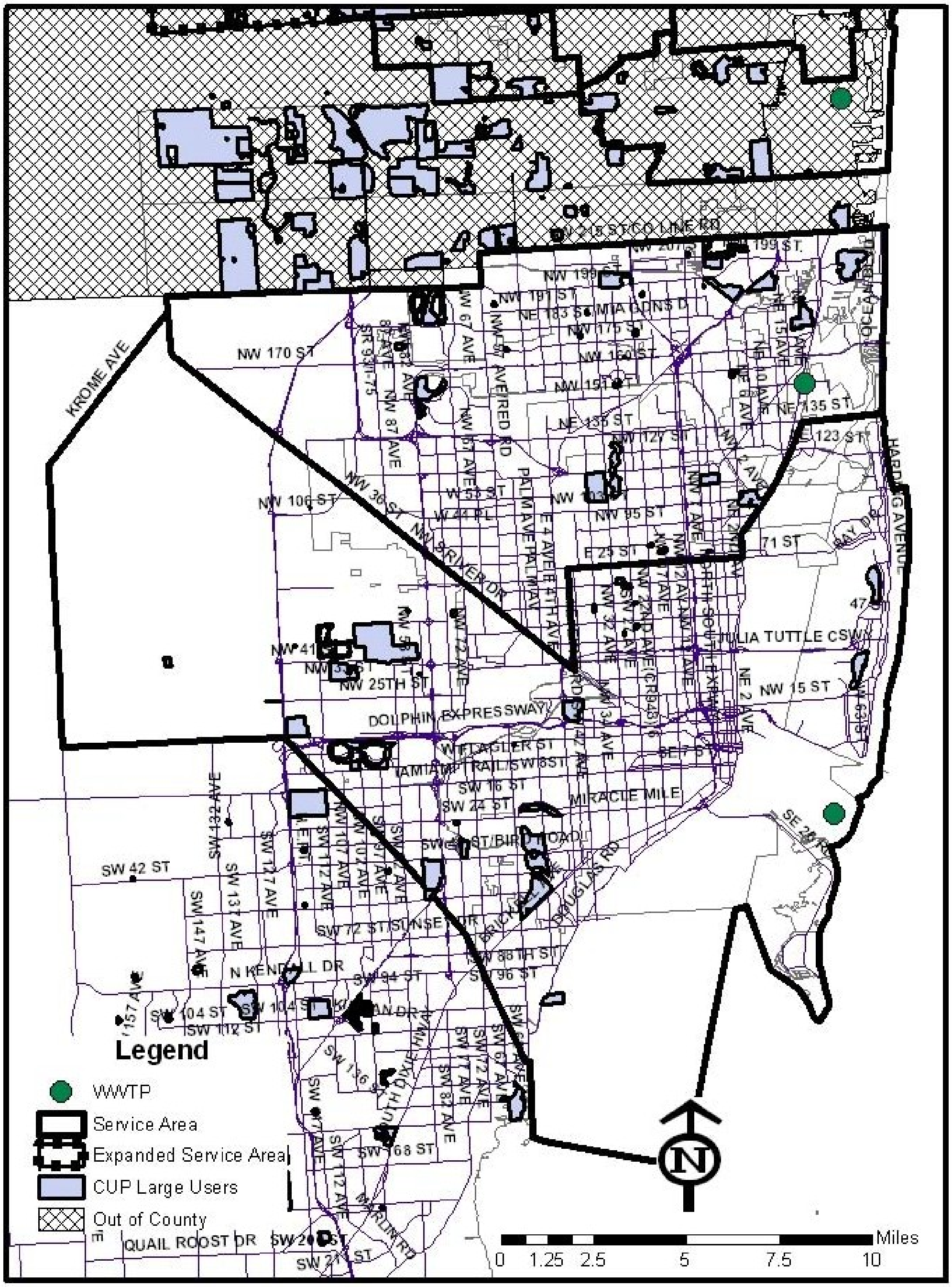

Figure 5-16. Miami-Dade County Large Water Users with Separate Permits

Large users are located randomly throughout the reuse districts, as evident by Figure 5-17. The histogram shows a breakdown of distance from the wastewater treatment plant for all large users in the three-county area.

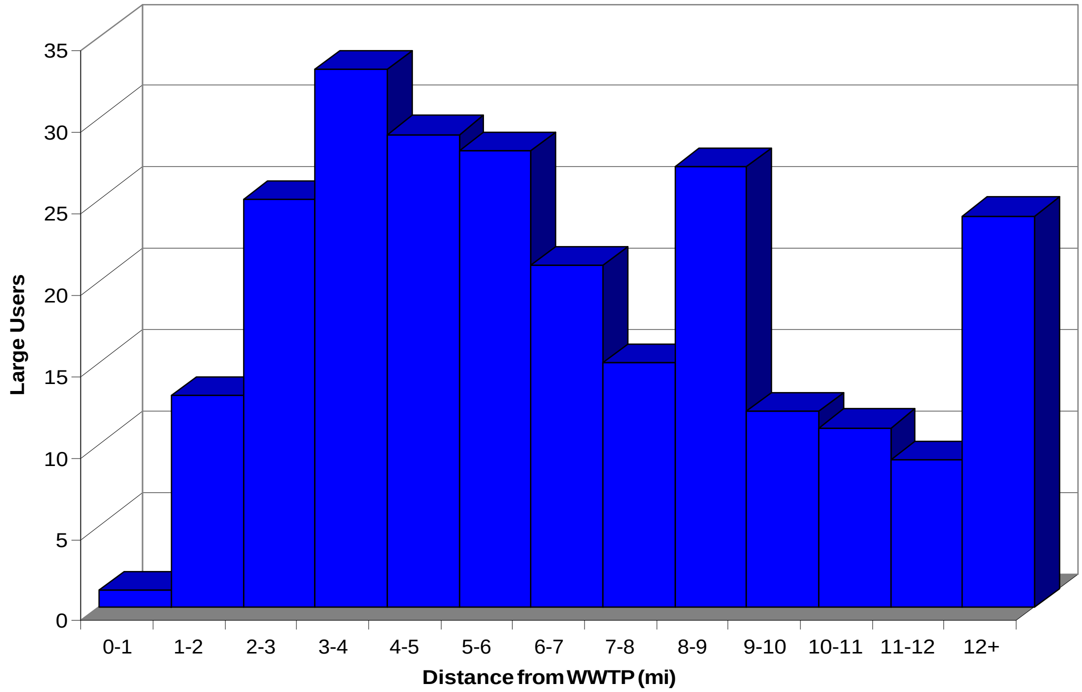

Figure 5-17. Distribution of Large Users' Distance from Wastewater Treatment Plant

The cumulative average demand of the large users, as given by permit data, was then plotted versus metropolitan distance[1] from the large users' respective wastewater treatment plants (Fig. 5-18). The reuse districts served by the Boynton-Delray, Boca Raton, and Broward/North WWTPs have much higher increments of water demand per mile than the districts served by the other three plants.

The slopes of the lines (MGD/mile) in Figure 5-18 fall into two groups. The cumulative demand of large users within 10 miles of the Boynton-Delray WWTP is 20 MGD. Cumulative demands for the reuse districts around the Boca Raton and Broward/North WWTPs have similar slopes. In contrast, the cumulative demand of large users within 10 miles of the Hollywood WWTP is only 3 MGD, or 15% of Delray Beach value. Similar relationships are seen for reuse districts around the Miami-Dade/North and Miami-Dade/Central WWTPs. Accordingly, the more promising opportunities for traditional water reuse are in Palm Beach County and northern Broward County.

[1] Distance measured in the directions of the street grid

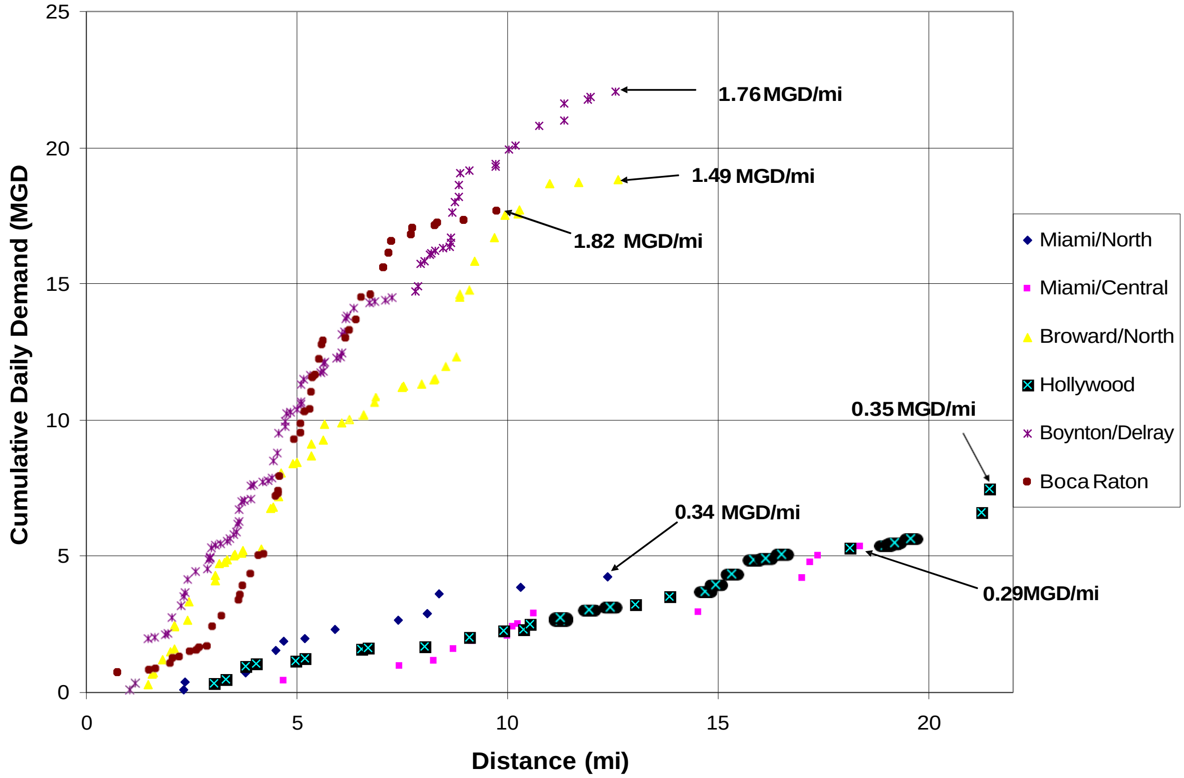

Figure 5-18. Cumulative Daily Demand versus Metropolitan Distance from the Wastewater Treatment Plants

5.6 Summary

Wastewater treatment in the United States has trended towards the construction of centralized treatment systems during the past 40 years for a number of reasons:

- Economies of scale from constructing larger treatment units offset the added piping costs associated with centralized systems
- Generous construction grants from the federal government during the 1970's and 1980's that favored centralized systems
- Problems with performance and reliability in smaller WWTPs.

The cost-effectiveness calculations for these systems did not typically include the possibility of water reuse. The case studies presented in this chapter illustrate how selected communities have integrated reuse systems into their overall wastewater management programs. These cities tend to be in areas where the demand for water is high and supplies are relatively scarce. As competition for water intensifies, more communities can be expected to incorporate reuse into retrofit and expansion plans for wastewater systems including evaluations of the best blend of centralized and decentralized WWTPs and reuse facilities.

As the case studies of water reuse indicate, irrigation of publicly accessible areas such as golf courses is a major application of reclaimed water. Augmentation of ground and surface water supplies with reclaimed water is growing in importance as areas subject to water deficits expand. Satellite water reclamation facilities greatly expand the potential for supplying reclaimed water to users throughout regional wastewater collection systems at reasonable distribution costs, while retaining the economy of scale of regional biosolids management systems. Satellite facilities also have the potential to improve the quality of reclaimed water by withdrawing wastewater upstream of areas that are impacted by inflow and infiltration of saline groundwater.

Traditional reuse (nonpotable reuse for public access applications) is seen from the analysis in Section 5.5 to have the greatest demand potential in Palm Beach County and the northern part of Broward County. A paucity of large urban irrigators lessens the demand potential of traditional reuse in southern Broward County and central and northern Miami-Dade County. There are opportunities to add industrial users in all three counties, although the potential is greatest in Miami-Dade County. Consumptive Use Permit data indicate a total industrial water demand of approximately 33 MGD, of which approximately half is located in proximity of the two WWTPs. The feasibility of adding these users would depend on the individual needs of the industries. Furthermore, the majority of the demand is in the Miami-Dade/Central service area, which has saline inflow. A further analysis would need to be conducted in order to evaluate the needs of large industrial users.

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6. Costs of Traditional Water Reuse and Groundwater Recharge in Southeast Florida

6.1 Introduction

Water reuse is an attractive option when it comes to saving water and reducing the amount of wastewater that is discharged to the ocean. This chapter studies groundwater recharge and traditional land irrigation, two of the more popular methods of water reuse. Several reports provide excellent cost information for the construction, operation and maintenance of the infrastructure required to provide water reuse. This information is used to estimate the costs of well fields for groundwater recharge. In addition, a case study for traditional water reuse is presented to determine if it is cost effective to implement. The results of this case study are used in projecting feasible traditional reclaimed water flows for the remaining five service areas with ocean outfalls, taking advantage of the methodology described in the previous chapter. These projections are used in Chapter 7 as part of the ocean outfall alternatives.

6.2 Methodology for Estimating Costs of Water Reuse Systems

The Florida Department of Environmental Protection (FL DEP 1991) requires that those responsible for domestic wastewater management provide a feasibility study of providing reclaimed water for reuse. The feasibility studies must assess different alternatives in providing water reuse, along with their present costs, costs that will be associated with the user, and the associated environmental and technical impacts.

The FL DEP (1991) guidelines prescribe four alternatives to evaluate:

1. No Action,
2. Minimal Reuse - less than 40% of the average wastewater flow
3. Medium Reuse - 40-75% of the average wastewater flow
4. Maximum Reuse - greater than 75% of the average wastewater flow

The guidelines present several options for reclaimed water, including irrigation of golf courses and other landscaped areas, agricultural uses, recharging groundwater, and industrial uses. Each of these uses requires that the wastewater be processed through secondary treatment and disinfection. Additional requirements for particulate matter and nutrients will be summarized in Chapter Seven.

The FL DEP (1991) methodology uses a net present value analysis, in which all revenues and costs that will be incurred over a twenty-year study period are brought back to the current year's dollar amount using the discount rate published by the United States Environmental Protection Agency. The costs that are to be considered include the capital costs to provide the required level of treatment to the wastewater, the transmission costs to provide water reuse to the users, and the operation and maintenance costs of these systems. A contingency is provided by taking a percentage of capital costs. The cost to pump and store the reclaimed water is identified in the capital costs. The guidelines consider treatment facilities already in operation as sunk costs. Salvage and replacement values are determined using the straightline depreciation method. Finally, revenues from the sale of reclaimed water, connection fees, crops produced, or lease of lands are considered in the net present value analysis.

This initial present value is compared to a present value resulting from the amount of water saved by using reclaimed water. The water usage from a reuse alternative is subtracted from the water usage from the No Action alternative. This flow is multiplied by the average residential rate to produce a cost savings. This present value is subtracted from the present value of the costs described above to determine the final net present value.

6.3 Cost Estimation

6.3.1 Water Reclamation

The costs of treatment to produce reclaimed water suitable for discharge through ocean outfalls, deep well injection, traditional (public access) reuse, or groundwater recharge were evaluated using CapdetWorks 2.1 (Hydromantis Inc., Hamilton, Ontario, Canada) as well as information from the literature.

a) Methodology for estimating wastewater treatment costs using CapdetWorks. CapdetWorks computes land, equipment, and operation and maintenance requirements for a wastewater treatment process train and estimates costs using the 1977 CAPDET database (Harris et al. 1982) or a U.S. July 2000 database. Information required by the program includes average daily, maximum, and minimum flow, influent wastewater characteristics, unit operations and processes to include in the treatment train, and desired effluent quality. The user can provide values for allowable loadings, unit costs, and cost indices or rely on default values.

The general procedure in CapdetWorks was to input certain general factors such as cost indices and then construct a process flow train by assembling and connecting objects representing various unit operations and processes. Details of the methodology are given below. A detailed step by step example is provided in Appendix 1.

i) General. Costs are estimated in 2005 dollars throughout the present report. Cost index values between January 2005 and September 2005 were collected from *Engineering News Record* and *Chemical Engineering* and averaged. The averages were 7410 for the ENR 20-City Construction Cost, 1250 for the Marshall & Swift Index, and 620 for the Pipe Cost Index. These values were input to CapdetWorks.

CapdetWorks inflates unit costs based on inputs for the three cost indices specified above. However, the program does not inflate land costs. A representative land cost of $100,000/acre in 1996 dollars was listed for urban areas by LEES (1997). The Marshall and Swift Index was used to inflate this cost to 2005 dollars ($120,000/acre). The latter value was input to CapdetWorks.

The cost report produced by the program includes the total project cost (construction, land, and interest paid during construction) and the operation and maintenance cost (materials and supplies, energy, and labor). Land cost is also available. The difference between the total project cost and the land cost (i.e., capital cost excluding land) was annualized on the basis of a discount rate of 7% and process life of 20 years. The corresponding capital recovery factor was 0.094. The values of discount rate and process life are the same as those employed by LEES (1997). The land cost reported by CapdetWorks was annualized by applying the discount rate directly. The total annualized cost of wastewater treatment by a particular system was the sum of the annualized net capital cost, annualized land cost, and the operation and maintenance cost.

ii) Influent object. The CapdetWorks influent object allows the user to characterize the influent wastewater in terms of flow and composition. The maximum flow was computed as the product of the average daily flow and the peak hour peaking factor. The peaking factor was found in the consultants' reports. The value of the minimum flow was set equal to the average daily flow. This setting did not alter the value of project cost estimated by Capdetworks. This was verified for minimum flows of 10–100% of the average daily flow.

Design concentrations of influent five-day carbonaceous biochemical oxygen demand ($CBOD_5$) and total suspended solids (TSS) were found in consultants' reports, as summarized in Table 6-1. Design concentrations of influent total Kjeldahl nitrogen (TKN) and total phosphorus (TP) were generally not available in the reports. These concentrations were therefore estimated based on the TKN/BOD_5 ratio (40/220) and TP/BOD_5 ratio (8/220) in medium strength domestic wastewater (Metcalf & Eddy 1991). The estimated concentrations of TKN and total P are also included in Table 6-1. Concentrations of soluble BOD, chemical oxygen demand, soluble chemical oxygen demand, soluble TKN, and ammonia in the influent object were set to zero. The results of preliminary simulations indicated that this approach gave appropriate results.

Table 6-1. Influent Wastewater Parameters Entered for WWTPs

Parameter	Boynton-Delray	Boca Raton	Broward/ North	Holly-wood	Miami Dade/ North	Miami Dade/ Central
Peaking Factor (max. hour)	2.26	2.28	2.3	2.28	2.26	2.28
TSS (mg/L)	250	150	248	150	250	150
BOD (mg/L)	225	200	142	150	225	150
TKN (mg/L)	40.9	36.4	26	27.3	41	27.3
TP (mg/L)	8.2	7.3	5	5.5	8	5.5

iii) Primary clarifier object. A primary clarifier object was included in the process trains of facilities that currently use this unit operation and omitted from the process trains of facilities that do not employ this unit operation. Design factors such as surface overflow rate and tank depth were left at the default settings when this object was used.

iv) SRT-based plug flow activated sludge object. The SRT-based plug flow activated sludge object was used to represent the activated sludge process employed at the six WWTPs with ocean outfalls to provide secondary treatment. The mixed liquor suspended solids was set at 2,000 mg/L and fine bubble aeration was selected unless design information for a facility indicated that coarse bubble aeration was in place. The solids residence time (SRT) was estimated using design information given in the consultants' reports.

v) Biological nutrient removal–3/5 stage object. The biological nutrient removal–3/5 stage object with 3 stages was employed to estimate costs of intermediate nutrient removal. An example of a 3 stage process is the A^2/O process (Metcalf & Eddy 1991). The object with 5 stages was used to estimate the costs of advanced nutrient removal. An example of a 5 stage process is the Bardenpho process (Metcalf & Eddy 1991). The treated effluent qualities associated with these levels of nutrient removal are described in Chapter 7. The mixed liquor suspended solids concentrations for both the 3 stage and 5 stage biological nutrient removal processes were set at 3,000 mg/L. Fine bubble aeration was selected. The solids residence time for nutrient removal was fixed at 6 days for 3 stage treatment and 9 days for 5 stage treatment. The values of solids residence time were selected based on default nitrification kinetics from the International Water Association activated sludge Model 2d (Henze et al. 2000). These solids residence times give simulated effluent ammonia levels of 0.2 mg/L, which provides a satisfactory safety factor for nitrification and also allow sufficient anoxic tank volume for adequate denitrification.

vi) Secondary clarifier object. The secondary clarifier is an integral component of the activated sludge process and was included in all of the process flow trains. The design factors were left at the default values.

vii) Filtration object. The object representing granular media filtration was used with default values for all design factors.

viii) Chlorination object. A contact time of 15 minutes at maximum flow and chlorine dose of 10 mg/L were input to the chlorination object to represent basic level chlorine disinfection. The contact time and chlorine dose were raised to 45 minutes and 16 mg/L, respectively, to represent high-level chlorine disinfection. All other design factors were left at the default values.

ix) Ultra-Violet disinfection object. The CapdetWorks model for UV disinfection requires that the allowable effluent concentration of coliforms be expressed in terms of total coliforms. The California Title 22 requirements for high-level disinfection, which limit maximum effluent total coliforms to 2.2/100 mL, may be considered equivalent to the FL DEP requirements for high-level disinfection, which specify that 75% or more of effluent samples should contain no detectable fecal coliforms. Therefore, a target effluent concentration of 2.2 total coliforms/100 mL after disinfection was employed in the CapdetWorks UV disinfection module. All other design factors were left at their default values.

x) Sludge processing and disposal. Objects representing unit operations and processes for sludge handling and disposal were not included in the wastewater treatment process trains. This is because the quantities of sludge produced by the alternative process trains are anticipated to change by an insignificant amount relative to the quantities produced by the secondary treatment processes now in operation. Upgrading biological treatment processes from secondary treatment to nitrogen removal generally decreases sludge production due to higher solids residence time. This would tend to offset a slight increase in solids production due to chemical precipitation of phosphorus remaining following application of processes for biological enhanced phosphate uptake.

b) Comparison of treatment upgrade costs obtained with CapdetWorks to costs reported by LEES (1997). A comparison of cost estimates for treatment upgrades obtained with CapdetWorks to those given by LEES (1997) was carried out. LEES (1997) gave annualized costs in 1996 dollars for adding a granular media filtration system to a secondary wastewater treatment system and for upgrading basic level chlorine disinfection to high level chlorine disinfection system. These two upgrades were simulated with CapdetWorks. To obtain a correct basis for comparison between the two approaches, the cost index values for 1996 (Marshall and Swift Index = 1040, ENR Cost Index = 5620, Pipe Cost Index = 514) were input to the program. The land value was input as $100,000/acre. Annualized costs estimated by the two approaches were very close at a flow rate of 20 MGD, but were off by a factor of 2 or more at the 1 MGD flow rate (Table 6-2). The capacities of the WWTPs evaluated are 15 MGD or higher. Hence, we would expect generally good agreement between costs estimated using CapdetWorks and costs estimated using the methodology of LEES (1997).

Table 6-2. Comparison of Costs for Adding Granular Media Filtration to a Process Train and Upgrading from Basic-Level to High-Level Chlorine Disinfection

	Filtration		Disinfection		
	1 mgd	20 mgd	1 mgd	20 mgd	
Law Engineering	0.33	0.11	0.098	0.044	$/1000 gal
CapdetWorks	0.17	0.10	0.040	0.041	$/1000 gal
Law Engineering/Capdetworks	1.9	1.1	2.4	1.1	

c) Estimation of costs for membrane filtration and reverse osmosis. CapdetWorks does not include objects for membrane filtration or reverse osmosis. A report by CDM (1998) that estimated the costs to add membrane filtration and reverse osmosis to a secondary wastewater treatment plant was used to find costs for these two unit operations. The capital and operation and maintenance costs of upgrading were estimated by the consulting engineers for a 10 MGD influent flow rate (Table 6-3). The capital cost was annualized using a discount rate of 7% and service life of 20 years. The annualized capital cost and operation and maintenance costs were added to give the total annualized cost of membrane filtration and reverse osmosis as $1.52/1000 gal. The base year for costing was not stated in the report. It was assumed that the costs were in 1997 dollars, since the report was published in 1998. The ENR Cost Indices for 2005 (7405) and 1997 (5825) were applied to inflate the annual cost to $1.93/1000 gal in terms of 2005 dollars.

The annual cost expressed in $/1000 gal was scaled in relation to flow. A scaling factor of 0.85 was determined on the basis of costs for a reverse osmosis process treating potable water (LEES 1997), which were given at several flow rates. The equation for estimating the unit cost of upgrading a secondary wastewater treatment plant with membrane filtration and reverse osmosis is thus

$$C = 0.272\,Q^{0.85} \qquad (6\text{-}1)$$

where C is the cost is expressed in 2005 dollars/1000 gal and Q is the flow rate in MGD.

d) Estimation of costs for advanced oxidation. The Florida DEP suggested the use of advanced oxidation in a treatment train for full treatment and disinfection. However, costs for advanced oxidation were not available in either CapdetWorks or in LEES (1997). Daugherty et al. (2005) dosed 3 ppm of H_2O_2 immediately upstream of a UV disinfection system to achieve advanced oxidation of reclaimed water in Orange County, California. An H_2O_2 cost of $0.50/lb (Brown 2004; Burridge 2004) and a dose of 3 ppm were used to compute annualized chemical costs associated with advanced oxidation.

6.3.2 Traditional Water Reuse

The methods used to estimate costs for this project follow the general concepts outlined in the FL DEP (1991) guidelines with one major change. Instead of using a prespecified percentage of wastewater reuse for the calculations, the net present value was determined for a variety of reuse percentages. As shown in the previous chapter, the relative importance of large users varies widely across the six wastewater treatment plants. Accordingly, the cost-effectiveness of traditional reuse for these six wastewater treatment plants will also vary widely. The addition of more points along a net cost function graph will show to what degree the option is cost effective. The method of how traditional reuse flow levels were determined and their names differs from the FL DEP (1991) report. The “Status Quo” alternative describes a plant that is providing its current amount of reclaimed water. The “Low” alternative finds additional users to take the plant to its existing traditional reuse capacity. The “Medium” alternative encompasses all “large users” in the plant’s service area. Large users are identified as having a demand greater than 0.05 MGD based on the Consumptive Use Permits and for application to golf courses and landscaped areas. Finally, the “Large” alternative is a combination of the large users in the service area combined with a selected amount of residential users. The residential users were determined by the Hazen and Sawyer (2004) report, based on their proximity to the traditional reuse line being designed to serve the large users.

Table 6-3. Estimated Costs for Adding Membrane Filtration and Reverse Osmosis to an Existing Secondary Treatment Facility, Based on Data from a 10 MGD pilot plant[1,2].

Construction	
Effluent Pump Station (Pump + Transmission)	690,000
Microfiltration Equipment (Equipment + MF Portion)	10,560,000
RO Feedwater Storage (Pump + Tanks)	425,000
RO Equipment (Membrane + Cartridge+RO Pump + Cleaning System + Building)	6,575,000
Degasification System (Tower + Blower + Pump)	935,000
Concrete Disposal	50,000
Reclaimed Water (Storage Tank + Water Pump Station)	1,110,000
Chemical Feed System (Sulfuric Acid + Antiscalent + Caustic Soda)	240,000
Site Facilities	770,000
Subtotal (Construction)	21,355,000
Other direct costs I	
Site Work (@5% Net Construction Cost)	1,067,750
Yard Piping (@5% Net Construction Cost)	1,067,750
Electrical and Instrumentation (@15% Net Construction Cost)	3,203,250
Subtotal (Construction + Other Direct Cost I)	26,693,750
Other direct costs II	
Bonds, Premiums, Mobilization, Indemnification, Demobilization, Insurance (8% (Net Construction + Other Direct Cost)	2,135,500
Subtotal (Construction + Other Direct Costs I, II)	28,829,250
Indirect costs	
Engineering, Legal and Administration (15% of Subtotal (Construction + Other Direct Cost I, II)	4,324,388
Contingency (10% of Subtotal (Construction + Other Direct Cost I, II)	2,882,925
Grand Total (Capital Cost) for MF/RO	36,036,563
Annualized capital cost	3,387,437 /yr
Operations and Maintenance	
Chemicals (MF Cleaning + Sulfuric Acid + Antiscalent + Caustic Soda + Chlorine)	296,380
Power	583,900
Labor	300,000
Replacement / Repair	968,380
Grand Total (O & M) for MF/RO	2,148,660 /yr
Total annual cost	5,536,097 /yr
Unit costs	
1997 basis	1.52 /1000 gal
2005 basis	1.93 /1000 gal

[1]All costs that feature in the table are in $. All annualized costs reported in the table are in $/yr. All unit costs reported in the table are in $/1000 gal.
[2]Data from CDM (1998)

Water and wastewater infrastructure is very capital intensive with long service lives that extend to 100 years for some transmission systems. For this project, excellent information is available on how costs should be calculated. The LEES (1997) report incorporates estimation techniques for all costs sought after by the FL DEP (1991) report. These cost estimates were updated by SFWMD (2004). In addition, Hazen and Sawyer (2004) created a database from several reuse treatment facilities that is used to calculate treatment costs. The reuse facilities in this database include the Broward/North, Boynton-Delray, Hollywood, and Boca Raton Wastewater Treatment Plants.

The capital costs determined in this project include the cost to expand the capacity of the traditional reuse facility, the cost to pump the water on-site and throughout the traditional reuse network, the cost of storage tanks, if needed, along with booster stations throughout the service area, the cost of transmission lines required to provide the traditional reuse demand, and land costs for the booster stations. A contingency cost is added to these capital costs.

The cost to expand traditional reuse capacity is based on data from Hazen and Sawyer (2004) and is summarized in Table 6-4. In calculating these costs, the wastewater treatment plant's capacity to treat reclaimed water is subtracted from the alternative demand flow to account for the sunk cost of the plant. The costs presented in Table 6-4 represent the infrastructure required to treat the reclaimed water. It includes the cost to equalize the flow during peak flow events, the cost of a filter feed pumping station to transfer effluent from secondary treatment to the filtration process, and the cost to provide the facilities for chemical pre-treatment, filtration, and disinfection through chlorination. The unit costs used for materials and energy were held constant for all reclaimed water demands.

Table 6-4. Traditional Reuse Expansion Costs (Hazen and Sawyer 2004)

Item	Cost ($/gal)
Facility Structures	0.825
Process Equipment	0.220
Auxiliary Equipment	0.055

The costs to pump the reclaimed water through the treatment process and the reuse network are combined into one category. These costs, along with the cost to store this reclaimed water, are found in a similar fashion. For a 45 MGD capacity system, Hazen and Sawyer (2004) found that a pump station would cost $7.3 million. Additionally, Hazen and Sawyer (2004) estimated that storage for this system would total $30 million. A cost function was implemented to determine the costs for all other flows demanded. The flow and the cost of this larger system are known. Costs are usually estimated using a power function, as shown in Equation 6-2. Using a typical exponent value of 0.7 for treatment systems (Heaney et al. 2002), and using the total cost and flow demand of the treatment system, the value of *a* can be calculated, where *a* in Equation 6-2 represents the cost of pumping or storing 1 MGD of this reclaimed water.

$$C = aQ^b \qquad (6\text{-}2)$$

where C equals cost in dollars, Q equals flow in MGD, and a and b are parameters. This function can be used to obtain pumping and storage costs for any flow desired.

Booster stations and storage tanks are placed throughout the service area. It is assumed that the plant can store reclaimed water up to its current flow, and that storage tanks throughout the system need to be designed to hold 40% of the daily demand (Hazen and Sawyer 2004). In these calculations, 2.5 MG storage tanks are assumed. The amount of booster stations required is any flow above the "Status Quo" multiplied by 40% and then divided by 2.5 MG. Each booster station was estimated to cost $750,000 and is to be situated on a one-acre plot of land that is estimated to cost $250,000 (Hazen and Sawyer 2004). However, because land is assumed not to depreciate, the standard way to cost it out is the foregone revenue for using it during the twenty-year study period, or 7% of the land value per year. Therefore, the cost to use an acre of land is $17,500 per year, which is then calculated as a present value.

Transmission costs are based on the diameter of pipe required, the type of installation required, and the cost of crossing roadways and canals (Hazen and Sawyer 2004). Table 6-5 summarizes these transmission costs.

Table 6-5. Transmission System Unit Construction Costs (Hazen and Sawyer 2004)

Pipe Diameter (in)	Pipe Installation-Paved ($/ft)	Pipe Installation-Unpaved ($/ft)	Roadway Crossings ($/ft)	Canal Crossings ($/ft)
6	75	37.50		
8	100	50.00		
10	125	62.50		
12	150	75.00	1140	1240
16	200	100.00	1330	1330
18	225	112.50	1370	1520
20	250	125.00	1600	1770
24	300	150.00	1670	2150
30	375	187.50	1980	2280
36	450	225.00	2280	2510
42	525	262.50	2340	2730
48	600	300.00	2520	2960

The pipe costs shown in Table 6-5 can be put into equation form as follows:

$$C_u = 6.25*D \text{ for unpaved areas, and} \quad (6\text{-}3)$$

$$C_p = 12.50*D \text{ for paved areas} \quad (6\text{-}4)$$

where C = pipe installation costs in $/foot and D = diameter in inches.

These transmission costs estimates are higher than those reported in South Florida Water Management District (2004), because the latter values, while including the cost to jack and bore underneath a roadway and the costs of valves, do not distinguish between paved and unpaved roadway installation. Finally, engineering, permitting, and administration costs are taken to be 25% of all capital costs.

Operation and maintenance costs are also calculated in Hazen and Sawyer (2004). These costs are shown in Table 6-6. This estimate takes into account that a larger distribution network capable of handling larger flows will require more maintenance. These costs also take into account that operation and maintenance costs historically increase throughout the service life. The percentage increases for years 6–10, 11–15, and 15–20 are 20%, 16%, and 14%, respectively.

Table 6-6. Annual Operation and Maintenance Cost Estimates (Hazen and Sawyer 2004)

	O&M Costs ($/1000 gal)			
Alternatives	**Years 1-5**	**Years 6-10**	**Years 11-15**	**Years 16-20**
Status Quo & Low	0.175	0.210	0.244	0.278
Medium & Large	0.215	0.258	0.299	0.341

The operation and maintenance costs are annualized over the twenty-year study period and brought back to a present value using a 7.0% discount rate. This rate corresponds to the value used in the LEES (1997) report. This value is combined with all capital costs to produce the present value of costs.

FL DEP (1991) regulations require a comparison of present cost values to a present value of savings enjoyed by the large users. Whitcomb (2005) provides water and sewer rates for Miami-Dade and Palm Beach Counties shown in Table 6-7.

Table 6-7. Miami-Dade and Palm Beach Counties Sewer and Water Service Costs (Whitcomb 2005)

Utility	Range in 1,000 gal./mo.	Water $/1,000 gal.	Sewer $/1,000 gal.	Total $/1,000 gal.
Miami-Dade	0 to 3.75	$ 0.50	$ 1.85	$ 2.35
Miami-Dade	3.75 to 7.5	$ 1.60	$ 2.90	$ 4.50
Miami-Dade	7.5 to 12.75	$ 2.20	$ 3.60	$ 5.80
Miami-Dade	> 12.75	$ 3.05	$ 3.60	$ 6.65
Palm Beach	0 to 4	$ 0.75	$ 1.00	$ 1.75
Palm Beach	4 to 10	$ 1.60	$ 2.00	$ 3.60
Palm Beach	> 10	$ 3.80	$ -	$ 3.80

Indoor water use for a typical family would correspond to the first rate category shown in Table 6-7. Irrigation use would be in the remaining categories. Assuming that outdoor water use is in the second category, the relevant savings are $4.50 per 1,000 gallons for Miami-Dade County and $3.60 per 1,000 gallons for Palm Beach County.

Hazen and Sawyer (2004) provide rates for Broward County. A residential customer using 7,000 gallons per month in 2002 was charged $2.35 per thousand gallons for sewer service and $1.69 per 1,000 gallons for water service, or a total of $4.04 per 1,000 gallons. These values are used to estimate the cost savings of implementing a traditional water reuse plan.

Sales of reclaimed water were not quantified in this report. In addition, salvage and replacement values for all capital costs were not calculated. This differs from FL DEP regulations, but is consistent with the methods used in the LEES (1997) report.

6.3.3 Groundwater Recharge

This section develops the groundwater recharge costs for the WWTPs with ocean outfalls. The groundwater recharge construction costs include the cost of the shallow injection wells and valves and the transmission costs from the WWTP to the injection site including pipe costs, jack and bore and canal crossings. Operation and maintenance costs include monitoring, as well as operation and maintenance, plus pumping through the transmission system.

The PBS&J (1992) reuse feasibility study reviewed the drainage wells in Miami-Dade County. The wells are located seaward of the salt front at locations where they will not interfere with other supply wells. The drainage wells, usually 14 to 16 inches in diameter, are typically drilled 60 to 80 feet deep near the coast into the most permeable strata of the aquifer and can drain up to an average of 2,000 gal/min (2.88 MGD) under a head of 1 to 3 ft, depending on site conditions and location. Background water level conditions are usually found at a distance of 500 feet from the recharge well. Under the worst conditions, the background water levels might not be reached in 800 to 1000 feet from the well. From this information it was found that a ten-well string spread 500 feet apart (ten to a mile) could recharge as much as 30,000 gal/min (43.2 MGD), and a system of several of these mile-long strings could be installed to control a wide frontal area of the coast. A pressurized system would allow for additional recharge. The study also mentioned where the shallow injection wells would be most beneficial. Injection wells could be spread along a broad front or concentrated where problems are occurring, such as near the coast where the salt front threatens existing well fields. They could also be installed near and around the control structures in canals to help increase the canal water levels.

The characteristics of the shallow injection wells and transmission lines at the six WWTPs are shown in Table 6-8. A shallow injection well AADF capacity of 2.0–2.85 MGD and an internal diameter of 12–16 inches were chosen for the six WWTPs based on the information presented in PBS&J (1992). The distance between the wells was set at 500 feet, as measured from the center of each well. Where possible, the injection wells were sited along a canal or where saltwater intrusion could be prevented. The locations of shallow injection wells at the respective WWTPs were determined after reviewing appropriate reports for each WWTP.

Table 6-8. Characteristics of the Shallow Injection Wells and Transmission Line

Plant	**No, of wells**	**AADF per well** (MGD)	**Dia. of wells** (inch)	**Trans-mission length** (feet)	**Trans-mission pipe dia.** (inch)	**Description of Transmission Line**
Boynton-Delray	6	2	12	14,001	36	11,500 feet along the L-30 Canal, injection wells along the Military Trail
Boca Raton	4	2.15	14	1,501	36	Injection wells between the WWTP and I-95 Freeway
Broward/North	15	2.7	14	8,001	66	1,000 feet from the WWTP to the C-3 Canal, injection wells along the C-3 Canal
Hollywood	14	2.8	14	16,587	66	10,086 feet from the WWTP to I-95 Freeway along Taft Street, injection wells along I-95 Freeway
Miami-Dade/North	34	2.85	16	16,751	108	250 feet from the WWTP to Snake Creek Canal, injection wells along Snake Creek Canal and Sunny Isles Blvd.
Miami-Dade/Central	40	2.8	14	Up to 35 miles	60	See Figure 6-1

The location of the injection well system for the Boynton-Delray WWTP in Delray Beach is based on the Brown & Caldwell (1993) reclaimed water system feasibility study that evaluated the costs for aquifer recharge through canal recharge and wetlands construction. The Boca Raton WWTP is located next to the I-95 Expressway; therefore the injection wells will be located between the WWTP and I-95 Expressway. The location of the injection well system for the Broward/North WWTP is based on the Hazen & Sawyer (1994) reuse feasibility study that evaluated the costs for canal recharge to C-3 Canal. The location of the injection well system for the Miami-Dade/North is based on the PBS&J (1992) and (1998) Reuse Feasibility Studies which evaluated the costs for canal recharge to Snake Creek Canal. The Miami-Dade/Central includes four transmission lines from the Miami-Dade/Central WWTP to four shallow injection well sites. The Miami-Dade/Central WWTP is located on Virginia Island. The injection well sites were chosen on the mainland, which requires a long transmission line through Miami. The PBS&J (1992) reuse feasibility study found that several well fields would benefit from a seaward movement of the salt front. These included the Miami Springs Well Field, the Hialeah Well Field, the Alexander Orr Well Field, the Homestead Air Force Base Well Field and Leisure City Well Field, mentioned in the order of importance to the overall public water supply. Four sites that would benefit from a program to reduce saltwater intrusion were chosen, as shown in Figure 6-1.

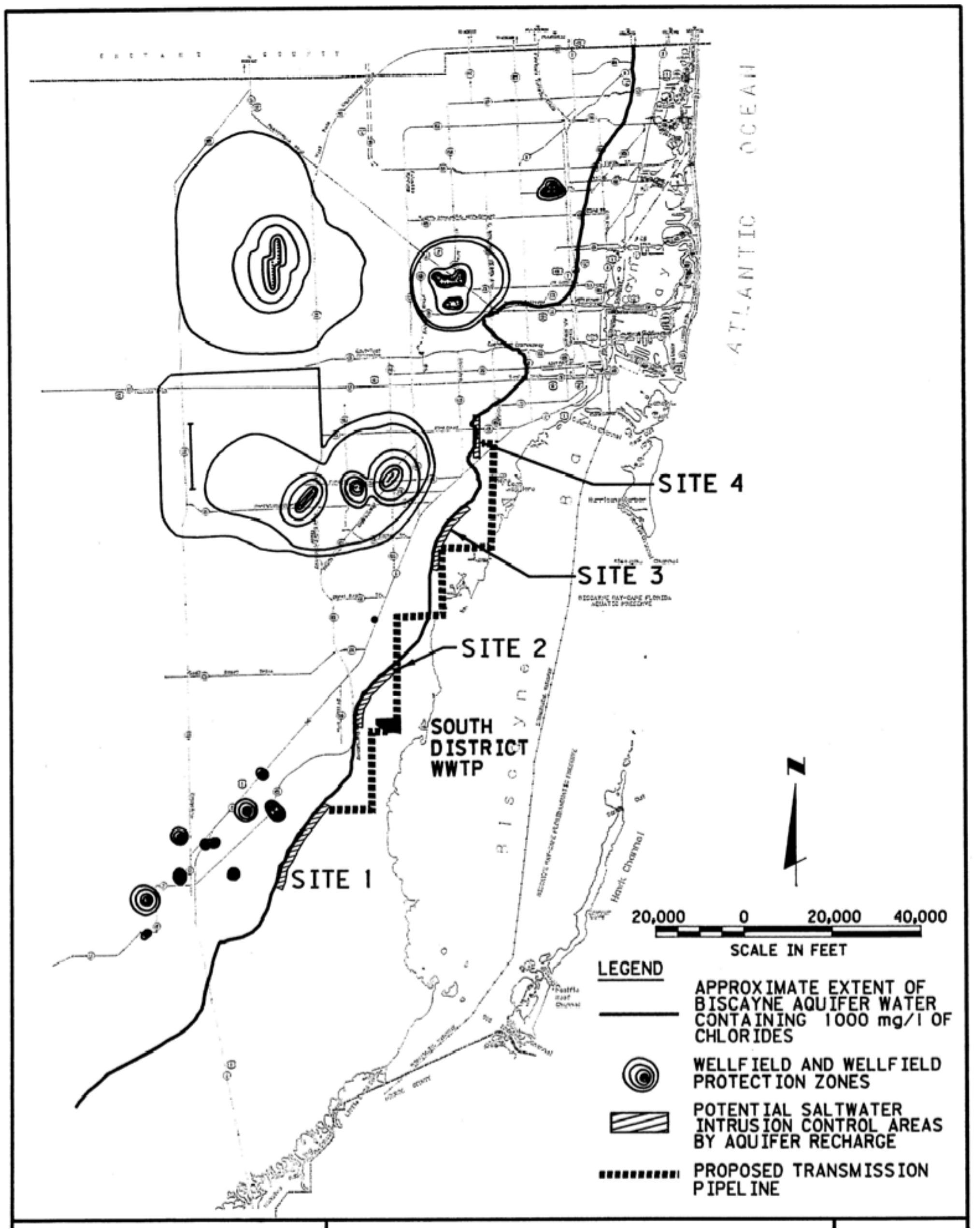

Figure 6-1. Miami-Dade/Central Shallow Injection Well Sites (PBS&J 1992)

A summary of the unit costs for shallow injection wells and transmission is given in Table 6-9. These unit costs were converted to 2005 dollars using the Engineering News Record Index. The injection well construction costs were calculated using values of $9,000/MGD/well and $5,000 for the automatic shut off valve at each well (PBS&J 1992). Transmission pipe costs were calculated from information in the Hazen & Sawyer (2004) reuse feasibility study. The unit cost of pipe installation through urban areas is given by Equation 6-4 (above). Roadway and canal crossing costs were calculated using values of $80,000/roadway crossing and $60,000/canal crossing (PBS&J 1992). Transmission pipes were sized based on information from Hazen and Sawyer (2004) and Brown and Caldwell (1993). The latter study examined a discharge of 12 MGD through a 36 inch transmission pipe to a pumping Station along E-3 canal. Hazen and Sawyer (2004) studied a discharge of about 69 MGD of reclaimed water through a 78 inch transmission pipe to C-3 Canal.

Table 6-9. Unit Costs for Shallow Injection Wells and Transmission

Item	Units	Unit Costs	Source
Injection wells	$/MGD/well	**9,000** (1992 Dollars)	PBS&J (1992)
Valves	$/valve	**5,000** (1992 Dollars)	PBS&J (1992)
Transmission Pipe for paved areas	$/feet	**12.50*Diameter** of pipe in inches (2004 Dollars)	Hazen & Sawyer (2004)
Jack & Bore	$/ roadway crossing	**80,000** (1992 Dollars)	PBS&J (1992)
Canal Crossing	$/ canal crossing	**60,000** (1992 Dollars)	PBS&J (1992)

The lengths of transmission line for five of the injection well systems were calculated by adding the length of transmission line from the WWTP to the injection site and the length of transmission line between the wells, as shown in Equation 6-5.

$$Trans\ Length = Trans\ Line\ from\ WWTP\ to\ Site + 500*(No.Wells - 1) + \frac{Well\ Dia}{12} \qquad (6\text{-}5)$$

The transmission costs for the Miami-Dade/Central WWTP were calculated using the information given in the PBS&J (1992) study. The transmission length given in Table 6-8 applies to transmission of reclaimed water from the Miami-Dade/South WWTP to the injection sites. Since the source of reclaimed water would actually be the Miami-Dade/Central WWTP, transmission costs were increased by $16,000,000, as suggested by PBS&J (1992).

Operation and maintenance costs were estimated from information in reuse studies by Brown and Caldwell (1993) and Hazen and Sawyer (1992). The latter study gave costs for 56 injection wells with a total capacity of 8.25 MGD to recharge Dixie Wellfield using reclaimed water from the Plantation WWTP. The construction costs of $6.69 million included the injection wells, manifold and the transmission pipeline. The operation and maintenance costs of $0.16 million/yr included electricity for pumping and maintenance of the transmission lines and injection wells. The operation and maintenance costs were 2.41% of the construction costs. The Brown and Caldwell (1993) study gave costs for canal recharge of 12 MGD of reclaimed water from the Boynton-Delray WWTP. The construction costs of $4.40 million included the canal discharge structure construction costs, transmission costs, canal use fee, valves and 15% contingency. The operation and maintenance costs of $0.07 million/yr included operation, repair and replacement and monitoring costs. Operation and maintenance costs were 1.59% of the construction costs. Operation and maintenance costs were therefore calculated as 2.5% of the construction costs on an annual basis.

The calculations for the total construction and operation and maintenance costs in 2005 dollars are given for each plant in Tables 6-10 through Table 6-15. The total construction and operation and maintenance costs for each plant are summarized in Table 6-16. The annualized costs assuming a 7% discount rate over 20-year period are shown in Table 6-17.

The annualized costs in $million/yr were scaled according to flow using the relationship shown in Equation 6-6.

$$\text{Cost} = aQ^b \qquad (6\text{-}6)$$

where Q is the design capacity of the system in MGD, b is a scaling coefficient, and a is a site-specific parameter. The value of b was assumed to be 0.7, which is appropriate for water and wastewater transmission systems. A cost scaling relationship is given for each system in Table 6-18.

Table 6-10. Boynton-Delray Shallow Injection Well Costs

Item	Units	Value	Item	Value
Flowrate	MGD	12	ENR (2005)	7405.3
Flowrate per well	MGD	2	ENR (2004)	7115
Total # of wells		6	ENR (1993)	5210
Distance between wells	LF	500	ENR (1992)	4985
Diameter of injection wells	Inches	12		
Diameter of transmission pipe	Inches	36		

Item	Quantity	Units	Unit Cost	Item Cost
CONSTRUCTION COST				
Injection Wells	6	EA	$26,739	$160,436
Valves	6	EA	7,428	$44,565
Total Injection Wells				**$205,001**
TRANSMISSION COST				
Transmission Pipe	14,001	LF	$468	$6,557,515
Jack and Bore	1	EA	$118,841	$118,841
Canal Crossing	1	EA	$89,131	$89,131
Total Transmission				**$6,765,488**
TOTAL COST				**$6,970,489**
O&M COST ($/year)				**$174,262**

Table 6-11. Boca Raton Shallow Injection Well Costs

Item	Units	Value	Item	Value
Flowrate	MGD	8.6	ENR (2005)	7405.3
Flowrate per well	MGD	2.15	ENR (2004)	7115
Total # of wells		4	ENR (1993)	5210
Distance between wells	LF	500	ENR (1992)	4985
Diameter of injection wells	Inches	14		
Diameter of transmission pipe	Inches	36		

Item	Quantity	Units	Unit Cost	Item Cost
CONSTRUCTION COST				
Injection Wells	4	EA	$28,745	$114,979
Valves	4	EA	7,428	$29,710
Total Injection Wells				**$144,689**
TRANSMISSION COST				
Transmission Pipe	1,501	LF	$468	$703,087
Jack and Bore	1	EA	$118,841	$118,841
Canal Crossing	0	EA	$89,131	$0
Total Transmission				**$821,929**
TOTAL COST				**$966,618**
O&M COST ($/year)				**$24,165**

Table 6-12. Broward/North Shallow Injection Well Costs

Item	Units	Value	Item	Value
Flowrate	MGD	40.5	ENR (2005)	7405.3
Flowrate per well	MGD	2.7	ENR (2004)	7115
Total # of wells		15	ENR (1993)	5210
Distance between wells	LF	500	ENR (1992)	4985
Diameter of injection wells	Inches	14		
Diameter of transmission pipe	Inches	66		

Item	Quantity	Units	Unit Cost	Item Cost
CONSTRUCTION COST				
Injection Wells	15	EA	$36,098	$541,471
Valves	15	EA	7,428	$111,414
Total Injection Wells				**$652,885**
TRANSMISSION COST				
Transmission Pipe	8,001	LF	$859	$6,870,289
Jack and Bore	1	EA	$118,841	$118,841
Canal Crossing	0	EA	$89,131	$0
Total Transmission				**$6,989,131**
TOTAL COST				**$7,642,015**
O&M COST ($/year)				**$191,050**

Table 6-13. Hollywood Shallow Injection Well Costs

Item	Units	Value	Item	Value
Flowrate	MGD	39.2	ENR (2005)	7405.3
Flowrate per well	MGD	2.8	ENR (2004)	7115
Total # of wells		14	ENR (1993)	5210
Distance between wells	LF	500	ENR (1992)	4985
Diameter of injection wells	Inches	14		
Diameter of transmission pipe	Inches	66		

Item	Quantity	Units	Unit Cost	Item Cost
CONSTRUCTION COST				
Injection Wells	14	EA	$37,435	$524,090
Valves	14	EA	7,428	$103,986
Total Injection Wells				**$628,076**
TRANSMISSION COST				
Transmission Pipe	16,587	LF	$859	$14,242,752
Jack and Bore	7	EA	$118,841	$831,889
Canal Crossing	2	EA	$89,131	$178,262
Total Transmission				**$15,252,903**
TOTAL COST				**$15,880,980**
O&M COST ($/year)				**$397,024**

Table 6-14. Miami-Dade/North Shallow Injection Well Costs

Item	Units	Value	Item	Value
Flowrate	MGD	96.9	ENR (2005)	7405.3
Flowrate per well	MGD	2.85	ENR (2004)	7115
Total # of wells		34	ENR (1993)	5210
Distance between wells	LF	500	ENR (1992)	4985
Diameter of injection wells	Inches	16		
Diameter of transmission pipe	Inches	108		

Item	Quantity	Units	Unit Cost	Item Cost
CONSTRUCTION COST				
Injection Wells	34	EA	$38,103	$1,295,519
Valves	34	EA	7,428	$252,538
Total Injection Wells				**$1,548,057**
TRANSMISSION COST				
Transmission Pipe	16,751	LF	$1,405	$23,536,989
Jack and Bore	1	EA	$118,841	$118,841
Canal Crossing	1	EA	$89,131	$89,131
Total Transmission				**$23,744,961**
TOTAL COST				**$25,293,018**
O&M COST ($/year)				**$632,325**

Table 6-15. Miami-Dade/Central Shallow Injection Well Costs

Item	Units	Value	Item	Value
Flowrate	MGD	112	ENR (2005)	7405.3
Flowrate per well	MGD	2.8	ENR (2004)	7115
Total # of wells		40	ENR (1993)	5210
Distance between wells	LF	500	ENR (1992)	4985
Diameter of injection wells	Inches	14		
Diameter of transmission pipe	Inches	60		

Item	Quantity	Units	Unit Cost	Item Cost
CONSTRUCTION COST				
Injection Wells	40	EA	$37,435	$1,497,401
Valves	40	EA	7,428	$297,103
Injection Wells Cost per site				$448,626
Total Injection Wells				**$1,794,504**
TRANSMISSION COST				
Transmission Pipe-Site 1	60,000	LF	$781	$46,836,051
Transmission Pipe-Site 2	19,000	LF	$781	$14,831,416
Transmission Pipe-Site 3	97,000	LF	$781	$75,718,282
Transmission Pipe-Site 4	127,400	LF	$781	$99,448,547
Jack and Bore-Site 1	1	EA	$118,841	$118,841
Jack and Bore-Site 2	1	EA	$118,841	$118,841
Jack and Bore-Site 3	1	EA	$118,841	$118,841
Jack and Bore-Site 4	2	EA	$118,841	$237,683
Canal Crossing-Site 1	1	EA	$89,131	$89,131
Canal Crossing-Site 2	2	EA	$89,131	$178,262
Canal Crossing-Site 3	6	EA	$89,131	$534,786
Canal Crossing-Site 4	8	EA	$89,131	$713,048
Transmission Cost-Site 1				$70,812,288
Transmission Cost-Site 2				$38,896,784
Transmission Cost-Site 3				$100,140,174
Transmission Cost-Site 4				$124,167,543
Total Transmission				**$334,016,789**
O&M Cost-Site 1				$1,781,523
O&M Cost-Site 2				$983,635
O&M Cost-Site 3				$2,514,720
O&M Cost-Site 4				$3,115,404
Total O&M Cost				**$8,395,282**
TOTAL COST				**$335,811,293**
O&M COST ($/year)				**$8,395,282**

Table 6-16. Summary Table for Shallow Injection Well Costs

Plant	**AADF** (MGD)	**Construction Cost** ($ million)	**Capital Cost*** ($ million)	**O&M Cost** ($million/yr)
Boynton-Delray	12	$6.97	$9.06	$0.17
Boca Raton	8.6	$0.97	$1.26	$0.02
Broward/North	40.5	$7.64	$9.93	$0.19
Hollywood	39.2	$15.88	$20.65	$0.40
Miami-Dade/North	96.9	$25.29	$32.88	$0.63
Miami-Dade/Central	112	$335.81	$436.55	$8.40

* 1.3 times the construction cost to account for engineering, legal, administrative and contingencies

Table 6-17. Annualized Shallow Injection Well Costs

Plant	**AADF** (MGD)	**Annualized Capital Cost*** ($ million/yr)	**O&M Cost** ($ million/yr)	**Total Cost** ($ million/yr)	**Cost** ($/1000 gal)
Boynton-Delray	12	$0.86	$0.17	$1.03	0.24
Boca Raton	8.6	$0.12	$0.02	$0.14	0.05
Broward/North	40.5	$0.94	$0.19	$1.13	0.08
Hollywood	39.2	$1.95	$0.40	$2.35	0.16
Miami-Dade/North	96.9	$3.10	$0.63	$3.74	0.11
Miami-Dade/Central	112	$41.21	$8.40	$49.60	1.21

Table 6-18. Shallow Injection Well Total Cost Equations for the Six Plants

Plant	**Cost Equation** ($million/yr)
Boynton-Delray	$0.1808*Q^{0.7}$
Boca Raton	$0.0317*Q^{0.7}$
Broward/North	$0.0846*Q^{0.7}$
Hollywood	$0.1799*Q^{0.7}$
Miami-Dade/North	$0.1520*Q^{0.7}$
Miami-Dade/Central	$1.8241*Q^{0.7}$

6.2.4 Reverse Osmosis Concentrate Disposal by Deep Well Injection

The procedure for estimating the concentrate costs from the reverse osmosis process for the WWTPs with ocean outfalls are described in this section. The concentrate construction costs include the costs for a conventional pump station that houses the pumps and drives and the costs for deep injection wells through which to dispose of the concentrate. It is assumed that the deep injection wells will be located at the plant sites and therefore no land costs were included. Injection wells are periodically taken out of service and tested to ensure their integrity. Accordingly, operation and maintenance costs include the costs for mechanical integrity testing of the wells. Testing procedures require a well to be out of service from 2 to 8 weeks, depending upon field conditions and status of the well (Hazen and Sawyer 1999).

The characteristics of the deep injection wells that would be required at the respective WWTPs are shown in Table 6-19. A criterion in the selection of the number of deep injection wells at each plant was to have sufficient capacity during non-peak events when one of the wells is out of service during the performance of mechanical integrity testing.

Table 6-19. Characteristics of the Deep Injection Wells for Concentrate Disposal

Plant	**Number of wells**	**AADF per well** (MGD)	**Diameter of wells** (inch)	**Capacity per well** (MGD)*
Boynton-Delray	2	1.5	12	4.6
Boca Raton	2	1.1	12	4.6
Broward/North	2	5.1	24	18.5
Hollywood	2	4.9	24	18.5
Miami-Dade/North	3	8.0	24	18.5
Miami-Dade/Central	3	9.3	24	18.5

* FDEP allows a peak hourly flow of 18.5 MGD to a 24 inch well (maximum velocity of 10 feet/sec)

The capital costs in 1998 dollars for the construction of a conventional pump station and one or two 24 inch deep injection wells were estimated as $11.1 million and $15.9 million, respectively according to the Hazen and Sawyer (1999) study. The engineering, legal, administrative and contingencies were assumed to be 20% of the construction costs. Based on this information, the construction costs were estimated at each plant and converted to 2005 dollars using the Engineering News Record Index.

Operation and maintenance costs in 2004 dollars were estimated from the Hazen and Sawyer (1992) reuse feasibility study. Mechanical integrity testing costs of four 16 inch wells were estimated as $0.12 million per year for the disposal system, assuming a full mechanical integrity test every 5 yrs and a partial test every 2.5 yrs. The amount needed for each well is therefore $30,000/year.

The total construction and operation and maintenance costs for each plant are summarized in Table 6-20. The annualized costs assuming a 7% discount rate over 20-year period are shown in Table 6-21. The annualized costs in $million/yr were scaled in relation to annual average daily flow using an expression having the form of Equation 6-6 (above). A cost scaling relationship is given for each system in Table 6-22.

Table 6-20. Summary Table for Deep Injection Well Costs

Plant	**AADF** (MGD)	**Construction Cost** ($ million)	**Capital Cost*** ($ million)	**O&M Cost** ($ million/yr)
Boynton-Delray	3	4.14	4.97	0.06
Boca Raton	2.1	4.14	4.97	0.06
Broward/North	10.1	16.57	19.89	0.06
Hollywood	9.7	16.57	19.89	0.06
Miami-Dade/North	24.1	21.58	25.89	0.09
Miami-Dade/Central	27.9	21.58	25.89	0.09

* 1.2 times the construction cost to account for engineering, legal, administrative and contingencies

Table 6-21. Annualized Deep Injection Well Costs

Plant	**AADF** (MGD)	**Annualized Capital Cost*** ($ million/yr)	**O&M Cost** ($ million/yr)	**Total Cost** ($ million/yr)	**Cost** ($/1000 gal)
Boynton-Delray	3	$0.47	$0.06	$0.53	0.49
Boca Raton	2.1	$0.47	$0.06	$0.53	0.69
Broward/North	10.1	$1.88	$0.06	$1.94	0.53
Hollywood	9.7	$1.88	$0.06	$1.94	0.55
Miami-Dade/North	24.1	$2.44	$0.09	$2.54	0.29
Miami-Dade/Central	27.9	$2.44	$0.09	$2.54	0.25

Table 6-22. Deep Injection Well Total Cost Equations for the Six Plants

Plant	**Cost equation** ($million/yr)
Boynton-Delray	$0.2465*Q^{0.7}$
Boca Raton	$0.3164*Q^{0.7}$
Broward/North	$0.3844*Q^{0.7}$
Hollywood	$0.3954*Q^{0.7}$
Miami-Dade/North	$0.2736*Q^{0.7}$
Miami-Dade/Central	$0.2469*Q^{0.7}$

6.4 Case Study of the Broward/North Wastewater Treatment Plant

A case study was performed on the Broward/North Wastewater Treatment Plant. Excellent cost estimation data was available for this service area as Hazen and Sawyer (2004) had conducted a feasibility study on this plant. In addition, this study identified large users that are compatible for traditional water reuse.

As mentioned before, this report differs when naming different levels of reuse in order to provide more data points to examine. Six different traditional reuse levels were examined in this report, including the “Status Quo,” “Low,” “Medium,” and “Large” options. The

“Medium” alternative was subsequently broken up into smaller subgroups to show the effect that distance away from the wastewater treatment plant has in determining when an option become less cost effective. The “Status Quo” alternative is the current level of traditional water reuse being provided in the service area, which is approximately 4.5 MGD. The “Low” alternative takes the plant to near capacity at 9.34 MGD. The “Medium” alternative includes the addition of several large users determined by Hazen and Sawyer (2004), situated throughout the service area. The “Medium Reuse: Large Users North” includes large users that are situated to the north of the treatment plant, and takes the demand flow past the current capacity to 11.34 MGD. The “Medium Reuse: Large Users” option includes all of the large users identified by Hazen and Sawyer (2004) as suitable for traditional water reuse. The demand for this alternative is 19.31 MGD. The “Medium Reuse: Additional Large Users” alternative is an additional point to show a higher demand of traditional water reuse. This point includes all large users identified in the Hazen and Sawyer report, but shows a higher demand flow to account for users not identified but feasible for traditional water reuse as determined from Consumptive Use Permit data. Finally the “Large Reuse” option includes just the large users identified in Hazen and Sawyer (2004) along with a group of residential users that are in close proximity to the traditional reuse network setup. This takes the demand to 41.98 MGD. The different traditional reuse levels and their corresponding flows can be seen in Table 6-23.

Table 6-23. Traditional Reuse Flow Levels with Corresponding Flow Demands for Broward/North Reuse District

Description	Flow Demanded (MGD)
Status Quo	4.46
Low	9.34
Medium Reuse: Large Users North	11.34
Medium Reuse:Large Users	19.31
Medium Reuse:Addl Large Users	30.00
Large Reuse	41.98

The names of the large users and their traditional reuse level are presented in Table 6-24. The locations of these users can be seen in Figure 6-2 with an approximate location of the traditional reuse network. The Broward/North WWTP is located at the intersection of Copans Road and Powerline Road. The large Consumptive User Permit users constitute nearly 18% of the area within 12 miles of the WWTP. Thus, many opportunities exist for traditional water reuse.

Table 6-24. Large Users in Broward/North Reuse District

Status Quo	**Medium Reuse: Large Users**
NRWWTP On-site	Tradewinds Park
WES	Wynmoor Golf Course
Pompano Commerce Park	Palm Aire
Low	Pompano Race Track
NRWWTP On-site	Oriole Golf Course
WES	Palm Lakes Executive Golf Club
Pompano Commerce	Carolina Golf Club
Tam O'Shanter Golf Club	Brokenwoods (Continental) Golf Club
Crystal Lake Country Club	Mullins Park
Medium Reuse: Large Users North	Coral Springs Golf Club
Adios Golf Club	Coral Springs Cypress Park
Quiet Waters Park	Eagle Trace Golf Club
Deer Creek Golf Course	Woodmont Golf Club
Century Village Golf Club	Colony West Golf Club

The irrigation demand data from the Hazen and Sawyer (2004) feasibility study are based on an average annual demand of 1.5 inches per week. This application rate differs from the allocated flow in the Consumptive Use Permit data, but for the case study, the Hazen and Sawyer (2004) estimates were used. These flows will be compared to the flows from the permit data for the Broward/North Regional to show that the flows obtained are comparable and can be extrapolated to the other five ocean outfall regions.

Treatment and pumping costs are shown in Table 6-25 and were estimated using methods discussed before. The "Status Quo" and "Low" alternatives show no additional cost because the treatment plant can process the demand flow.

Storage costs, shown in Table 6-26, were estimated by the power function for the medium and large alternatives, as discussed previously. The "Low" alternative used a value found from Hazen and Sawyer (2004). The required volume of the storage tanks for the remaining alternatives was based on 40% of the daily demand. The "Low" scenario assumes that storage is handled on-site and therefore no booster stations or land costs were calculated for this option. The tanks required for the "Medium" and "Large" options take into account that the treatment plant can handle the flow that it currently processes. Also for the "Medium" and "Large" scenarios, no additional storage construction was assumed at the treatment plant as in the "Low" alternative. Instead, these storage tanks with booster stations are to be distributed throughout the service area.

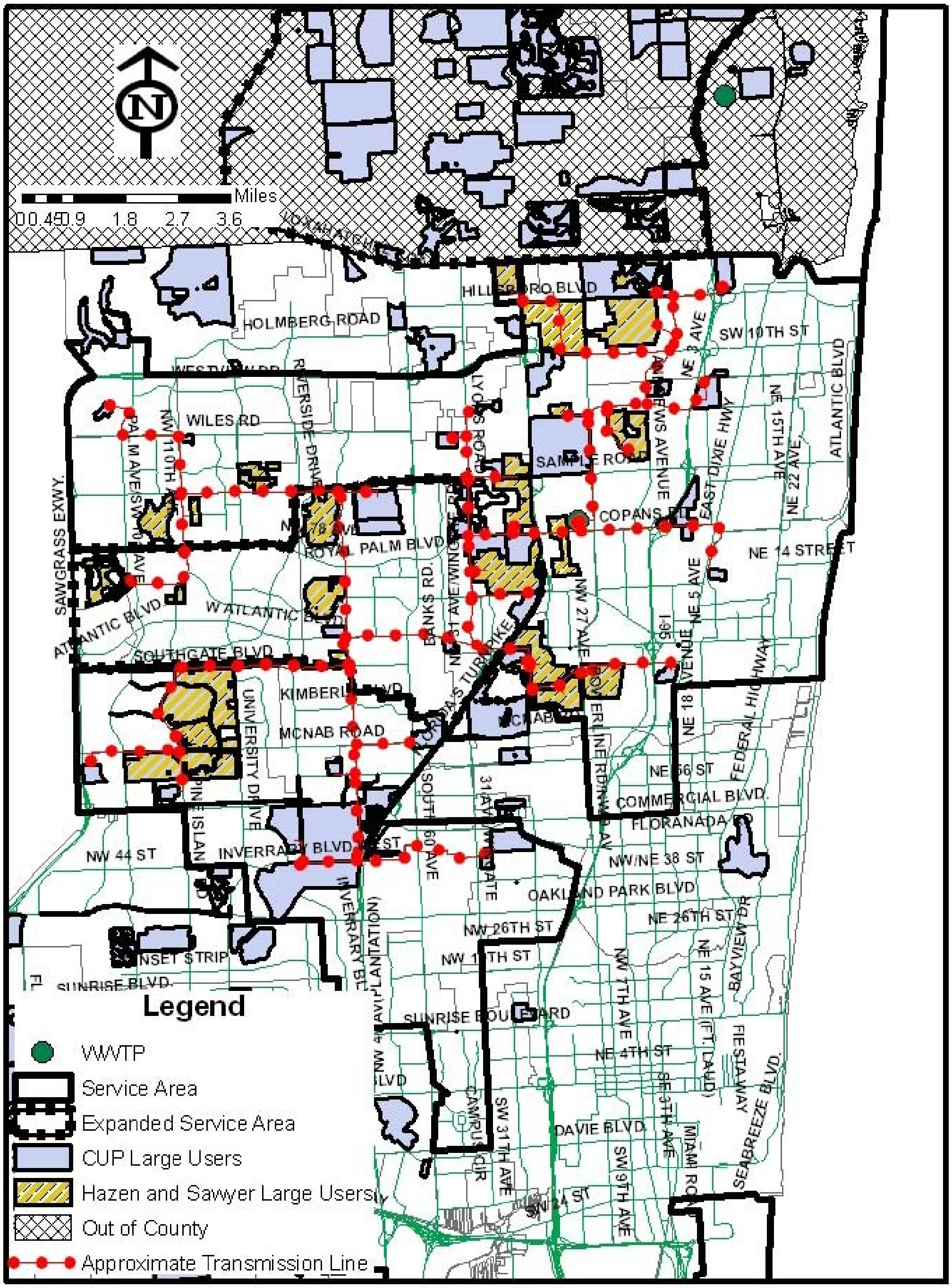

Figure 6-2. Broward/North Large Users and Transmission Line

Table 6-25. Treatment and Pumping Costs for Various Levels of Reuse

Description	Reclaimed Water Treatment	Process Equipment	Auxiliary Equipment	Pumps
Status Quo	$0	$0	$0	$0
Low	$0	$0	$0	$0
Medium Reuse: Large Users North	$1,105,500	$294,800	$73,700	$2,781,655
Medium Reuse:Large Users	$7,680,750	$2,048,200	$512,050	$4,037,585
Medium Reuse:Addl Large Users	$16,500,000	$4,400,000	$1,100,000	$5,496,155
Large Reuse	$26,383,500	$7,035,600	$1,758,900	$6,953,506

Table 6-26. Storage and Land Costs

Description	Storage	Tanks Reqd	Reuse and Booster Pump	Land
Status Quo	$0	0	$0	$0
Low	$1,250,000	0	$0	$0
Medium Reuse: Large Users North	$11,431,458	2	$1,500,000	$370,790
Medium Reuse:Large Users	$16,592,816	3	$2,250,000	$556,186
Medium Reuse:Addl Large Users	$22,586,939	5	$3,750,000	$926,976
Large Reuse	$28,576,050	6	$4,500,000	$1,112,371

Transmission costs are estimated based on the approximate location of the distribution network shown in Figure 6-2 (above). The values for the “Low,” “Medium Reuse: Large Users North,” and “Large Reuse” were calculated in Hazen and Sawyer (2004). A total of 55,000 residential users were used in the “Large Reuse” category, with an estimated cost of $4,800 per connection used (Hazen and Sawyer 2004). This price includes fifty feet of distribution pipe, a meter, and a dual check valve. The “Medium Reuse: Large Users” and the “Medium Reuse: Additional Large Users” options had the pipes downsized to account for the absence of residential flow. In completing this calculation, a velocity of five feet per second was assumed. These costs, along with the engineering, permitting, and administration costs, can be seen in Table 6-27. These added costs were estimated as 25% of all of the capital costs, not including land.

Table 6-27. Transmission and Engineering Costs

Description	Transmission and Distribution Cost	Engineering, Permitting, and Administration
Status Quo	$0	$0
Low	$1,231,500	$620,375
Medium Reuse: Large Users North	$9,419,866	$6,651,745
Medium Reuse:Large Users	$44,351,236	$19,368,159
Medium Reuse:Addl Large Users	$76,764,865	$32,649,490
Large Reuse	$349,886,170	$106,273,431

Finally, annual operation and maintenance costs were separated into five-year blocks and estimated as described previously. The values, seen in Table 6-28, were then brought back to a present value, which is 2004 dollars, using a discount rate of 7%.

Table 6-28. Annual Operation and Maintenance Costs

Description	O&M				
	1-5 years	6-10 years	11-15 years	16-20 years	PV @ i=7.0%
Status Quo	$284,883	$341,859	$396,556	$452,074	$3,665,843
Low	$596,593	$715,911	$830,457	$946,721	$7,676,900
Medium Reuse: Large Users North	$889,907	$1,067,888	$1,238,750	$1,412,175	$11,451,238
Medium Reuse:Large Users	$1,515,352	$1,818,423	$2,109,370	$2,404,682	$19,499,419
Medium Reuse:Addl Large Users	$2,354,250	$2,825,100	$3,277,116	$3,735,912	$30,294,282
Large Reuse	$3,294,381	$3,953,257	$4,585,778	$5,227,787	$42,391,798

All costs in 2004 dollars are added, and are converted to 2005 dollars using the Engineering News Record index. The present worth over the twenty-year period is calculated using a 7% discount rate in Table 6-29 and can then be converted to a daily cost and plotted against flow in thousands of gallons per day.

Table 6-29. Present Value and Equivalent Uniform Annual Costs

Description	Q (kgd)	Total Cost (2004$)	Total Cost (2005$)	Annual Costs, i=7.0%, N=20	Daily Cost
Status Quo	4,460	$3,665,843	$3,815,259	$360,133	$987
Low	9,340	$10,778,775	$11,218,106	$1,058,910	$2,901
Medium Reuse: Large Users North	11,340	$45,080,753	$46,918,197	$4,428,746	$12,134
Medium Reuse:Large Users	19,310	$116,896,401	$121,660,977	$11,483,936	$31,463
Medium Reuse:Addl Large Users	30,000	$194,468,706	$202,395,049	$19,104,661	$52,342
Large Reuse	41,980	$574,871,327	$598,302,484	$56,475,522	$154,727

The resulting graph, shown as Figure 6-3, has an excellent coefficient of determination (R^2) when a power function is fit to the data. The cost function was also plotted using the same users identified in the Hazen and Sawyer (2004) report, but with flows obtained from Consumptive Use Permit data. As mentioned before, the difference between the two data sets does not result in a large difference when calculating marginal costs.

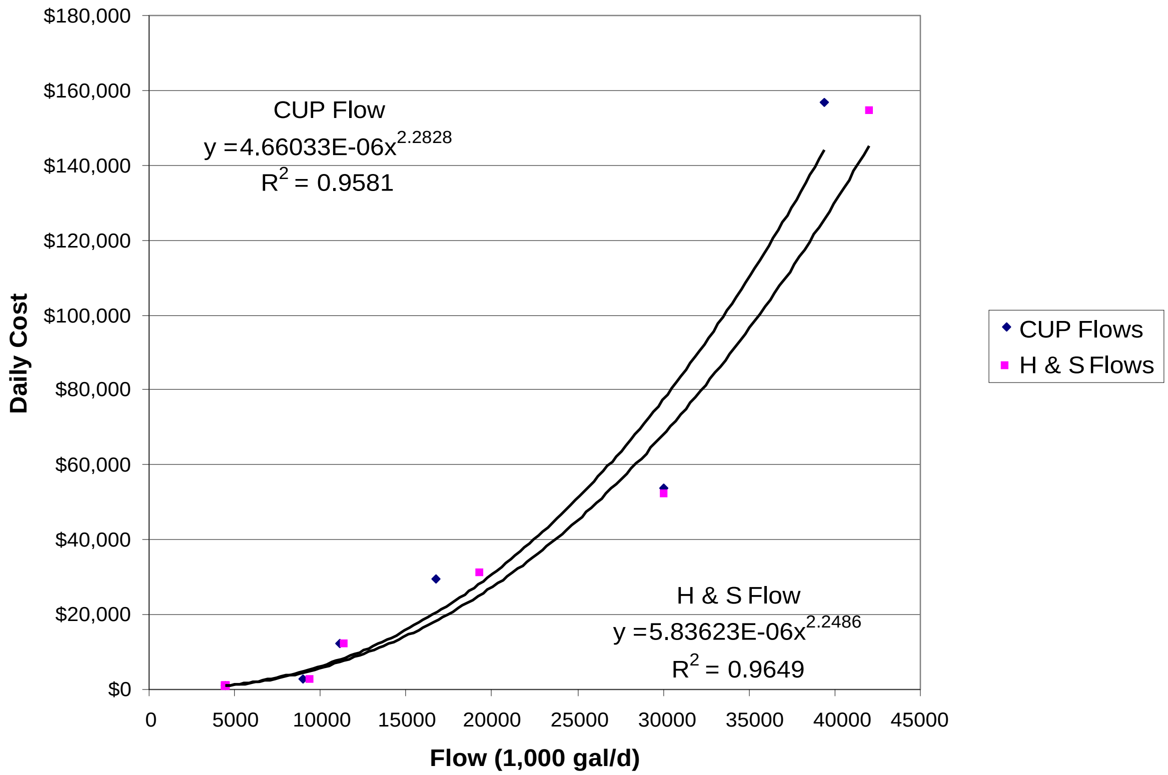

Figure 6-3. Daily Cost versus Flow

The resulting power function for the Hazen and Sawyer data was found to be:

$$C = .00000583623Q^{2.24859} \qquad (6\text{-}7)$$

where C equals total daily costs and Q equals flow in thousand gallons per day.

The derivative of this total cost function gives the marginal cost curve, as seen in Equation 6-8.

$$MC = ab*Q^{b-1} \qquad (6\text{-}8)$$

Using the parameters from the total cost function, i.e., a = 5.83623 E-06 and b = 2.24859, the equation for the marginal cost is

$$MC = 1.29901\text{ E-}05*Q^{1.24859} \qquad (6\text{-}9)$$

where MC = marginal cost, $/1,000 gallons, and Q = demand in 1,000 gal/day.

In economics parlance, the marginal cost curve is the supply curve. Customers who decrease irrigation demand on the central water system save an estimated $4.04 per 1,000 gallons in 2002 dollars, or $4.58 in 2005 dollars. Thus, the optimal amount of water reuse to provide in this case is about 26.5 MGD as shown in Figure 6-4. If user savings are $2.00 per 1,000 gallons, then the optimal amount is about 14 MGD. Similarly, if the user savings are $6.00 per 1,000 gallons, then the optimal amount of reuse is about 34 MGD. The use of intermediate data points allows these total and marginal cost curves to be generated more accurately.

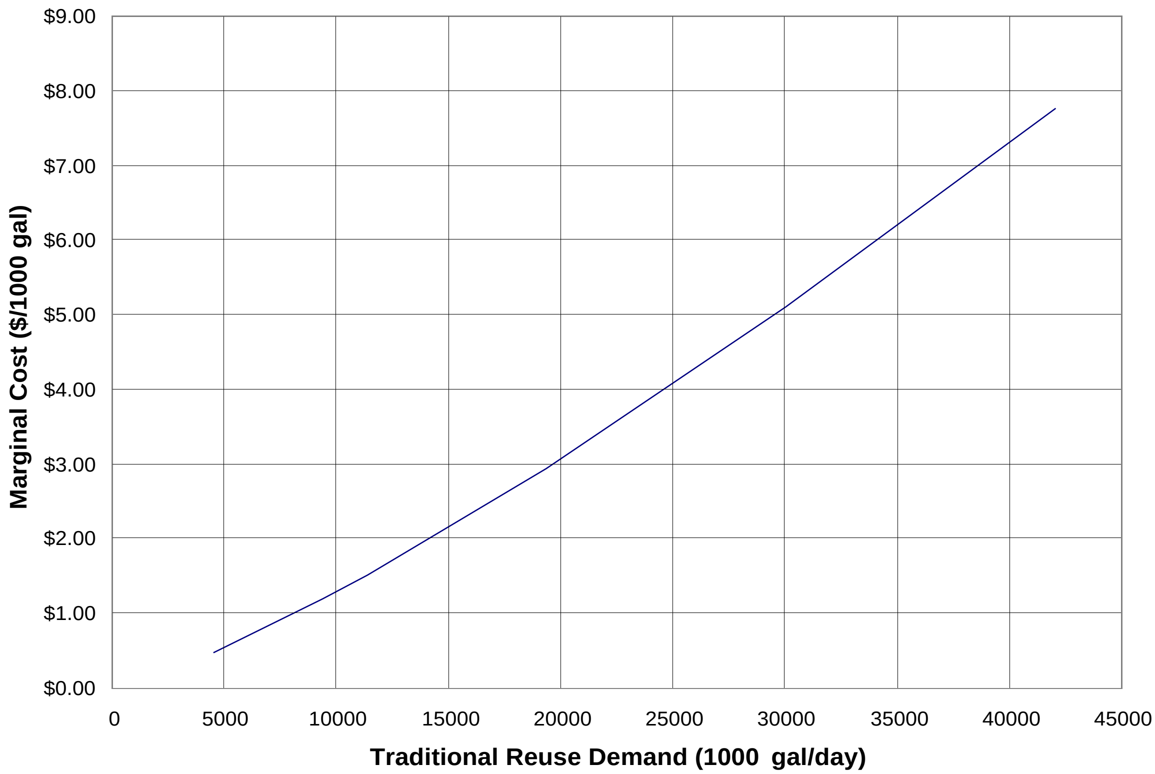

Figure 6-4. Marginal Cost of Providing Water Reuse.

Another, and equivalent, way to evaluate the benefits and costs is to look at total values. The total daily benefits and costs are presented in Table 6-30. If total values are used, then the objective function is to maximize total benefits minus total costs. If the value of water reuse is $4.58/1,000 gallons, then the total benefits of reuse exceed the total costs over the entire range of flows. However, the best solution is where net benefits are maximized. For the indicated data, this occurs at 30 MGD. Using the fitted equation, as was done for the marginal cost analysis, the actual optimal amount turns out to be 26.2 MGD.

However, public utilities typically seek to break even rather than maximizing net revenues, that is, the daily benefits equaling the daily costs. As evident in Table 6-30, additional traditional reuse flow can be added until this situation occurs. Daily costs and daily benefits are plotted as a function of flow in Figure 6-5. If the two regression lines are set equal to one another, the total flow to satisfy a break-even condition is 52.6 MGD. This value should be used with caution, however. If additional residential users are added to achieve this flow, the costs will exceed the benefits before 52.6 MGD as the transmission costs increase greatly for residential use.

Table 6-30. Cost Savings

Description	Flow Demanded (MGD)	Potable Water Cost (2002$/1000gal)	Daily Benefits (2002$/day)	Daily Benefits (2005$/day)	Daily Benefits - Daily Costs ($/day)
Status Quo	4.46	$4.04	$18,018	$20,408	$19,421
Low	9.34	$4.04	$37,734	$42,737	$39,836
Medium Reuse: Large Users North	11.34	$4.04	$45,814	$51,889	$39,755
Medium Reuse:Large Users	19.31	$4.04	$78,012	$88,358	$56,895
Medium Reuse:Addl Large Users	30.00	$4.04	$121,200	$137,272	$84,931
Large Reuse	41.98	$4.04	$169,599	$192,090	$37,362

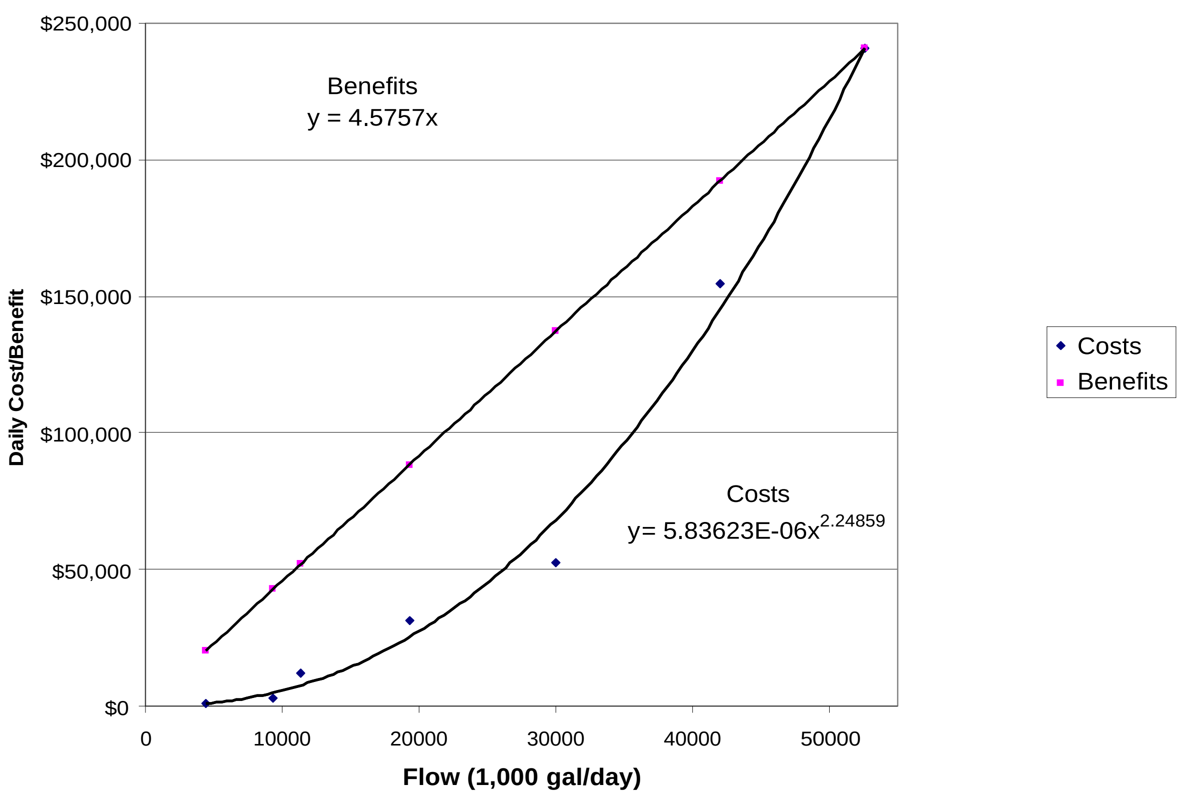

Figure 6-5. Daily Costs and Daily Benefits as a Function of Flow

It was mentioned before that the flows in the Hazen and Sawyer (2004) report were based on an irrigation rate of 1.5 inches per week using the irrigable acres for each of the large users. However, the flow values extracted for use in the other five regions used daily allocation values given in the Consumptive Use Permit data, as discussed earlier. It was discussed how this difference in flow values does not affect marginal cost; however Consumptive Use

Permit data also indicate more large users in the Broward/North Regional environs. In spite of this fact, by comparing the maps in Figure 5-5 and Figure 6-2 (both above), the golf courses and landscaped areas considered to be large users by the new designation are located close to the large users already identified by Hazen and Sawyer. Therefore they can be easily served by the traditional reuse distribution network setup for this case study and will not affect marginal cost values greatly with greater transmission lengths.

By looking at the analysis thus far, it can be seen that transmission costs, and therefore, distance away from the wastewater treatment plant plays a vital role in determining if a user should be considered for reuse. The users and demanded flow determined by Hazen and Sawyer (2004) are spread throughout the Broward/North Regional. However, at $2.95 per thousand gallons to provide traditional water reuse, it is considered quite attractive in spite of the distance from the wastewater treatment plant. It can also be seen from Figure 6-2 that while some users may be at larger distances from the wastewater treatment plant, they tend to be grouped together.

An analysis was conducted on one such group to the north of the Broward/North WWTP in Broward County to determine the effect of distance on marginal costs. Flow data from Consumptive Use Permits, with the exception of on-site use for the treatment plant, WES, and Quiet Waters Park, were employed for the twelve users in this group, as described in Table 6-31.

Table 6-31. Large Users to the North of the Broward/North WWTP

Large User	Flow, MGD
NRWWTP (ON-SITE)	5.390
CENTRAL SANITARY LANDFILL AND RECYCLING CENTER	0.078
WES	2.300
CRYSTAL LAKE COUNTRY CLUB/TAM O'SHANTER GOLF CLUB	0.682
HIGHLAND VILLAGE MOBILE PARK	0.064
DEERFIELD BEACH HIGH SCHOOL	0.050
MEADOWS OF CRYSTAL LAKE	0.055
CENTURY VILLAGE EAST	1.504
DEER CREEK COUNTRY CLUB COMMUNITY	0.316
DEER CREEK GOLF COURSE	0.439
DEERFIELD COUNTRY CLUB	0.224
THE WATERWAYS	0.412
QUIET WATERS PARK	0.330
ADIOS GOLF CLUB	0.242

Estimating the costs of these users was carried out in the same way as the overall cost estimation. The cost was estimated to provide traditional water reuse to one user, and then expanded by adding additional users until all twelve were served to see the effect of adding to the distribution network. The length of the transmission lines was estimated using Figure 6-2 and sized by dividing the demand by an assumed velocity of five feet per second. The costs of the transmission lines were estimated assuming paved construction only. The expansion of the traditional reuse distribution network along with present value costs and annual costs can be seen in Table 6-32. The flows shown in this table are the cumulative total flows and the large users are arranged in increasing distances from the Broward/North Wastewater Treatment Plant.

Table 6-32. Present and Annual Costs for Large Users North of Wastewater Treatment Plant

From Node (i)	To Node (j)	Distance (mi)	Flow Demanded (MGD)	Total Cost (2005$)	Annual Worth, i=7.0%, N=20
NRWWTP	NRWWTP (ON-SITE)	0.000	5.390	$4,610,817	$435,229
NRWWTP	CENTRAL SANITARY LANDFILL AND RECYCLING	1.412	5.468	$14,330,881	$1,352,734
NRWWTP	WES	2.501	7.768	$20,634,402	$1,947,742
NRWWTP	CRYSTAL LAKE COUNTRY CLUB/TAM O'SHANTER	3.560	8.450	$23,344,288	$2,203,536
NRWWTP	MEADOWS OF CRYSTAL LAKE	4.586	8.506	$23,975,514	$2,263,119
NRWWTP	HIGHLAND VILLAGE MOBILE PARK	5.717	8.570	$24,677,764	$2,329,406
NRWWTP	DEERFIELD BEACH HIGH SCHOOL	6.343	8.620	$25,092,357	$2,368,541
NRWWTP	CENTURY VILLAGE EAST	7.907	10.124	$34,708,050	$3,276,194
NRWWTP	DEER CREEK COUNTRY CLUB COMMUNITY	8.874	10.441	$36,798,925	$3,473,558
NRWWTP	DEER CREEK GOLF COURSE	9.036	10.880	$39,732,984	$3,750,513
NRWWTP	DEERFIELD COUNTRY CLUB	10.027	11.104	$41,608,800	$3,927,576
NRWWTP	THE WATERWAYS	12.023	11.517	$44,451,327	$4,195,891
NRWWTP	QUIET WATERS PARK	12.473	11.847	$46,153,783	$4,356,591
NRWWTP	ADIOS GOLF CLUB	13.934	12.088	$47,730,422	$4,505,414

A total cost function can again be plotted using daily cost versus flow in thousands of gallons per day as shown in Figure 6-6.

The power function fit to this equation is shown in Equation 6-10.

$$C = 0.0000108498Q^{2.22477} \qquad (6\text{-}10)$$

The marginal costs for each expanded segment of the distribution network can be calculated by taking the derivative of this total cost function. The resulting marginal cost equation is Equation 6-11.

$$MC = 0.000024138Q^{1.22477} \qquad (6\text{-}11)$$

The marginal costs at the various distances are shown in Table 6-33. They range from $0.90/1,000 gallons to $2.41/1,000 gallons at a distance of 13.9 miles. Distances are measured using the metropolitan metric to more accurately represent that pipelines would follow north-south, east-west pathways. Marginal costs increase with metropolitan distance from the wastewater treatment plant. However, due to the density of large users in this area, there are certain places where marginal cost remains relatively constant as distance increases. The large user is considered more attractive to serve if other large users that can share the cost of expanding the plant's traditional water reuse capacity surround it.

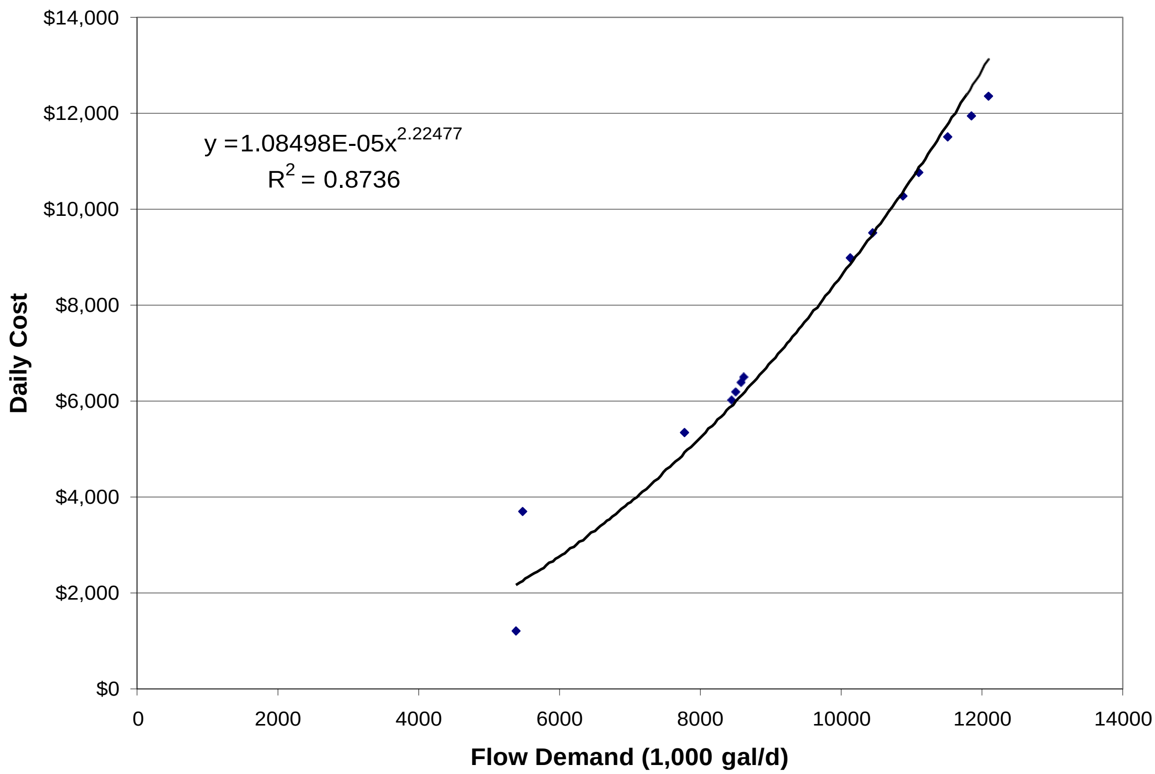

Figure 6-6. Total Cost Function for Users to North of Wastewater Treatment Plant

Table 6-33. Marginal Costs for Large Users North of Wastewater Treatment Plant

From Node (i)	To Node (j)	Distance (mi)	Flow Demanded (MGD)	Marginal $/k gal
NRWWTP	NRWWTP (ON-SITE)	0.000	5.390	$0.90
NRWWTP	CENTRAL SANITARY LANDFILL AND RECYCLING	1.412	5.468	$0.91
NRWWTP	WES	2.501	7.768	$1.40
NRWWTP	CRYSTAL LAKE COUNTRY CLUB/TAM O'SHANTER	3.560	8.450	$1.56
NRWWTP	MEADOWS OF CRYSTAL LAKE	4.586	8.506	$1.57
NRWWTP	HIGHLAND VILLAGE MOBILE PARK	5.717	8.570	$1.58
NRWWTP	DEERFIELD BEACH HIGH SCHOOL	6.343	8.620	$1.60
NRWWTP	CENTURY VILLAGE EAST	7.907	10.124	$1.94
NRWWTP	DEER CREEK COUNTRY CLUB COMMUNITY	8.874	10.441	$2.02
NRWWTP	DEER CREEK GOLF COURSE	9.036	10.880	$2.12
NRWWTP	DEERFIELD COUNTRY CLUB	10.027	11.104	$2.18
NRWWTP	THE WATERWAYS	12.023	11.517	$2.27
NRWWTP	QUIET WATERS PARK	12.473	11.847	$2.35
NRWWTP	ADIOS GOLF CLUB	13.934	12.088	$2.41

6.5 Developing Consumptive Use Permit Flows

The total cost function shown in Figure 6-6 (above) shows that the demand flows for traditional water reuse from Hazen and Sawyer (2004) compare well to the daily allocation values found in the Consumptive Use Permit data. Therefore, it is possible to extrapolate the Consumptive Use Permit data to all six wastewater treatment plants with ocean outfalls. This will permit an evaluation to how much wastewater can be allocated to traditional reuse, thereby reducing the flow discharged to the ocean. The methods discussed in Chapter 5 using Consumptive Use Permit flow data are also used in this evaluation.

Golf courses and landscaped areas within the urban areas of Palm Beach, Broward, and Miami-Dade Counties are summarized in Table 6-34. The first row shows the urbanized area of these counties, as approximated using GIS software. Broward County has the largest area of 386 square miles. The total urbanized area for the three counties is 962 square miles. The number of golf courses with Consumptive Use Permits varies widely, ranging from 98 for Palm Beach County to 26 for Miami-Dade County, and totals 164 among the three counties. Water use per golf course is fairly consistent across the three service areas, averaging 0.47 MGD. The total water demand for golf courses is 77.5 MGD, with Palm Beach County accounting for 47.9 MGD of this total. The 396 landscape large users have a total demand of 70.2 MGD, with an average demand of about 0.18 MGD per user. Palm Beach and Broward Counties account for 35.4 and 30.4 MGD, respectively, of this amount. The total demand for all large users is 148 MGD. Palm Beach County accounts for 83.3 MGD of this total. Broward County has a total large user demand of 49.3 MGD and Miami-Dade has a total large user demand of 15 MGD. These totals indicate that the more promising areas for traditional reuse are Palm Beach and Broward Counties.

Table 6-34. Summary of Urban Users

Attribute	**Palm Beach**	**Broward**	**Miami-Dade**	**Total**
Approximate Urban Area, sq. mi.	268	386	308	962
Golf Users	98	40	26	164
Golf Demand, MGD	47.949	18.920	10.615	77.484
Golf MGD per course	0.489	0.473	0.408	0.472
Landscape Users	228	140	28	396
Landscape Demand, MGD	35.377	30.423	4.373	70.173
Landscape MGD per user	0.155	0.217	0.156	0.177
Total Users	326	180	54	560
Total Demand, MGD	83.326	49.343	14.988	147.657
Average Irrigation Rate, in/yr	6.537	2.685	1.022	3.225

Traditional reuse flow for each of the six wastewater treatment plants with ocean outfalls is summarized in Table 6-35. The service areas of each wastewater treatment plant as described by their individual consultant reports are reported in the first line. The second portion of each section shows the number of large users as described earlier within each of the six service areas. The service areas for the Broward/North WWTP in Broward County and the Boynton-Delray WWTP in Delray Beach include the greatest amount of large users.

Table 6-35. Summary of Traditional Reuse Demands

Broward/North			Boynton-Delray			Miami-Dade/North		
Approx Area	28	mi^2	Approx Area	46	mi^2	Approx Area	128.95	mi^2
Service Area			**Service Area**			**Service Area**		
Large Users	47		Large Users	40		Large Users	16	
Flow Demand	17.0	MGD	Flow Demand	9.1	MGD	Flow Demand	4.5	MGD
Expanded Service Area			**Expanded Service Area**			**Expanded Service Area**		
Large Users	53		Large Users	90		Large Users	16	
Flow Demand	18.8	MGD	Flow Demand	22.1	MGD	Flow Demand	4.5	MGD
Feasible Users			**Feasible Users**			**Feasible Users**		
Large Users	53		Large Users	90		Large Users	10	
Flow Demand	18.8	MGD	Flow Demand	22.1	MGD	Flow Demand	3.6	MGD
Hollywood			Boca Raton			Miami-Dade/Central		
Approx Area	46.66	mi^2	Approx Area	14.3	mi^2	Approx Area	253.35	mi^2
Service Area			**Service Area**			**Service Area**		
Large Users	26		Large Users	6		Large Users	17	
Flow Demand	4.8	MGD	Flow Demand	1.8	MGD	Flow Demand	5.5	MGD
Expanded Service Area			**Expanded Service Area**			**Expanded Service Area**		
Large Users	34		Large Users	47		Large Users	17	
Flow Demand	7.6	MGD	Flow Demand	17.7	MGD	Flow Demand	5.5	MGD
Feasible Users			**Feasible Users**			**Feasible Users**		
Large Users	17		Large Users	47		Large Users	9	
Flow Demand	3.2	MGD	Flow Demand	17.7	MGD	Flow Demand	2.9	MGD

The next grouping gives the number of large users and reclaimed water demand for the expanded service areas. The two service areas within Palm Beach County have the greatest potential to provide traditional water reuse by expansion. The Boynton-Delray WWTP could add a possible 50 users by expanding its service area, followed by the Boca Raton WWTP with a potential of 41 additional users. The two plants in Broward County are surrounded by other wastewater treatment plants and therefore have lesser potential. The Miami-Dade/North and Miami-Dade/Central WWTPs have no potential as their combined service area encompasses all Consumptive Use Permit holders.

Finally, the last set of values show the demand for users that were considered feasible for traditional water reuse service. This set of values takes into account large users within the defined service areas of the plants as well as the expanded service areas. In order to determine whether these users would be feasible to serve, the case study for the Broward/North WWTP was used. The case study determined that the flows demanded by large users could be met throughout the 28 square mile service area. Transmission costs are a key factor in determining whether it is feasible to serve a large user, as determined by an analysis completed on a group of large users to the north of the treatment plant. The largest distance from a large user to the Broward/North WWTP was twelve miles.

Additionally, cumulative daily demand was plotted against distance from the wastewater treatment plant for all six reuse districts, as originally shown in Chapter 5 (Fig. 5-7). As mentioned before, the Boynton-Delray, Boca Raton, and Broward/North WWTPs exhibit high flow per mile values. In addition, all of the large users could be reached with a transmission line that was less than twelve miles in length. Therefore, all of the large users identified in these service areas were determined to be feasible for traditional water reuse. Several large users in the remaining three reuse districts went beyond twelve miles, as seen in Figure 6-7. Therefore, the highest flow per mile value was found near this twelve-mile mark, and the users outside this mark were considered infeasible and therefore were excluded.

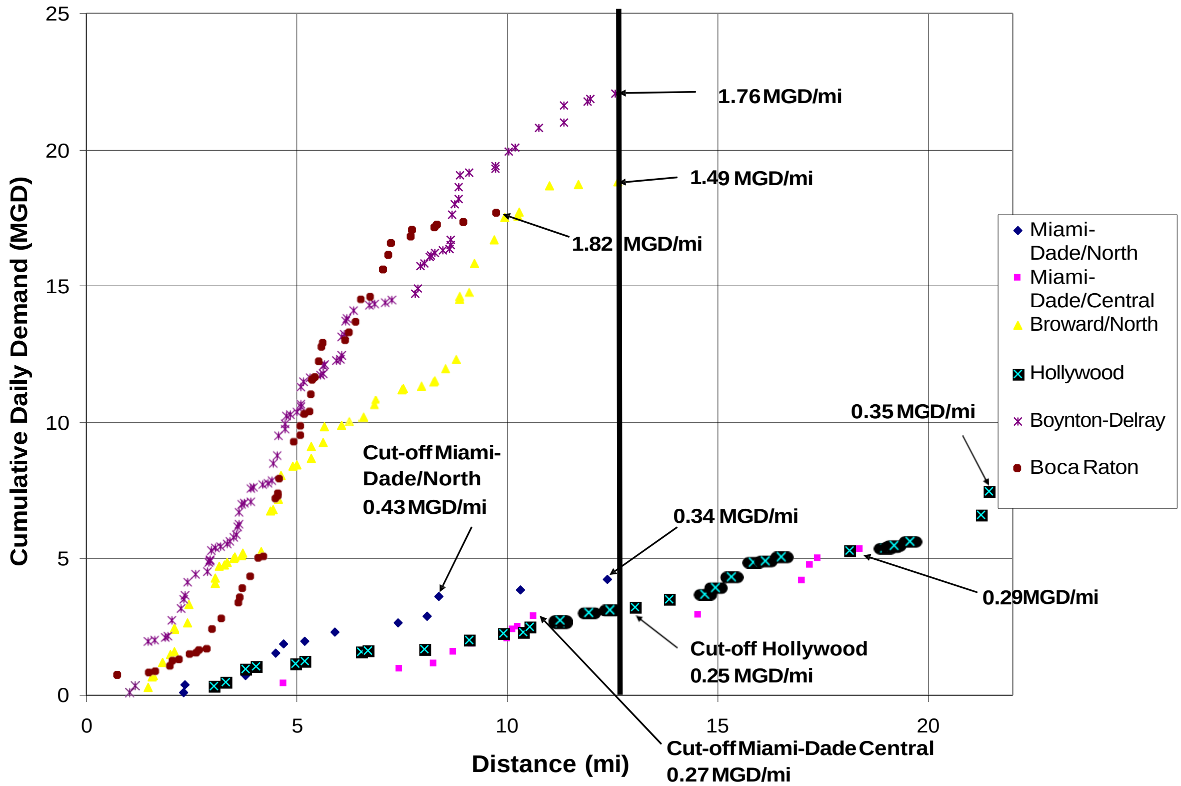

Figure 6-7. Cumulative Daily Demand versus Metropolitan Distance from Wastewater Treatment Plant

The twelve-mile cut-off is based on the marginal cost curve of Figure 6-4 for the Broward/North WWTP. The case study found that the benefits of using traditional water reuse were $4.58 per thousand gallons. If the benefits of using traditional water reuse are higher, as is the case in other counties, the optimal amount of flow would be greater, and the twelve-mile cut-off would be extended.

As evident in Table 6-35, there are large users with potential demand for traditional water reuse that are not feasible to serve from the central plant. The use of satellite treatment facilities could make it feasible to serve these users and the greatest potential lies in the Hollywood, Miami-Dade/North, and Miami-Dade/Central reuse districts. As discussed in Chapter 5, previous experience shows that satellite plants are capable of producing 0.01-35 MGD of reclaimed water with reasonable distribution costs. There is a potential traditional water reuse demand of 4.4 MGD (17 large users), 0.9 MGD (6 large users), and 2.6 MGD (8 large users) in the Hollywood, Miami-Dade/North, and Miami-Dade/Central reuse districts, respectively. Additionally, these large users tend to be grouped together spatially as the longest distance between two large users is less than 10 miles (using the metropolitan distance). Adding to the potential for satellite plants is the possible inclusion of industrial users. As mentioned in Chapter 5, there is industrial user demand in all six reuse districts, although it is mainly concentrated in the Miami-Dade/Central district. Consumptive Use Permit data indicate a total industrial water demand of approximately 27.5 MGD within the Miami-Dade Central reuse district, of which 15.4 MGD is located outside the twelve mile feasibility limit. If a further analysis is conducted in order to evaluate the needs of these large industrial users, the traditional water reuse demand could increase dramatically through the utilization of satellite plants in the Miami-Dade/Central reuse district.

6.6 Summary

This chapter was able to produce cost estimating strategies for groundwater recharge and traditional water reuse, which are two major alternatives to disposing effluent through ocean outfalls. As the data shows, the costs are dependent on the size of the system needed based on flow values and transmission requirements.

The case study in Section 6.4 shows that the large users selected in Chapter 5 can be served in a cost effective manner as the benefits of using a reuse water system minus the costs is at a maximum under that scenario. The introduction of residential users still allows for a breakeven situation, but was proven to not be as effective as the large user only scenario. A further step would be to use a select number of residential users identified by the Hazen and Sawyer (2004) report to find a proportion that does maximize benefits minus costs. An overall optimization problem on all six reuse districts can also be prepared to determine how the reuse network should be setup to maximize cost effectiveness.

The use of satellite plants has a potential to add traditional water reuse demand for the Hollywood, Miami-Dade/North, and Miami-Dade/Central reuse districts. All large users that were deemed infeasible due to their large distance from the central plants are within ten miles (metropolitan distance) of each other in the three districts. A properly placed satellite plant would provide additional water reuse while keeping the costs of distribution at a minimum.

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7. Wastewater Management Options for Alternative Ocean Outfall Strategies

7.1 Alternative Ocean Outfall Strategies

Four alternative ocean outfall strategies were examined under the defined scope of this study. Under the Currently Planned Use alternative (Alt I), ocean outfalls would be used at currently planned levels. Under the Limited Use Alternative (Alt II), ocean outfall disposal would be limited to flows remaining after traditional reuse options were maximized and underground injection flows reached full 2005 permitted capacity. Under the Ocean Outfalls as Backups alternative (Alt III), ocean disposal would only be used during wet weather periods to handle flow that would otherwise go to traditional reuse. Complete elimination of ocean outfalls was considered under the No Use alternative (Alt IV). Florida's 1.2 BGD reuse capacity clearly indicates that reuse is feasible within Florida and that state statutes (403.064 and 373.250, F.S.) encourage and promote water reuse. Therefore, it is assumed that unaccounted for flows will be directed to reuse in alternatives that involve some level of curtailment of ocean outfalls.

The assumption was made that permitted capacities of the ocean outfalls would be maintained at 2005 levels and that no additional ocean outfalls would be permitted. It was also assumed that Class I injection control wells for effluent disposal would be held at 2005 permitted capacities and, furthermore, that Class I injection wells for effluent disposal that were in testing or under construction during 2005 would not receive permits.

7.2 Priorities for Allocating Effluent and Reclaimed Water Flows

Four options for wastewater management in Southeast Florida were considered in this study: disposal of treated effluent through ocean outfalls, disposal of treated effluent through Class I injection wells, traditional reuse of reclaimed water, and groundwater recharge of reclaimed water. Groundwater can be recharged through surface spreading, vadose zone injection wells or direct injection of reclaimed water (CDM 2004). Canals in Southeast Florida can be used to recharge groundwater with reclaimed water. The present study examines only the direct injection method for groundwater recharge. A canal recharge option is being evaluated in another study that is still in progress. The surface water quality constraints on canal recharge may require similar treatment levels to those required for direct injection of reclaimed water.

In consideration of the above criteria, effluent and reclaimed water flows in the four ocean outfall alternatives were allocated as indicated below:

Alternative I—Ocean outfalls used at current levels

- Priority 1: Use utility's projections and plans (supplemented by UF projections) for flows to the existing ocean outfalls—capping flows at 2005 permitted capacities.
- Priority 2: Use utility's projections and plans (supplemented by UF projections) for flows to the existing underground injection wells—capping flows at 2005 permitted capacities.

- Priority 3: Use utility's projections and plans (supplemented by UF projections) for flows to traditional[1] reuse activities.
- Priority 4: Direct flows not allocated in Priorities 1–3 above to groundwater recharge[2].

Alternative II—Ocean outfalls used for flows not expected to be handled by reuse or other disposal options

- Priority 1: Use utility's projections and plans (supplemented by UF projections) for flows to traditional reuse activities.
- Priority 2: Use utility's projections and plans (supplemented by UF projections) for flows to the existing underground injection wells—capping flows at 2005 permitted capacities.
- Priority 3: Use utility's projections and plans (supplemented by UF projections) for flows to existing ocean outfalls—capping flows at 2005 permitted capacities.
- Priority 4: Direct flows not allocated in Priorities 1–3 above to groundwater recharge.

Alternative III—Ocean outfalls used as backups to traditional reuse activities

- Priority 1: Use utility's projections and plans (supplemented by UF projections) for flows to traditional reuse activities.
- Priority 2: Use utility's projections and plans (supplemented by UF projections) for flows to the existing underground injection wells—capping flows at 2005 permitted capacities.
- Priority 3: Use ocean outfalls only as backups to traditional reuse activities (no dry weather flows to the ocean)—capping flows at 2005 permitted capacities.
- Priority 4: Direct flows not allocated in Priorities 1–3 above to groundwater recharge.

Alternative IV—Ocean outfalls not used

- Priority 1: Ocean outfalls are not used.
- Priority 2: Use utility's projections and plans (supplemented by UF projections) for flows to traditional reuse activities.
- Priority 3: Use utility's projections and plans (supplemented by UF projections) for flows to the existing underground injection wells—capping flows at 2005 permitted capacities.
- Priority 4: Direct flows not allocated in Priorities 1–3 above to groundwater recharge.

Each of the four alternatives was evaluated over a 20-year planning period, beginning in 2005, for each of the WWTPs having ocean outfalls.

7.3 Effluent and Reclaimed Water Flow Distributions

Wastewater flow projections for the years 2005–2025 from Chapter 2 were used together with the priorities described above to determine the distributions of effluent and reclaimed water flow under the four alternatives. This exercise was carried out for each of the six WWTPs for the years 2005–2025 in five year increments as shown in Tables 7-3 through 7-8. The progression of flows to the respective reuse and disposal options is not necessarily the

[1] Part III activities—golf courses, parks, residential and Part VII industrial uses

[2] Permitted under Part V, injection to groundwater having TDS < 1000 mg/L

same as the flows that would be used in a constructed alternative. This is because the implementation schedule of various treatment capabilities in a constructed alternative would be optimized over the appropriate project period (e.g., the years 2005–2025), whereas the flows in the tables were determined by the priorities defined in Chapter 7, Section 7.2, along with the feasible extent of public access reuse based on methodology explained in Chapters 5 and 6. A number of the alternatives involve construction of groundwater recharge treatment units in 2005 which are later replaced by traditional reuse treatment units. The useful life of these groundwater recharge facilities would be 20 years; thus implementation of traditional reuse would be a reasonable alternative for retrofitting them.

The reclaimed water flows to traditional reuse for each of the six WWTPs under Alternative I are summarized in Table 7-1. The flows to traditional reuse for each of the six WWTPs under Alternatives II, III and IV are summarized in Table 7-2.

7.3.1 Effluent and Reclaimed Water Distribution for the Boynton-Delray WWTP

The distribution of effluent and reclaimed water from the Boynton-Delray WWTP under the four ocean outfall alternatives is summarized in Table 7-3. The rationale for the flow allocations is discussed below.

a) Flows to traditional reuse under Alternative I. The utility currently delivers 3.7 MGD flow for traditional reuse, which includes 2.2 MGD for golf course irrigation (5 golf courses), 0.8 MGD for residential irrigation (FL DEP 2004) and 0.7 MGD for on-site irrigation at the WWTP. The on-site irrigation was estimated by subtracting the on-site process use from the total on-site use of 1.3 MGD (FL DEP 2004). The on-site process use was calculated using the information given for Broward/North WWTP. This plant will need about 0.5 MGD for process use when the plant is expanded from 80 to 100 MGD (Hazen and Sawyer 2004). Therefore it was assumed that 2.5% of the plant capacity will be used for process use. The utility plans to provide reclaimed water to new users, including 0.8 MGD for irrigation of four golf courses and 0.4 MGD for residential irrigation, by the year 2010 (FL DEP 2005). Traditional reuse is expected to increase to 6.2 MGD in 2015 through additional flows of 1.4 MGD for golf course and residential irrigation in Areas 1 through 8 (Matthews Consulting 2003). The water reclamation capacity is expected to increase to 7.5 MGD by 2025, after a reclaimed water flow of 1.3 MGD is provided to Areas 9 through 16 via the ocean outfall pipeline, as suggested by Matthews Consulting (2003).

b) Flows to traditional reuse under Alternatives II, III and IV. The Consumptive Use Permits were used, as explained in Chapters 5 and 6, to project traditional reuse demand. Reuse flows of 6.5 MGD by year 2010, 12.9 MGD by year 2015, and 19.7 MGD by year 2020 are expected as the large users within 3, 6, and 9 mile metropolitan distances of the WWTP are connected. A reclaimed water flow of 22.7 MGD is expected by 2025 through inclusion of all large users within a metropolitan distance of 12.6 miles of the WWTP.

Table 7-1. Traditional Reuse and On-site Process Flows under Alternative I

Year	Boynton-Delray[1]	Boca Raton[2]	Broward/North[3]	Hollywood[4]	Miami-Dade/North[5]	Miami-Dade/ Central[6]
2005	- 0.6 MGD for on-site process use, - 3.7 MGD for golf course, on-site and residential irrigation	- 0.4 MGD for on-site process use, - 5.2 MGD for golf course, on-site, residential and other public access areas irrigation	- 2.1 MGD for on-site process use, - 2.4 MGD at another facility, on-site and other public access areas irrigation	- 2.6 MGD for golf course irrigation	- 2.2 MGD for on-site process use - 0.1 MGD for other public access areas irrigation	- 8.9 MGD for on-site process use
2010	Add 1.2 MGD for golf course and residential irrigation	Add 3.7 MGD for golf course, residential and other public access areas irrigation	- Add 2 MGD for on-site process use, - Add 1.8 MGD for another facility and other public access areas irrigation	Add 1.1 MGD for golf course and other public access areas irrigation	-	-
2015	Add 1.4 MGD for golf course and residential irrigation in Areas 1-8	Add 2.4 MGD for residential and other public access areas irrigation	Add 1 MGD for golf course irrigation	-	-	-
2020	Increase reuse capacity to 24 MGD	Add 2.4 MGD for residential and other public access areas irrigation	-	-	-	-
2025	Add 1.3 MGD for public access reuse in Areas 9-16	Add 2.4 MGD for residential and other public access areas irrigation	-	-	-	-

Sources: [1] (PBS&J 2003; FL DEP 2004); (FL DEP 2005), [2] (PBS&J 2003; FL DEP 2004), [3] (Hazen and Sawyer 2004), [4] (FL DEP 2004), [5, 6] (PBS&J 2003; FL DEP 2004)

Table 7-2. Traditional Reuse and On-site Process Flows under Alternatives II, III and IV

Year	Boynton-Delray[1]	Boca Raton[2]	Broward/North[3]	Hollywood[4]	Miami-Dade/North[5]	Miami-Dade/Central[6]
2005	- 0.6 MGD for on-site process use, - 3.7 MGD for golf course, on-site and residential irrigation	- 0.4 MGD for on-site process use, - 5.2 MGD for golf course, on-site, residential and other public access areas irrigation	- 2.1 MGD for on-site process use, - 2.4 MGD at another facility, on-site and other public access areas irrigation	- 2.6 MGD for golf course irrigation	- 2.2 MGD for on-site process use - 0.1 MGD for other public access areas irrigation	- 8.9 MGD for on-site process use
2010	Add 2.8 MGD by large users within 3 mile*	Add 0.9 MGD by large users within 2 mile*	- Add 2 MGD for on-site process use, - Add 1.8 MGD for another facility and other public access areas irrigation	Add 1.1 MGD for golf course and other public access areas irrigation	Add 0.4 MGD by large users within 3 mile*	Add 0.4 MGD by large users within 5 mile*
2015	Add 6.4 MGD by large users within 6 mile*	Add 3.5 MGD by large users within 4 mile*	Add 5.2 MGD by large users within 4 mile*	Add 0.6 MGD by large users within 5 mile*	Add 1.5 MGD by large users within 5 mile*	Add 0.6 MGD by large users within 8 mile*
2020	Add 6.8 MGD by large users within 9 mile*	Add 8.5 MGD by large users within 6 mile*	Add 6.1 MGD by large users within 8 mile*	Add 1 MGD by large users within 10 mile*	Add 0.4 MGD by large users within 7 mile*	Add 1.1 MGD by large users within 10 mile*
2025	Add 3 MGD by large users within 12.6 mile*	Add 3.2 MGD by large users within 7.2 mile* (Alternatives II and IV)**	Add 7.5 MGD by large users within 12.6 mile*	Add 0.9 MGD by large users within 12.5 mile*	Add 1.3 MGD by large users within 8.4 mile*	Add 0.8 MGD by large users within 10.6 mile*

Sources: [1, 2, 3, 4, 5, 6] (PBS&J 2003; FL DEP 2004), [3] (Hazen and Sawyer 2004), [4] (FL DEP 2004)
* Metropolitan distance of the WWTP
** Add 1.6 MGD by large users within 6.5 mile (Alternative III)

Table 7-3. Flow distribution for Boynton-Delray WWTP

Alt.	Year	**WWTP effluent** (MGD)	**Ocean outfall** (MGD)	**Traditional reuse** (MGD)	**Groundwater recharge** (MGD)	**RO concentrate** (MGD)
I	2005	19.4	15.7	3.7	0.0	0.0
	2010	21.3	16.4	4.8	0.0	0.0
	2015	23.2	17.0	6.2	0.0	0.0
	2020	25.2	19.0	6.2	0.0	0.0
	2025	27.1	19.6	7.5	0.0	0.0
II	2005	19.4	15.7	3.7	0.0	0.0
	2010	21.3	14.7	6.5	0.0	0.0
	2015	23.2	10.3	12.9	0.0	0.0
	2020	25.2	5.4	19.7	0.0	0.0
	2025	27.1	4.4	22.7	0.0	0.0
III	2005	19.4	0.4	3.7	12.2	3.1
	2010	21.3	0.7	6.5	11.2	2.8
	2015	23.2	1.4	12.9	7.1	1.8
	2020	25.2	2.1	19.7	2.7	0.7
	2025	27.1	2.4	22.7	1.5	0.4
IV	2005	19.4	0.0	3.7	12.5	3.1
	2010	21.3	0.0	6.5	11.8	2.9
	2015	23.2	0.0	12.9	8.2	2.1
	2020	25.2	0.0	19.7	4.4	1.1
	2025	27.1	0.0	22.7	3.5	0.9

c) Flows to ocean outfall and groundwater recharge. Under Alternatives I and II, the flows remaining after allocation to traditional reuse are sent to ocean outfalls. Since the flows to ocean outfalls would remain below the 2005 permitted capacity of 24 MGD, there would be no flow to groundwater recharge.

Under Alternative III, the ocean outfalls were used only as backups to traditional reuse during wet weather periods. The wet weather period was chosen as the days receiving greater than 0.4 inches of rain. For Boynton-Delray WWTP the wet weather period was 35.5 days. The ocean outfall flow was calculated multiplying the traditional reuse flow with the ratio of the wet and dry days. Flow remaining after allocation to traditional reuse and ocean outfall is directed to groundwater recharge. The groundwater recharge flow is projected to decrease from 12.2 MGD in 2005 to 1.5 MGD in 2025, as flow to traditional reuse increases.

Under Alternative IV, no flow is allowed to the ocean outfall. Flow remaining after allocation to traditional reuse is therefore directed to groundwater recharge. The groundwater recharge flow is projected to decrease from 12.5 MGD in 2005 to 3.5 MGD in 2025. The flow of reverse osmosis concentrate was assumed to be 25% of the reverse osmosis permeate flow that is injected to the potable aquifer for recharge (i.e., 20% of reverse osmosis influent flow). Thus, reverse osmosis concentrate flow varies in proportion to the groundwater recharge flow.

7.3.2 Effluent and Reclaimed Water Distribution for the Boca Raton WWTP

The distribution of effluent and reclaimed water from the Boca Raton WWTP under the four ocean outfall alternatives is summarized in Table 7-4. Rationale for the flow allocations is discussed below.

a) Flows to traditional reuse under Alternative I. The utility currently delivers 5.2 MGD of reclaimed water, including 0.8 MGD for golf course irrigation (2 golf courses with 224 acres), 1.5 MGD for residential irrigation, 2.2 MGD for other public access areas including 0.9 MGD for Florida Atlantic University (FL DEP 2004) and 0.7 MGD for on-site irrigation at the WWTP. The on-site irrigation was estimated by subtracting the on-site process use of 0.4 MGD from the total on-site use of 1.1 MGD. The CDM (1990) reclaimed water system master plan identified reuse demands of 2.1 MGD for golf courses, 9.9 MGD for residences, 2.4 MGD for other public access areas (landscape areas, green spaces, multi-family houses, highway medians, cemeteries, parks, recreational facilities, other public properties) and 0.9 MGD for Florida Atlantic University irrigation. It was assumed that golf course irrigation demand will be met by the year 2010, when 1.3 MGD is delivered to two more golf courses with 135 acres of land, as suggested by CDM (1990). It was also assumed that reclaimed water flows of 2.1 MGD for residential irrigation and 0.3 MGD for irrigation of other public access areas would be added every five years between the years 2010 and 2025 to satisfy the suggested residential and other public access irrigation reclaimed water demand.

b) Flows to traditional reuse under Alternatives II, III and IV. The reuse flow is projected to increase to 6 MGD by year 2010, 9.5 MGD by year 2015, and 18 MGD by year 2020 as large users within metropolitan distances of 2, 4 and 6 miles are connected to the reuse system. Under Alternatives III and IV reuse flows of 19.6 and 21.3 MGD would be reached by year 2025 through inclusion of all large users within 6.5 and 7.2 metropolitan miles of the WWTP.

c) Flows to ocean outfall and groundwater recharge. Under Alternatives I and II, the flows remaining after allocation to traditional reuse are sent to the ocean outfall. Since the flows to the ocean outfall would remain below the 2005 ocean outfall permitted capacity of 17.5 MGD, there would be no flow to groundwater recharge.

Under Alternative III, the wet weather period was 35.5 days for Boca Raton WWTP. The ocean outfall flow was calculated multiplying the traditional reuse flow with the ratio of the wet and dry days. Flow remaining after allocation to traditional reuse and ocean outfall is directed to groundwater recharge. The groundwater recharge flow of 8.3 MGD in 2010 is projected to diminish by 2025, as flow to traditional reuse increases.

Table 7-4. Flow distribution for Boca Raton WWTP

Alt.	Year	**WWTP effluent** (MGD)	**Ocean outfall** (MGD)	**Traditional reuse** (MGD)	**Groundwater recharge** (MGD)	**RO concentrate** (MGD)
I	2005	15.6	10.4	5.2	0.0	0.0
	2010	17.1	8.3	8.8	0.0	0.0
	2015	18.7	7.5	11.2	0.0	0.0
	2020	20.2	6.7	13.6	0.0	0.0
	2025	21.8	5.8	15.9	0.0	0.0
II	2005	15.6	10.4	5.2	0.0	0.0
	2010	17.1	11.1	6.0	0.0	0.0
	2015	18.7	9.1	9.5	0.0	0.0
	2020	20.2	2.2	18.0	0.0	0.0
	2025	21.8	0.5	21.3	0.0	0.0
III	2005	15.6	0.6	5.2	7.9	2.0
	2010	17.1	0.6	6.0	8.3	2.1
	2015	18.7	1.0	9.5	6.5	1.6
	2020	20.2	1.9	18.0	0.2	0.0
	2025	21.8	2.1	19.6	0.0	0.0
IV	2005	15.6	0.0	5.2	8.3	2.1
	2010	17.1	0.0	6.0	8.9	2.2
	2015	18.7	0.0	9.5	7.3	1.8
	2020	20.2	0.0	18.0	1.8	0.4
	2025	21.8	0.0	21.3	0.4	0.1

No flow may be sent to the ocean outfall under Alternative IV. The flow remaining after allocation to traditional reuse is therefore directed to groundwater recharge. The groundwater recharge flow under Alternative IV is projected to decrease from 8.9 MGD in 2010 to 0.4 MGD in 2025. Reverse osmosis concentrate flow varies in proportion to groundwater recharge flow.

7.3.3 Effluent and Reclaimed Water Distribution for the Broward/North WWTP

The distribution of effluent and reclaimed water from the Broward/North WWTP under the four ocean outfall alternatives is summarized in Table 7-5. Rationale for the flow allocations is discussed below.

a) Flows to traditional reuse under Alternative I. The utility currently delivers 2.4 MGD of flow for traditional reuse, which includes 1.3 MGD for on-site irrigation at the WWTP and 1.1 MGD for off-site use at the Broward County Office of Environmental Services septage receiving facility, Wheelabrator Environmental Services, and Pompano Commerce Park. The on-site irrigation was estimated by subtracting the on-site process use of 2.1 MGD from the total on-site use of 3.4 MGD. The utility plans to increase the total on-site and off-site reuse flow to 9.3 MGD by the year 2024 (Hazen and Sawyer 2004). The increase in traditional reuse to 4.2 MGD in 2010 includes the following reuse demands: 0.5 MGD for Pompano Commerce Park and 1.3 MGD for Wheelabrator Environmental Services if the company adds boilers at its resource recovery facility. Also, by the year 2010 a 2 MGD of reclaimed water will be added for on-site process use for WWTP expansion to 100 MGD. The next increase in traditional reuse to 5.3 MGD in 2015 includes 0.6 MGD for the Tam O'Shanter Golf Club and 0.4 MGD for the Crystal Lake Country Club.

Table 7-5. Flow distribution for Broward/North WWTP

Alt.	**Year**	**WWTP effluent** (MGD)	**Ocean outfall** (MGD)	**Underground injection control wells** (MGD)	**Traditional reuse** (MGD)	**Groundwater recharge** (MGD)	**RO concentrate** (MGD)
I	2005	84.2	51.7	30.0	2.4	0.0	0.0
	2010	88.6	54.3	30.0	4.2	0.0	0.0
	2015	90.8	55.5	30.0	5.3	0.0	0.0
	2020	92.2	56.9	30.0	5.3	0.0	0.0
	2025	94.1	58.8	30.0	5.3	0.0	0.0
II	2005	84.2	51.7	30.0	2.4	0.0	0.0
	2010	88.6	54.3	30.0	4.2	0.0	0.0
	2015	90.8	51.3	30.0	9.4	0.0	0.0
	2020	92.2	46.6	30.0	15.6	0.0	0.0
	2025	94.1	41.1	30.0	23.0	0.0	0.0
III	2005	84.2	0.3	30.0	2.4	41.2	10.3
	2010	88.6	0.4	30.0	4.2	43.1	10.8
	2015	90.8	1.0	30.0	9.4	40.3	10.1
	2020	92.2	1.6	30.0	15.6	36.0	9.0
	2025	94.1	2.4	30.0	23.0	30.9	7.7
IV	2005	84.2	0.0	30.0	2.4	41.4	10.3
	2010	88.6	0.0	30.0	4.2	43.5	10.9
	2015	90.8	0.0	30.0	9.4	41.1	10.3
	2020	92.2	0.0	30.0	15.6	37.3	9.3
	2025	94.1	0.0	30.0	23.0	32.8	8.2

b) Flows to traditional reuse under Alternatives II, III and IV. Traditional reuse demand under Alternatives II, III and IV is the same as under Alternative I until the year 2010. The reclaimed water demand is expected to increase to 9.4 MGD by the year 2015, which includes large users within 4 metropolitan miles of the WWTP. Connecting large users within 8 metropolitan miles of the WWTP by the year 2020 would increase the reuse demand to 15.6 MGD. A reuse demand 23 MGD by year 2025 would be realized by inclusion of all large users within 12.6 metropolitan miles of the WWTP.

c) Flows to ocean outfall and groundwater recharge. Flow to the underground injection wells is projected to remain at 30 MGD under all four alternatives. This is the current flow and is also the maximum flow that can be delivered to the wells according to their total 2005 permitted peak hourly flow of 60 MGD with a hourly peaking factor of 2.0.

Under Alternatives I and II, the flow remaining after allocation to traditional reuse and underground injection wells is sent to the ocean outfall. Since the flow to the ocean outfall remains below the 2005 ocean outfall capacity of 66 MGD, no flow is directed to groundwater recharge.

Under Alternative III, the wet weather period was 34.8 days for Broward/North WWTP. The ocean outfall flow was calculated multiplying the traditional reuse flow with the ratio of the wet and dry days. Flow remaining after allocation to traditional reuse, ocean outfall and underground injection wells is directed to groundwater recharge. The groundwater recharge flow is expected to decrease from 43.1 MGD in 2010 to 30.9 MGD by 2025, as flow to traditional reuse increases.

No flow to the ocean outfall is allowed under Alternative IV. In this case, the flow remaining after allocation to traditional reuse and underground injection wells is directed to groundwater recharge. The groundwater recharge flow is projected to decrease from 43.5 MGD in 2010 to 32.8 MGD in 2025 as flow to traditional reuse increases. Reverse osmosis concentrate flows vary in proportion to the groundwater recharge flow.

7.3.4 Effluent and Reclaimed Water Distribution for the Hollywood WWTP

The distribution of effluent and reclaimed water from the Hollywood WWTP under the four ocean outfall alternatives is summarized in Table 7-6. Rationale for the flow allocations is discussed below.

a) Flows to traditional reuse under Alternative I. The utility currently delivers 2.6 MGD of reclaimed water flow to six golf courses. There are plans to add infrastructure to supply reclaimed water for a golf course and other landscape irrigation, bringing capacity to 4 MGD (FL DEP 2004). It was assumed that this reuse demand will be met by the year 2010.

b) Flows to traditional reuse under Alternatives II, III and IV. Reuse demand under Alternatives II, III and IV will remain the same as under Alternative I through 2010. Reclaimed water flow would be increased to 4.2 MGD by year 2015, 5.2 MGD by year 2020, and 6.1 MGD by year 2025 through connection of the large users within 5, 10 and 12.5 metropolitan miles of the WWTP.

c) Flows to ocean outfall and groundwater recharge. Under Alternatives I, II and III, the flow remaining after allocation to traditional reuse is sent to the ocean outfall and groundwater recharge. The ocean outfall 2005 permitted capacity of 46.3 MGD would be reached by year 2020 under Alternative I. Groundwater recharge flow under this alternative is projected at 0.8 MGD in 2020, increasing to 3.6 MGD by 2025. Under Alternative II, the ocean outfall is expected to reach its capacity by the year 2025. The groundwater recharge flow in this year is projected at 1.7 MGD.

Table 7-6. Flow distribution for Hollywood WWTP

Alt.	Year	WWTP effluent (MGD)	Ocean outfall (MGD)	Traditional reuse (MGD)	Groundwater recharge (MGD)	RO concentrate (MGD)
I	2005	40.0	37.4	2.6	0.0	0.0
	2010	43.5	39.9	3.6	0.0	0.0
	2015	47.2	43.5	3.6	0.0	0.0
	2020	50.9	46.3	3.6	0.8	0.2
	2025	54.5	46.3	3.6	3.6	0.9
II	2005	40.0	37.4	2.6	0.0	0.0
	2010	43.5	39.9	3.6	0.0	0.0
	2015	47.2	42.9	4.2	0.0	0.0
	2020	50.9	45.6	5.2	0.0	0.0
	2025	54.5	46.3	6.1	1.7	0.4
III	2005	40.0	0.3	2.6	29.7	7.4
	2010	43.5	0.4	3.6	31.6	7.9
	2015	47.2	0.4	4.2	34.0	8.5
	2020	50.9	0.6	5.2	36.1	9.0
	2025	54.5	0.6	6.1	38.2	9.5
IV	2005	40.0	0.0	2.6	29.9	7.5
	2010	43.5	0.0	3.6	31.9	8.0
	2015	47.2	0.0	4.2	34.3	8.6
	2020	50.9	0.0	5.2	36.5	9.1
	2025	54.5	0.0	6.1	38.7	9.7

Under Alternative III, the wet weather period was 34.8 days for Hollywood WWTP. The ocean outfall flow was calculated multiplying the traditional reuse flow with the ratio of the wet and dry days. The groundwater recharge flow is projected to increase from 29.7 MGD in 2005 to 38.2 MGD in 2025.

No flow to the ocean outfall is allowed under Alternative IV. Accordingly, all flow remaining after allocation to traditional reuse flow would be directed to groundwater recharge. The projected groundwater recharge flow is very similar to the flows under Alternative III. Reverse osmosis concentrate varies in proportion to the groundwater recharge flow.

7.3.5 Effluent and Reclaimed Water Distribution for the Miami-Dade/North WWTP

The distribution of effluent and reclaimed water from the Miami-Dade/North WWTP under the four ocean outfall alternatives is summarized in Table 7-7. Rationale for the flow allocations is discussed below.

a) Flows to traditional reuse under Alternative I. The utility currently uses 2.2 MGD of reclaimed water for on-site process use and 0.1 MGD for irrigation at Florida International University. There are no plans to increase the reclaimed water flow (PBS&J 2003; FL DEP 2004).

Table 7-7. Flow distribution for Miami-Dade/North WWTP

Alt.	**Year**	**WWTP effluent** (MGD)	**Ocean outfall** (MGD)	**Traditional reuse** (MGD)	**Groundwater recharge** (MGD)	**RO concentrate** (MGD)
I	2005	107.9	107.8	0.1	0.0	0.0
	2010	111.9	111.8	0.1	0.0	0.0
	2015	116.6	112.5	0.1	3.2	0.8
	2020	121.3	112.5	0.1	6.9	1.7
	2025	126.3	112.5	0.1	10.9	2.7
II	2005	107.9	107.8	0.1	0.0	0.0
	2010	111.9	111.4	0.5	0.0	0.0
	2015	116.6	112.5	2.0	1.7	0.4
	2020	121.3	112.5	2.4	5.1	1.3
	2025	126.3	112.5	3.7	8.0	2.0
III	2005	107.9	0.0	0.1	86.2	21.6
	2010	111.9	0.1	0.5	89.1	22.3
	2015	116.6	0.2	2.0	91.5	22.9
	2020	121.3	0.3	2.4	94.9	23.7
	2025	126.3	0.4	3.7	97.7	24.4
IV	2005	107.9	0.0	0.1	86.2	21.6
	2010	111.9	0.0	0.5	89.1	22.3
	2015	116.6	0.0	2.0	91.7	22.9
	2020	121.3	0.0	2.4	95.1	23.8
	2025	126.3	0.0	3.7	98.0	24.5

b) Flows to traditional reuse under Alternatives II, III and IV. The reclaimed water flow could be increased to 0.5 MGD by year 2010, 2 MGD by year 2015, 2.4 MGD by year 2020, and 3.7 MGD by year 2025 by connecting the large users within 3, 5, 7 and 8.4 metropolitan miles of the WWTP.

c) Flows to ocean outfall and groundwater recharge. Under Alternatives I, II and III the flow remaining after allocation to traditional reuse is sent to the ocean outfall and groundwater recharge. Under Alternative I, the ocean outfall 2005 permitted capacity of 112.5 MGD would be reached by 2015, with a groundwater recharge flow of 3.2 MGD in that year, increasing to 10.9 MGD by year 2025. Similarly under Alternative II, the ocean outfall permitted capacity would be reached by the year 2015, with a groundwater recharge flow in that year of 1.7 MGD, increasing to 8.0 MGD by the year 2025.

Under Alternative III, the wet weather period was 38.5 days for Miami-Dade/North WWTP. The ocean outfall flow was calculated multiplying the traditional reuse flow with the ratio of the wet and dry days. The groundwater recharge flow is projected to increase from 86.2 MGD in 2005 to 97.7 MGD in 2025.

Under Alternative IV there is no flow to the ocean outfall. The flow remaining after allocation to traditional reuse would be directed to groundwater recharge. The groundwater recharge flows are very similar to the flows under Alternative III. Reverse osmosis concentrate flow varies in proportion to groundwater recharge flow.

7.3.6 Effluent and Reclaimed Water Distribution for the Miami-Dade/Central WWTP

The distribution of effluent and reclaimed water from the Miami-Dade/Central WWTP under the four ocean outfall alternatives is summarized in Table 7-8. Rationale for the flow allocations is discussed below.

a) Flows to traditional reuse under Alternative I. The utility currently uses 8.9 MGD for on-site process use. There are no plans to increase reclaimed water flow (PBS&J 2003; FL DEP 2004).

b) Flows to traditional reuse under Alternatives II, III and IV. The demand for traditional reuse could be increased to 0.4 MGD by year 2010, 1 MGD by year 2015, 2.1 MGD by year 2020, and 2.9 MGD by year 2025 through inclusion of the large users within 5, 8, 10 and 10.6 metropolitan miles of the WWTP. Since the chloride levels are high at the Miami-Dade/Central WWTP, users with landscapes resistant to high-chloride levels would be required.

c) Flows to ocean outfall and groundwater recharge. Under Alternatives I, II and III the flow remaining after allocation to traditional reuse is sent to the ocean outfall and groundwater recharge. Under Alternatives I and II, the ocean outfall 2005 permitted capacity of 143 MGD would be reached by 2020. Under Alternative I, groundwater recharge flow will be 1.9 MGD in that year, increasing to 6.7 MGD by year 2025. Under Alternative II, groundwater recharge flow will increase to 4.4 MGD by the year 2025.

Under Alternative III, the wet weather period was 38.5 days for Miami-Dade/Central WWTP. The ocean outfall flow was calculated multiplying the traditional reuse flow with the ratio of the wet and dry days. The groundwater recharge flow is projected to increase from 103.5 MGD in 2005 to 118.5 MGD in 2025.

Table 7-8. Flow distribution for Miami-Dade/Central WWTP

Alt.	Year	WWTP effluent (MGD)	Ocean outfall (MGD)	Traditional reuse (MGD)	Groundwater recharge (MGD)	RO concentrate (MGD)
I	2005	129.4	129.4	0.0	0.0	0.0
	2010	134.1	134.1	0.0	0.0	0.0
	2015	139.8	139.8	0.0	0.0	0.0
	2020	145.4	143.0	0.0	1.9	0.5
	2025	151.3	143.0	0.0	6.7	1.7
II	2005	129.4	129.4	0.0	0.0	0.0
	2010	134.1	133.7	0.4	0.0	0.0
	2015	139.8	138.9	1.0	0.0	0.0
	2020	145.4	143.0	2.1	0.2	0.1
	2025	151.3	143.0	2.9	4.4	1.1
III	2005	129.4	0.0	0.0	103.5	25.9
	2010	134.1	0.1	0.4	106.9	26.7
	2015	139.8	0.1	1.0	111.0	27.8
	2020	145.4	0.2	2.1	114.5	28.6
	2025	151.3	0.3	2.9	118.5	29.6
IV	2005	129.4	0.0	0.0	103.5	25.9
	2010	134.1	0.0	0.4	106.9	26.7
	2015	139.8	0.0	1.0	111.1	27.8
	2020	145.4	0.0	2.1	114.6	28.7
	2025	151.3	0.0	2.9	118.8	29.7

Under Alternative IV, no flow may be sent to the ocean outfall. The flow remaining after allocation to traditional reuse would be directed to groundwater recharge. The projected groundwater recharge flow is very similar to the flows under Alternative III. Reverse osmosis concentration varies in proportion to groundwater recharge flow.

7.4 Wastewater Management Options and their Water Quality Requirements

Current and potential treatment requirements for the considered wastewater management options are summarized in Table 7-9.

Dischargers to Class I injection wells were required to provide secondary treatment with no disinfection. The U.S. EPA published new rules governing Class I underground injection wells in 24 Florida Counties including Palm Beach, Broward and Miami-Dade Counties on 11/22/05. These federal rules became effective on 12/22/05. The new requirements for underground injection wells include secondary treatment with filtration and high-level disinfection. Secondary treatment with filtration and high-level disinfection is required for reclaimed water supplied for traditional (public access) reuse activities. Groundwater recharge would require full treatment and disinfection. The regulatory requirements for these wastewater management options are shown in Table 7-10. Ocean outfall dischargers are currently required to provide secondary treatment with basic-level disinfection as explained in Chapter 2, Table 2-5. The future requirements for ocean outfalls could include intermediate or full nutrient control (Table 7-11) with basic-level disinfection. Reclaimed water suitable for groundwater recharge would also be sufficiently low in phosphorus concentration (< 10 μg/L) for use as makeup water for the Everglades.

Table 7-9. Current and Potential Treatment Requirements of Wastewater Management Options*

	Treatment requirements	
Option	**Potential**	**Current**
Ocean outfalls	Secondary with basic-level disinfection (T2)	Intermediate or full nutrient control w/ basic-level disinfection (T4/T5)
Class I injection wells	Secondary with no disinfection (T1)	Secondary w/ filtration & high-level disinfection (T3)
Traditional reuse	Secondary w/ filtration & high-level disinfection (T3)	
Groundwater recharge	Full treatment and disinfection (T6)	

*Process trains (T1, T2, etc.) capable of meeting the requirements are described in Figure 7-1

In order to conceptualize the linkage between process trains and the different wastewater management options, a code is appended to each treatment requirement in Table 7-9. This code (T1, T2, etc.) identifies a specific process train that has been conceptualized for meeting the effluent quality requirements of the associated wastewater management option. The process trains are presented in Figure 7-1. Schematic diagrams of the process sequences along with information about the application of each process train and the effluent quality standards that the process train is capable of meeting are given in Appendix 2. There are many options for process sequences that could meet the requirements shown in Table 7-9. The appropriate choice would be influenced by site-specific conditions.

Table 7-10. Regulatory Requirements for Different Wastewater Management Options

Parameter	Units	Limit	Class I Injection Wells *	Public Access Reuse	Groundwater Recharge
$CBOD_5$	mg/L	Maximum annual average	20	20	-
TSS	mg/L	Maximum annual average	20	5.0	-
Total Nitrogen as N	mg/L	Maximum annual average	-	-	10
Total Phosphorus as P	mg/L	Maximum annual average	-	-	-
Total Dissolved Solids (TDS)	mg/L	Maximum annual average	-	-	500
Total Organic Carbon (TOC)	mg/L	Maximum monthly average	-	-	3.0
Total Organic Halogen (TOX)	mg/L	Maximum monthly average	-	-	0.2
Fecal Coliforms			-	**	***

* These requirements are for secondary treatment with no disinfection and do not include the new rules by U.S. EPA published on 11/22/05 and became effective on 12/22/05.

** *[62-600.440(5)f]*

- Over a 30-day period, 75 percent of the fecal coliform values shall be below the detection limits.
- Any one sample shall not exceed 25 fecal coliform values per 100 mL of sample.
- Any one sample shall not exceed 5.0 milligrams per liter of TSS at a point before application of the disinfectant.

*** Total coliforms undetectable, any one sample shall not exceed 4 total coliform values per 100 mL of sample.

Table 7-11. Assumed Annual Effluent Limits for Ocean Outfall Disposal

Parameter	Units	Level of nutrient control	
		Intermediate	Full
$CBOD_5$	mg/L	10.0	5.0
TSS	mg/L	10.0	5.0
Total Nitrogen	mg/L as N	10.0	3.0
Total Phosphorus	mg/L as P	3.0	1.0

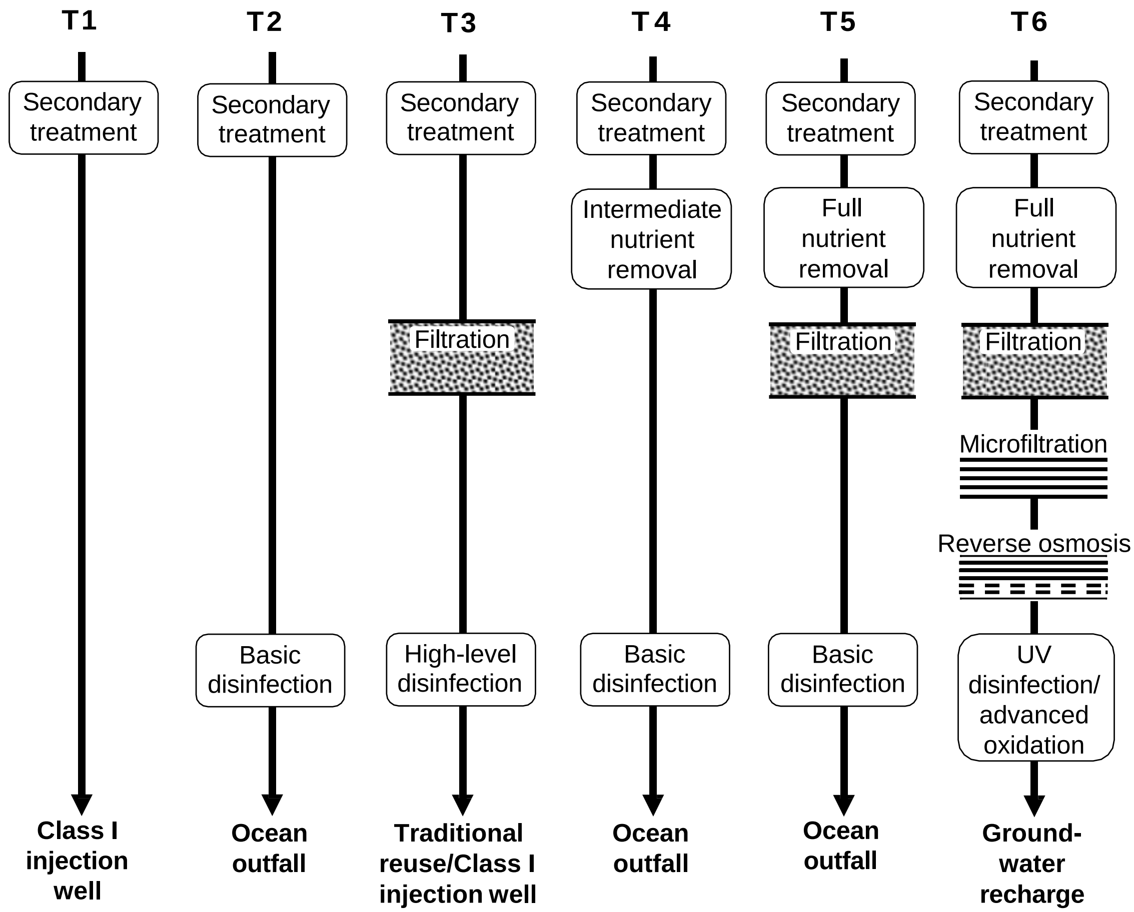

Figure 7-1. Process Trains Capable of Meeting Current and Potential Treatment Requirements of Wastewater Management Options

7.5 Summary

- The Boynton-Delray and Boca Raton WWTPs are reclaiming 19% and 33%, respectively, of their 2005 total wastewater flows for traditional reuse
- The Broward/North and Hollywood WWTPs are reclaiming 3% and 7%, respectively, of their 2005 total wastewater flows for traditional reuse
- The Miami-Dade/North and Miami-Dade/Central WWTPs are using small amounts of reclaimed water—mainly for on-site process use; therefore traditional reuse constitutes 0% of their 2005 total wastewater flows
- Under current plans (Alternative I), the Boynton-Delray and Boca Raton WWTPs would increase their reuse percentages to 28% and 73%, respectively, by 2025
- Under current plans (Alternative I), the Broward/North would increase its reuse percentage slightly (to 6%) by 2025
- Under current plans (Alternative I), the Hollywood, Miami-Dade/North and Miami-Dade/Central WWTPs would see no increase in their reuse percentages by 2025

- Under Alternatives II, III and IV, the Boynton-Delray and Boca Raton WWTPs would increase their reuse percentages to 84% and greater than 90%, respectively
- Under Alternatives II, III and IV, the Broward/North and Hollywood WWTPs would increase their reuse percentages to 24% and 11%, respectively
- Under Alternatives II, III and IV, the Miami-Dade/North and Miami-Dade/Central WWTPs would increase their reuse percentages to 3% and 2%, respectively

As seen from Alternatives II, III and IV, the WWTPs in Palm Beach County (Boynton-Delray and Boca Raton) have large potential for traditional reuse. The WWTPs in Miami-Dade County (Miami-Dade/North and Miami-Dade/Central) have small potential for traditional reuse but high potential for groundwater recharge. However, groundwater recharge costs for the Miami-Dade/Central WWTP are high relative to the estimated groundwater recharge costs for other five facilities due to the large transmission costs from the WWTP to groundwater recharge sites on the mainland.

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8. Indicators

The 2003 Reuse Strategies Report (Reuse Coordinating Committee and the Water Conservation Initiative Water Reuse Work Group 2003) presented the following vision for water reuse in Florida in 2020:

- Water reuse will be employed by all domestic wastewater treatment facilities having capacities of 0.1 million gallons per day (MGD) and larger. Statewide, on the order of 65 percent of all domestic wastewater will be reclaimed and reused for beneficial purposes.
- Effluent disposal using ocean outfalls, other surface discharges, and deep injection wells will be largely limited to facilities that serve as backups to water reuse facilities.
- Regulatory agencies, health agencies, utilities, and the public will embrace a "water is water" philosophy and will fully and readily accept the full range of water reuse options and the full range of alternative water supplies.
- Reclaimed water will be used in an efficient and effective manner, as a means to conserve and recharge potable quality water resources. Newer reuse systems will have potable quality water offsets and/or recharge fractions of 75 percent or larger.
- Groundwater recharge and indirect potable reuse projects will become common practice.
- Membrane treatment technologies will be widely used for the production of high-quality reclaimed water, particularly for the control of pathogens and organic compounds.
- Ultraviolet (UV) disinfection will be the norm for water reuse and domestic wastewater facilities.
- Use of satellite facilities will be common practice, particularly in the larger urban areas, as a means for enabling effective use of reclaimed water.
- Reclaimed water will be widely used to flush toilets in commercial facilities, industrial facilities, hotels and motels, and multiple-family residential units in Florida.

The second of the above goals relates to the stated desire to reduce disposal of treated wastewater via ocean outfalls and deep injection wells. This study focuses on evaluating current prospects for reuse based on specific evaluations of the six ocean outfalls in Southeast Florida.

The 2003 Reuse Strategies Report (Reuse Coordinating Committee and the Water Conservation Initiative Water Reuse Work Group 2003) used the following three criteria to rank a variety of water conservation initiatives including water reuse:

- Amount of water saved (maximum of 5 points)
- Cost effectiveness (maximum of 3 points)
- Ease of implementing (maximum of 3 points)

These three criteria are used in this report with a fourth criterion and a point system was not used during the evaluation of these indicators.

- Public health and Environmental impact

Definitions of these criteria and how they are measured are presented below.

8.1 Amount of Water Saved

Whitcomb (2005) provides data on water use throughout Florida for single family homes. His summary statistics can be used to estimate indoor and outdoor water use for the six water utilities in southeast Florida. Based on a detailed evaluation of the tax assessor's database for every parcel in Florida, Whitcomb (2005) developed the following median attributes of residential users:

- Property value = $84,330
- Year built = 1979
- House size = 1,747 square feet
- Lot size = 9,931 square feet (0.23 acres).

Heaney (1998) and Mayer (1999) summarized the results of a nationwide evaluation of water use in 1,200 houses in 12 cities across North America, including Tampa, Florida. The average annual water use for the 100 residences in Tampa was 98,900 gallons per year of which 54.5% was indoor and 45.5% was outdoor. Using the Tampa numbers to calibrate the estimates for Southeast Florida yields the following irrigation estimates for SE Florida:

- People/house = 2.5
- Indoor gal./capita/day = 60
- Irrigation rate, feet/year = 3.0
- % of non-house area that is irrigated = 25%

These calibrated estimates indicate the following median water use per residence in Southeast Florida:

- Indoor water use = 54,750 gallons per year
- Irrigation water use = 45,800 gallons per year
- Irrigable area per house about 2,000 square feet.

Water use per square foot of house and irrigated area are similar (31 vs. 23 gal/sq ft/yr). At this rate, each added person has an average annual outdoor demand equivalent to applying 3 feet of water on 800 square feet of area.

A study by GEC (2003) indicates that water users in Southeast Florida are often classified by the water utilities as being high outdoor water users if their outdoor water use is about 65% of total use. Similarly, medium outdoor water use is defined as 50% outdoor water use and low outdoor water use is considered to be 35% of total use.

Water utilities in Southeast Florida employ conservation rate structures wherein the first block is assumed to represent indoor water use. Whitcomb (2005) lists the initial block as monthly water use up to 4,000 gallons for Palm Beach County and 3,750 gallons for Miami-Dade County. These numbers are slightly less than our estimate of outdoor use for Tampa of 4,500 gallons per month.

Whitcomb (2005) estimates the following percentages of residential customers who use individual wells for irrigation.

- Miami-Dade—27%
- Palm Beach—20%
- Broward—No estimate provided
- Average for Florida—28%

Local data are needed to get accurate information on individual irrigation wells. Using the average of the three estimates shown above results in an estimate that 25% of the residential customers have individual irrigation wells. We could not find any data that showed the spatial distribution of individual wells.

Irrigation is the largest water user in Florida and in many parts of the United States. Most of this irrigation is for agricultural purposes. As mentioned above, irrigation accounts for roughly 40 to 60% of residential water use in urban areas. Outdoor water use is much more sensitive to increasing prices. Whitcomb (2005) recently completed the largest study ever conducted on how water rates affect single-family residential water use in Florida. An illustrative increasing block rate structure for water supply is shown in Figure 8-1 (SWFWMD 2005). The lowest rate of $1.50/1,000 gallons is for the initial 5,000 gallons per month which approximates indoor water usage for a typical family. The rate then jumps to $2.50/1,000 gallons for the next 7,500 gallons per month. This range would represent the outdoor water use by a typical family. Usage beyond 12,500 gallons per month is charged an even higher rate of $3.50/1,000 gallons. The purpose of the conservation rate structure is to assure that people can have access to relatively inexpensive water for their more critical indoor needs. However, it also tries to reduce outdoor water use that is less critical by charging higher rates for this less vital use of water.

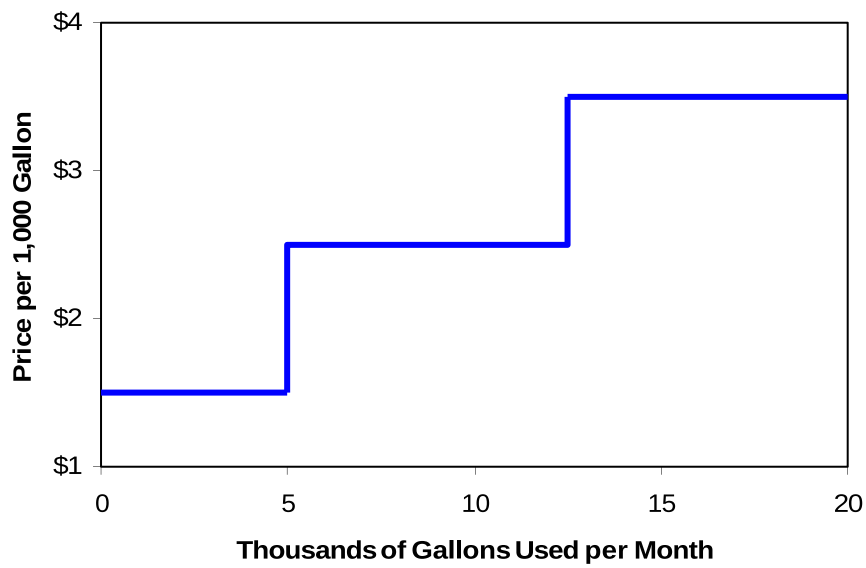

Figure 8-1. Inclining Block Rate Structure Example

Whitcomb (2005) divided single-family residential water customers into four profiles based on assessed property values of homes, with Profile 1 being the homes with the lowest assessed value and Profile 4 the highest. Demand curves for water in Florida are shown in Figure 8-2. The report takes several factors into account when calculating water demand per household. Factors such as net irrigation rate, people per household, pool data, and irrigation restriction data were normalized in this calculation and shown as such in Figure 8-2. At relatively low water prices of $2.00/1,000 gallons, per capita demand for a Profile 2-3 user would be about 180 gal/capita/day. Profile 2-3 represents the average single-family residential water customer based on property value and is represented in Figure 8-2 by interpolating between the Profile 2 and Profile 3 demand curves. Indoor water use is about 60-70 gal/capita/day so about 2/3 of the water use is outdoor. If the water price is $4.00/1,000 gallons, then the demand for the profile 2-3 user decreases sharply to about 120 gal/capita/day, a 33% reduction. Now the mix of indoor and outdoor water use is about equal. This is about where we are in Southeast Florida at present. If water prices are $6.00/1,000 gallons, then total water use drops to about 90 gal/capita/day and outdoor water use is only about 33% of total use. Finally, at $8.00/1,000 gallons, water demand is about 70 gal/capita/day with outdoor water use constituting an even smaller percentage of total water use. As prices increase, indoor water use can be expected to decline. Best estimates at present are that indoor water use will decrease from 60 to about 40 gal/capita/day due to the installation of low-flush toilets and other water saving devices. Thus, given expected increasing scarcity of water, prices will increase and people will use water more efficiently.

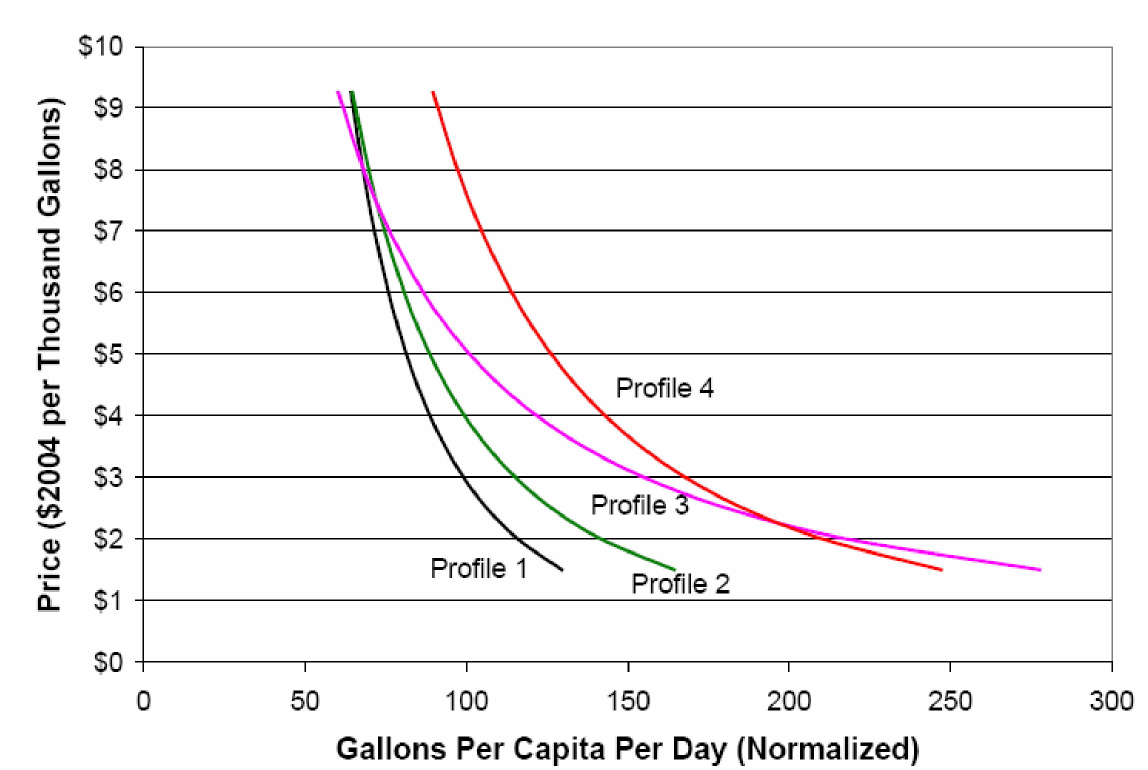

Figure 8-2. Demand for water as a function of price in Florida for four wealth profiles (Whitcomb 2005)

Irrigation water use per family can also be expected to decline due to smaller irrigable area per family. About one half of the future housing starts in southeast Florida will be multi-family dwellings. As land use intensifies, irrigable area per family can be expected to decline. Thus, overall, future outdoor water use per family should decrease. However, additional population growth can be expected to offset these savings. Also, the need for much more high quality water going to the Everglades will further intensify competition for the available fresh water supply. It is reasonable to assume that a larger percentage of future water use will be for indoor purposes. The water demand forecasts presented in Chapter 3 assumed a constant per capita usage over the planning horizion from 2005 to 2025. These estimates were based on the best available information from published reports by consultants and planning agencies in Southeast Florida. They probably did not take into account the very recent results of Whitcomb (2005) that were described in this section. In terms of reuse planning, it is probably more accurate to assume that per capita outdoor water use will decline due to a combination of decreased irrigable area and more efficient irrigation practices in response to the growing scarcity and cost of water. On the other hand, water use forecasts for Southeast Florida need to more fully incorporate the demand for fresh water associated with the Everglades Restoration.

8.2 Public Health and Environmental impact

A wide range of pollutants are removed by wastewater treatment processes. Water quality regulations are typically based on key indicators of water quality that are most important for a receiving water. Total maximum daily loads are being calculated for receiving waters throughout the State of Florida. Drew (2005) summarizes the first five years of this program. She notes that Florida has 52,000 miles of rivers and streams, nearly 800 lakes, 4,500 square miles of estuaries, and more than 700 springs. Drew (2005) points out three open issues with regard to assessing receiving water quality in Florida as described below:

- *Most Florida waterways are identified as Class III, "fishable and swimmable." It has become clear in recent years that this classification, which includes rivers, streams, lakes and estuaries as well as wetlands, urban drainage ditches, urban lakes, and canal systems, is too broad. Some of these water bodies or water body types never did and indeed should not be expected to provide the same quality of "swimmable or fishable" recreation as others.*
- *Florida's freshwater dissolved oxygen (DO) criterion requires oxygen levels in surface waters to be at or above five milligrams per liter (5 mg/l) at all times at all places, ostensibly in an effort to protect water quality. In fact, wetlands, springs, drainage ditches, and canals do not typically exist, whether naturally or as artificially created, with DO levels as high as 5 mg/l, often because of the significant inflow of low-oxygen groundwater into surface waters. In effect, some water bodies are being required to meet unnatural conditions or conditions that are not otherwise caused by pollutants.*
- *The state's criteria for nutrients (nitrogen and phosphorous, for example) are narrative rather than numeric, which on occasion has led to differing interpretations by third parties on DEP's determination as to whether a water body is impaired by excessive nutrients.*

Drew (2005) listed the primary pollutants that are causing the impairment of Florida's surface waters and the number of water body segments impaired. These were:

- *Nutrients, such as nitrogen and phosphorus, which promote the growth of algae and other aquatic plants that cause wide swings in oxygen levels and lead to fish kills and damaged habitat-373 segments*
- *Bacteria, which may threaten public health and can close waters to swimming or shellfish harvesting-236 segments*
- *Metals, such as iron, silver, copper, cadmium, and zinc that adversely affect the health and reproduction of aquatic organisms-61 segments*
- *Mercury, based largely on the existence of Department of Health fish consumption advisories. (It generally is agreed that mercury is predominately the result of atmospheric deposition, but the relative contributions of local, regional and even global sources remains the subject of debate.)-40 segments*

Water reuse is an important benefit of a total maximum daily load program. For a given receiving water, a determination is made of the allowable load of the constituent(s) of interest. Then, a combination of point and nonpoint controls must be installed to avoid exceeding this allowable load. Reclaimed water can be given full credit for eliminating a discharge to a receiving water. Thus, it is very attractive from this point of view for most receiving waters.

In the case of ocean disposal via outfalls, the assimilative capacity of the ocean is extremely large. Thus, total maximum daily loads have not been developed for these cases. From a total maximum daily load perspective, discharge to an ocean outfall or landside water reuse eliminates a direct source of pollution to a receiving water.

For ocean disposal via outfalls, one may distinguish two different environments:

1. Discharge to open marine waters
2. Discharge to open marine waters that are near reefs.

Existing evidence suggests that the human and ecological risks from ocean outfalls are low because the wastewater is treated to reduce the contaminants and the rapid mixing and dilution reduces residual impacts to low levels (US EPA 2003). Studies by Tichenor (Tichenor 2003; Tichenor 2004b; Tichenor 2004a) suggest that the outfall discharge at Boynton Beach may be having an adverse effect on Lynn's Reef. A biomarker study by Fauth et al. (Fauth et al. 2006) also indicates that reefs are being impacted. However, neither of these studies attempted to directly link the outfall discharges to reef impacts by measuring the concentrations of contaminants from the outfalls. LaPointe et al. (2004) have shown how wastewater discharges can detrimentally impact reefs in the Florida Keys. In this case, the wastewater discharges are not by ocean outfalls and the effluents are discharged in close proximity to the reefs with much less dilution. If scientific evidence demonstrates that current wastewater treatment levels are insufficient to protect water quality, then more stringent treatment requirements such as intermediate or full nutrient control may be imposed in the future. However, the current water quality impacts near these six ocean outfalls are less obvious than in other receiving waters in the State of Florida that have experienced more apparent impacts such as widespread algal blooms.

8.3 Cost Effectiveness

8.3.1 Cost of the Reuse System

Water and wastewater infrastructure are very capital intensive with long service lives that extend to 100 years for some transmission systems. For this project, excellent information is available on how costs should be calculated. The Florida DEP (1991) developed guidelines for estimating costs for reuse projects. The Reuse Coordinating Committee (1996) for the State of Florida expanded on the 1991 FL DEP guidelines. The 1996 Reuse Feasibility Study Guidelines deal with preparation of reuse feasibility studies by water users (applicants for consumptive use permits). The LEES (1997) report contains excellent cost information for water and wastewater systems. This database was updated and refined by SFWMD (2004) as part of the South Florida Water Management District's water supply planning program. In addition to these general references, numerous consulting reports on water and wastewater infrastructure in Southeast Florida provided additional cost information. Finally, state of the art wastewater treatment cost estimating software called CapdetWorks was used to do more detailed process-level cost estimating (Hydromantis Inc., Hamilton, Ontario, Canada). All costs are expressed in July 2005 dollars. A discount rate of 7% and a service life of 20 years are assumed, consistent with the LEES (1997) report.

8.3.2 Benefits of the Reuse System

As described above, customers on the central water supply system are paying in the range of \$4.00 per 1,000 gallons for water. Typically, they would be paying this rate as the second step in the water use rate structure. Thus, if reclaimed water is available, they would save this amount assuming that the reclaimed water was provided free of a separate charge.

8.3.3 Determining the Optimal Amount of Reuse

As detailed in Chapter 6, two definitions of optimality can be used for this problem. If the utility follows a profit maximizing objective, then the optimal amount of reclaimed water is found by maximizing total benefits minus total costs. This model is typically used by private enterprise. However, public utilities have traditionally used a breakeven objective of finding that flow where total benefits = total costs. Public utilities are regulated as monopolies. Thus, they are typically restricted to recovering their costs including a "fair" rate of return on their investment (AWWA 1990; AWWA 1999). This is an important point as illustrated by the simple example shown below.

Assume that total benefits from reuse, $TB = 3x$ and total costs for reuse, $TC = x^2/2$ where x = amount of reuse. Thus, the net benefits (NB) are given by

$$NB = TB - TC = 3x - x^2/2 \qquad (8\text{-}1)$$

This net benefit function is plotted in Figure 8-3.

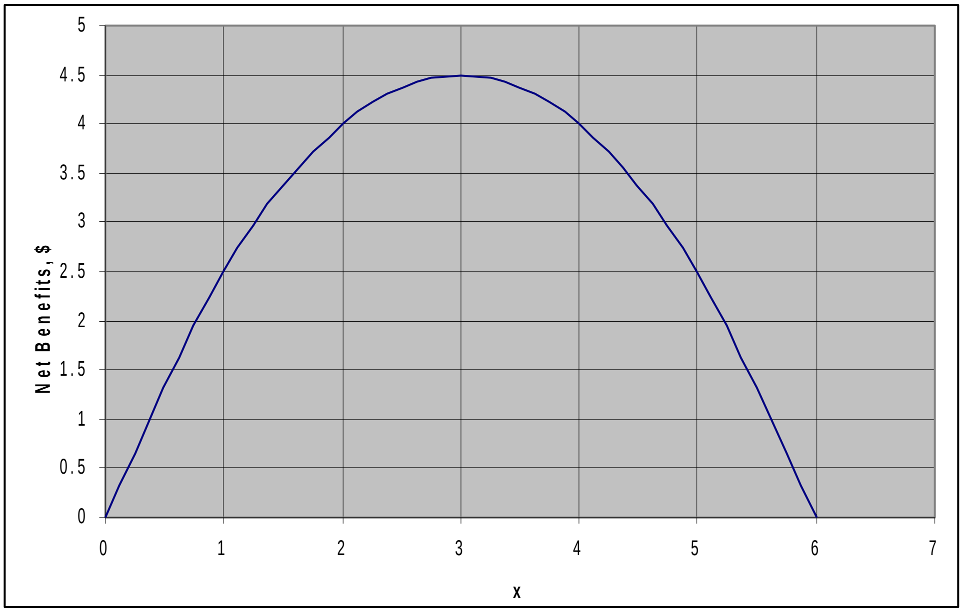

Figure 8-3. Hypothetical Net Benefit Function for Water Reuse

If the utility seeks to maximize net benefits, then the optimal solution is a net benefit of $4.50 and 3 units of reclaimed water would be provided. However, if the utility seeks to maximize the amount of reclaimed water provided subject to breaking even, i.e., net benefits = 0, then 6 units of reclaimed water will be provided. The breakeven objective has been used traditionally for public utilities. Both solutions were presented for the cost effectiveness analysis.

8.4 Ease of Implementation

The results of three recent surveys of public acceptance of reuse are shown in Table 8-1. Public acceptance is very high for irrigation types of reuse. It is also high for other non-human contact uses such as street sweeping, fire protection, concrete production, vehicular wash water and dust control. Toilet flushing is also considered to be an acceptable use. However, toilet flushing is not widely used at this time with the exception of newer high rise construction. Discharge of reclaimed water to augment streams and wetlands is less favored and also has significant regulatory hurdles. Water reuse associated with human contact and/or ingestion is less popular (Marks 2003; Po et al. 2003; CDM 2004; Hartley 2006) Similarly, early social-psychological studies of Bruvold (1988) showed that greater than 94% of the respondents were positive towards using reclaimed water for irrigation purposes whereas 77% were positive towards using reclaimed water to recharge groundwater and 44% were positive towards drinking reclaimed water. Proactive utilities (Orange County, CA and Singapore, for example) have successfully implemented projects involving groundwater recharge and indirect potable reuse, respectively. This was achieved through engagement of the public throughout the planning, implementation and operational phases of the projects, documentation of the ability of the water reclamation system to reliably meet water quality goals, and scientific validation of the absence of health impacts from ingestion of reclaimed water (FSAWWA Water Conservation Committee 1999; Macpherson et al. 2003; Crook 2004). A good example of the public engagement is the approach developed by the City of

San Diego to study all aspects of a viable water reuse program (City of San Diego 2005). Steps of the study approach are

- Assemble stakeholders and identify issues
- Develop a public involvement program
- Identify reuse opportunities and investigate issues
- Assess reuse opportunities based on community values

It should also be noted that generating public acceptance of traditional reuse activities such as irrigation of public access landscapes may translate to greater potential for generating public support for indirect potable reuse and groundwater recharge.

Table 8-1. Positive and Negative Responses* to Potential Alternatives for Reclaimed Water. Adapted from CDM (2004)

	% Yes	% Yes	% Yes
Use	WW operators	Tampa	San Fran.
Concrete production	90%		
Golf course irrigation	89%		96%
Street cleaning	87%		96%
Irrigation of highway right of way	85%		
Fire protection	84%		98%
Irrigation of parks			96%
Irrigation of athletic fields	84%		
Wetland creation	84%		
Dust control	82%		
Irrigation of agricultural crops	82%		
Irrigation of office parks and business campuses	82%	94%	
Toilet flushing	80%		92%
Industrial process water	78%		
Vehicle wash water	76%		
Residential landscape irrigation & maintenance	74%	84%	
Stream augmentation	67%		
Ornamental ponds/fountains	56%		
Potable reuse-indirect	40%		
Irrigation of crops for direct human consumption	30%		
Potable reuse-direct	18%		
Pools/spas	15%		

*Based on a survey of 50 wastewater treatment plant operators and managers and 15,000 Tampa customers

8.5 Summary

Four indicators of amount of water saved (freshwater savings), cost effectiveness, public health and environmental impact (nutrient load reduction) and ease of implementation (public acceptance) are used in the evaluation of the alternatives without a point system applied.

- Several studies have shown that residential irrigation accounts for 35 to 65% of residential water use in urban areas. In terms of reuse planning, it is expected that per capita outdoor water use will decline due to a combination of decreased irrigable area and more efficient irrigation practices in response to the growing scarcity and cost of water. The indoor water use is also estimated to decrease from 60 to about 40 gal/capita/day due to the installation of low-flush toilets and other water saving devices.
- Nutrients (nitrogen and phosphorus) are found to be among the primary pollutants that are causing the impairment of Florida's surface waters. Some studies have shown evidence for reef damage from ocean outfalls. However, there is need for definitive studies that explore the link between wastewater disposal through ocean outfalls and reefs.
- The water users in the second step of the rate structure are paying in the range of \$4.00 per 1,000 gallons for water. If reclaimed water is available, they would save this amount assuming that the reclaimed water was provided free of a separate charge.
- Public acceptance of reclaimed water used for irrigation is higher than groundwater recharge. Public education programs and community involvement throughout the planning, implementation, and continued use of water reuse projects can help mitigate public concerns.

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9. Evaluation of Ocean Outfall Strategies

An evaluation of the four ocean outfall strategies (use at current levels, limited use, use as backup for traditional reuse, and no use) with respect to four indicators (pollutant load reduction, cost effectiveness, amount of freshwater saved and public acceptance) is presented in this chapter. Methods for quantifying the indicators are described in Section 9.1, followed by presentation of indicator outcomes in Sections 9.2–9.7, comparison of the outcomes among the six WWTPs in Section 9.8, and a summary in Section 9.9.

9.1 Methods for Quantifying Indicators

Methods for estimating freshwater savings, nutrient load reductions, and costs for liquid treatment, reuse and disposal are described below.

9.1.1 Definition of the Base Case

A base case against which the outcomes of the various ocean outfall alternatives can be compared is defined as follows:

- Treatment level: secondary with basic level disinfection for disposal using ocean outfalls and no disinfection for disposal using Class I injection wells
- Disposal method: discharge of 100% of flow to ocean outfalls or, in the case of the Broward/North WWTP, discharge of 100% of flow to ocean outfalls and Class I injection wells.

Flows and nutrient loads to the ocean associated with the base case are summarized in Table 9-1.

9.1.2 Estimation of Freshwater Savings

Freshwater may be saved by substituting reclaimed water for water from a potable supply. Thus, a savings of 1.0 gallon of freshwater per gallon of reclaimed water provided for traditional reuse was assumed. No credit for offsetting municipal water treatment demands was taken, since consumptive use permittees withdraw water from local wells rather than public supplies. Water savings from groundwater recharge was taken as 0.8 gallons of freshwater per gallon of reclaimed water recharged. Selection of the recharge value was based on the assumption that the groundwater recharge fraction for injection through shallow wells near the coast is intermediate to recharge fractions for canals and rapid infiltration basins, which are given as 0.7 and 0.95, respectively, in the *2003 Reuse Strategies Report* (Reuse Coordinating Committee and the Water Conservation Initiative Water Reuse Work Group 2003). Freshwater savings in percent are expressed relative to the ocean outfall flows under the base case as defined in Section 9.1.1 (Table 9-1).

9.1.3 Estimation of Nutrient Load Reductions

Nitrogen and phosphorus are of documented concern with respect to the health of reefs in the coastal waters of southeast Florida. These nutrients are therefore used as model pollutants. Nutrient loads to the ocean can be decreased by reducing flows to ocean outfalls and by tertiary treatment to remove nutrients from wastewater. Nutrient load reductions in percent are expressed relative to ocean nutrient loads under the base case as defined in Section 9.1.1 (Table 9-1).

Table 9-1. Flows and Nutrient Loads to the Ocean associated with the Base Case

	Effluent conc.* (mg/L)	Year	Flows (MGD)			Loads to ocean (tons/yr)	
			Influent	UIC wells**	Ocean outfall	TN	TP
Boynton-Delray	Total N	2005	19.4	0	19.4	551	50.1
	18.7	2010	21.3	0	21.3	605	55.0
	Total P	2015	23.2	0	23.2	660	60.0
	1.7	2020	25.2	0	25.2	716	65.1
		2025	27.1	0	27.1	771	70.1
		Avg	23.2	0	23.2	661	60.1
Boca Raton	Total N	2005	15.6	0	15.6	401	16.6
	16.9	2010	17.1	0	17.1	440	18.2
	Total P	2015	18.7	0	18.7	480	19.9
	0.7	2020	20.2	0	20.2	520	21.6
		2025	21.8	0	21.8	560	23.2
		Avg	18.7	0	18.7	480	19.9
Broward/ North	Total N	2005	84.2	30	54.2	1,220	107.2
	14.8	2010	88.6	30	58.6	1,320	115.9
	Total P	2015	90.8	30	60.8	1,369	120.3
	1.3	2020	92.2	30	62.2	1,400	123.0
		2025	94.1	30	64.1	1,444	126.8
		Avg	90.0	30	60.0	1,351	118.6
Hollywood	Total N	2005	40.0	0	40.0	1,010	66.9
	16.6	2010	43.5	0	43.5	1,100	72.9
	Total P	2015	47.2	0	47.2	1,192	79.0
	1.1	2020	50.9	0	50.9	1,286	85.2
		2025	54.5	0	54.5	1,376	91.2
		Avg	47.2	0	47.2	1,193	79.0
Miami-Dade/ North	Total N	2005	107.9	0	107.9	2,874	279.2
	17.5	2010	111.9	0	111.9	2,980	289.5
	Total P	2015	116.6	0	116.6	3,107	301.8
	1.7	2020	121.3	0	121.3	3,230	313.8
		2025	126.3	0	126.3	3,363	326.7
		Avg	116.8	0	116.8	3,111	302
Miami-Dade/ Central	Total N	2005	129.4	0	129.4	3,308	315.0
	16.8	2010	134.1	0	134.1	3,430	326.6
	Total P	2015	139.8	0	139.8	3,575	340.5
	1.6	2020	145.4	0	145.4	3,717	354.0
		2025	151.3	0	151.3	3,870	368.6
		Avg	140.0	0	140.0	3,580	341

*From 31 Aug. 2003 through 31 Oct. 2004 Monthly Discharge Reports
**Class I

9.1.4 Estimation of the Costs for Liquid Treatment, Reuse and Disposal

The costs reported in this chapter are the sum of liquid treatment, reuse and disposal costs. Methods employed to estimate these costs are described below.

a) Costs of liquid treatment. Costs of primary treatment, secondary treatment, nutrient removal, filtration, basic level disinfection with chlorine, high level disinfection with chlorine, and high level disinfection with UV were estimated using CapdetWorks 2.1. Costs of microfiltration, reverse osmosis and advanced oxidation were estimated on the basis of case studies. Details of these methods are given in Chapter 6.

b) Costs of reclaimed water distribution for traditional reuse. Equation (6-7) gives the sum of costs for treatment beyond secondary (filtration and the difference between high level and basic level disinfection) and distribution costs as a function of flow for traditional reuse. Data used in the fitting of this equation are given in Table 6-29. Since the costs of treatment for reuse are included in the CapdetWorks simulations, the costs of treatment beyond secondary must be removed from Equation (6-7) in order to avoid double-counting.

The capital costs for treatment beyond secondary are given in Table 6-25. These costs were annualized on the basis of a 20 year service life and 7% discount rate and then subtracted from the annual costs in Table 6-29. Operation and maintenance costs for treatment beyond secondary are not separated from reclaimed water distribution costs in the Hazen and Sawyer (2004) database. They were therefore estimated using CapdetWorks. The results, expressed in power equation form, are given by

$$C = 24{,}330\,Q^{0.8506} \qquad (9\text{-}1)$$

where C is the operations and maintenance cost for treatment beyond secondary in $/yr and Q is the reclaimed water flow in MGD. The operations and maintenance costs thus estimated were also subtracted from the annual costs in Table 6-29. The remaining costs of reclaimed water distribution within the applicable range of flows (4.46–30 MGD) were fitted to a power relationship, giving

$$C = 8{,}167\,Q^{2.3496} \qquad (9\text{-}2)$$

where C and Q have the same units described previously. Equation 9-2 is used to estimate the cost of distributing reclaimed water to large users in the present chapter.

Equation (9-2) is specific to the service area of the Broward/North WWTP in Broward County. Costs reflected in this equation are influenced by the density of large users. The densities of large consumptive use permittees in the service areas of the Boynton-Delray and Boca Raton WWTPs are similar to the density near the Broward/North plant. Equation (9-2) should therefore provide a reasonably good approximation for these plants. Densities of large consumptive use permittees in the Hollywood, Miami-Dade/North and Miami-Dade/Central WWTP service areas are lower. As a result, Equation (9-2) will underestimate reclaimed water distribution costs at these facilities. Because the projected traditional reuse demands for the Hollywood, Miami-Dade/North and Miami- Dade/Central WWTPs are low (10% or less of the total wastewater treated), underestimation of traditional reuse distribution costs will have a negligible effect on overall cost trends that are projected for these facilities. For example, the Hollywood WWTP has the highest traditional reuse among the three facilities with low densities of consumptive use permittees. The maximum contribution of traditional reuse distribution cost to the cost of liquid treatment, reuse and disposal at this facility is estimated to be less than 3%.

c) Costs of reclaimed water injection through shallow wells. The methodology for estimating costs to inject highly treated reclaimed water through shallow wells was described in Chapter 6.

d) Disposal costs. It is assumed that the permitted capacities of the ocean outfalls and Class I UIC wells will be held constant. Therefore, no costs are allocated for these disposal methods. Deep well injection is assumed as a disposal method for concentrate from the reverse osmosis process. Costs for this disposal method are based on case studies, as described in Chapter 6.

9.2 Boynton-Delray WWTP

A summary of the projected flow allocations and costs for liquid treatment, reuse and disposal for the Boynton-Delray WWTP is given in Table 9-2. A matrix of indicator outcomes for the 2005–2025 projection period is shown in Table 9-3.

Freshwater savings. Total wastewater flows are expected to increase from 19.4 MGD in 2005 to 27.1 MGD in 2025 for all four alternatives. The current level of ocean outfall discharge of 15.7 MGD is expected to increase to 19.6 MGD under alternative I (currently planned use of ocean outfalls). Under alternative II (limited use of ocean outfalls), traditional reuse would grow from 3.7 to 22.7 MGD. If groundwater recharge and concentrate are included, then ocean outfall discharges in 2025 can be reduced to 2.4 MGD or eliminated.

Freshwater savings of 24–56% are achieved in the first two alternatives through traditional reuse. The freshwater savings for alternative III (use of ocean outfalls as backups) is 80% while that for alternative IV (no use of ocean outfalls) is 84%. Much of the freshwater savings under the latter two alternatives comes from groundwater recharge (24% and 28% of the flow treated, respectively).

Nutrient load reduction. In scenario A (secondary treatment of ocean-bound wastewater), ocean discharge of nitrogen and phosphorus is decreased by 24% under alternative I and 56% under alternative II. These percentages are identical to the respective freshwater savings under the two alternatives and represent diversions of the nutrients from the ocean to land. Greater load reductions (up to 93% for nitrogen and 74% for phosphorus) are achieved by applying nutrient removal processes to ocean-bound wastewater.

Table 9-2. Summary of Projected Flow Allocations and Costs for Liquid Treatment, Disposal and Reuse for the Boynton-Delray WWTP

			Flows (MGD)				Cost ($/1000 gal)		
Alterna-tive	Year	WWTP	Ocean outfall	Trad. Reuse	GW recharge	Concen-trate	Scenario* A	C	E
I	2005	19.4	15.7	3.7	0	0	0.90	1.22	1.50
	2010	21.3	16.4	4.8	0	0	0.91	1.21	1.48
	2015	23.2	17.0	6.2	0	0	0.93	1.21	1.46
	2020	25.2	19.0	6.2	0	0	0.91	1.18	1.44
	2025	27.1	19.6	7.5	0	0	0.95	1.19	1.44
II	2005	19.4	15.7	3.7	0	0	0.90	1.22	1.50
	2010	21.3	14.7	6.5	0	0	0.97	1.24	1.49
	2015	23.2	10.3	12.9	0	0	1.29	1.50	1.66
	2020	25.2	5.4	19.7	0	0	1.91	2.03	2.12
	2025	27.1	4.4	22.7	0	0	2.21	2.27	2.33
III	2005	19.4	0.4	3.7	12.2	3.1	4.10	4.10	4.10
	2010	21.3	0.7	6.5	11.2	2.8	3.64	3.64	3.64
	2015	23.2	1.4	12.9	7.1	1.8	3.14	3.14	3.14
	2020	25.2	2.1	19.7	2.7	0.7	2.78	2.78	2.78
	2025	27.1	2.4	22.7	1.5	0.4	2.80	2.80	2.80
IV	2005	19.4	0	3.7	12.5	3.1		4.13	
	2010	21.3	0	6.5	11.8	2.9		3.70	
	2015	23.2	0	12.9	8.2	2.1		3.25	
	2020	25.2	0	19.7	4.4	1.1		2.96	
	2025	27.1	0	22.7	3.5	0.9		3.02	

*The scenarios for ocean outfall treatment requirements preceding basic level disinfection are: A--secondary, C--intermediate nutrient removal, and E--full nutrient removal. These scenarios are applicable to alternatives I, II, and III, which involve use of ocean outfalls.

Table 9-3. Outcomes of Indicators for Ocean Outfall Alternatives at the Boynton-Delray WWTP

		Treatment applied for ocean outfall discharge		
		A--Secondary treatment	**C--**Intermediate nutrient removal	**E--**Full nutrient removal
Alternative I-- Ocean outfalls used at current levels	N load reduction	24%	60%	88%
	P load reduction	24%	24%	56%
	Freshwater savings	24% (including 0% from groundwater recharge)		
	Public acceptance	High		
Alternative II-- Limited use of ocean outfalls	N load reduction	56%	77%	93%
	P load reduction	56%	56%	74%
	Freshwater savings	56% (including 0% from groundwater recharge)		
	Public acceptance	High		
Alternative III-- Ocean Outfalls as backups	N load reduction	94%	97%	99%
	P load reduction	94%	94%	96%
	Freshwater savings	80% (including 24% from groundwater recharge)		
	Public acceptance	Low-Moderate to Moderate-High		
Alternative IV-- No use of ocean outfalls	N load reduction	100%		
	P load reduction	100%		
	Freshwater savings	84% (including 28% from groundwater recharge)		
	Public acceptance	Low-Moderate to Moderate-High		

Discharge of nutrients to the ocean is decreased by 94–99% under alternative III. The nutrient load reduction in alternative III is high compared to alternatives I and II, due to the low volumes of treated effluent that are discharged through the ocean outfall. The nutrient load reduction in alternative III increases slightly as the degree of treatment is increased from secondary to full nutrient removal. Discharge of nutrients to the ocean is decreased by 100% under alternative IV, where use of the ocean outfall is eliminated.

Public acceptance. The public acceptance of alternatives I and II is anticipated to be high because water reuse is primarily for irrigation by large users. Groundwater recharge in alternative III at 24% could be expected to lead to low-to-moderate public acceptance, but a concerted effort to engage and educate the public could boost this level to moderate-to-high. Public acceptance of alternative IV—with groundwater recharge accounting for 28% of the flow treated—would be similar to that for alternative III.

Cost-effectiveness. The costs for the three liquid treatment scenarios range from $0.90 to $1.50/1,000 gallons in 2005 under both alternatives I and II. They increase to the range of $0.95 to $1.40/1,000 gallons in 2025 under alternative I and $2.20–2.30/1,000 gal under alternative II. Increases of costs due to higher degrees of treatment of ocean-bound wastewater are limited under alternative II because most of the flow is reused. The costs under alternative IV are in the range of $3.00 to $4.10/1,000 gal. These costs are high because full treatment (including membrane filtration and reverse osmosis) is applied to flow not destined for traditional reuse. Additionally, the highly treated reclaimed water must be transported to the injection site and the reverse osmosis concentrate must be disposed of. The costs of alternative IV decrease between 2005 and 2025 because more flow is applied for traditional reuse in 2025 and therefore less is groundwater injected. Alternative III allows use of ocean outfalls as backups and therefore involves slightly lower recharge flows. This leads to slightly lower costs than alternative IV.

Summary. The benefits, costs and public acceptance of the ocean outfall alternatives for the Boynton-Delray WWTP are compared in Figure 9-1. The benefit is the average of percent freshwater savings and overall nutrient (N, P) load reduction. Public acceptance is rated on a scale of high = 97%, moderate = 71%, and low = 45%, as suggested by the survey from CDM (2004).

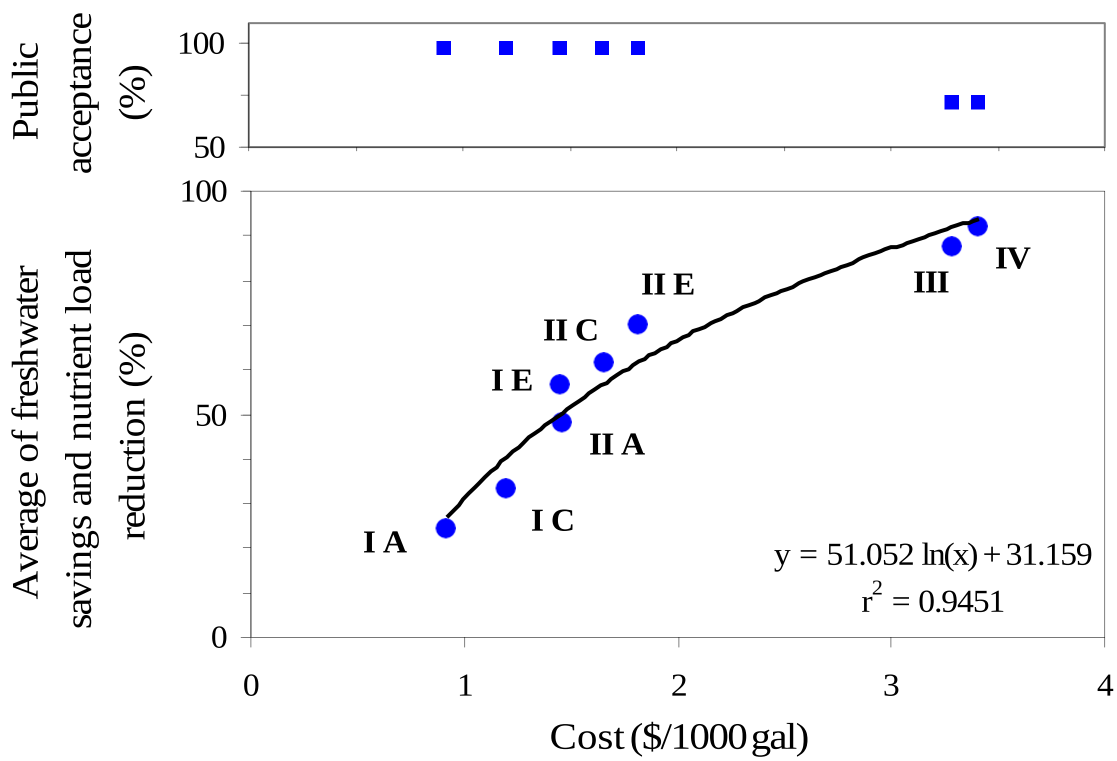

Figure 9-1. Public Acceptance and the Average of Percent Freshwater Savings and Nutrient Load Reduction versus Cost of Ocean Outfall Alternatives for the Boynton-Delray WWTP. Alternatives are Currently Planned Use (I), Limited Use (II), Ocean Outfalls as Backups (III) and No Use (IV). The scenarios for ocean outfall treatment are: A–secondary, C–intermediate nutrient removal, and E–full nutrient removal.

A benefit of up to 70% is achieved through various combinations of traditional reuse and nutrient control technology (alternatives I and II). These are also the alternatives with the highest public acceptance. The alternatives involving groundwater recharge (III and IV) achieve the highest benefits (87–92%), but are also most expensive and receive a lower level of public acceptance. The cost to achieve a benefit of 50% is $1.40/1,000 gal. The cost to achieve a benefit of 75% increases to $2.40/1,000 gal.

9.3 Boca Raton WWTP

A summary of the projected flow allocations and costs for liquid treatment, reuse and disposal for the Boca Raton WWTP is given in Table 9-4. A matrix of indicator outcomes over the years 2005–2025 is shown in Table 9-5.

Freshwater savings. Freshwater savings of 59–64% are achieved in the first two alternatives (currently planned and limited use of ocean outfalls) through implementation of traditional reuse. The freshwater recovery under alternative III (use of ocean outfalls as backups) is 82%, while that under alternative IV (no use of ocean outfalls) is 87%. Much of the freshwater savings under alternatives III and IV is from groundwater recharge, which accounts for savings of 20 to 23% relative to total flow treated.

Nutrient load reduction. Management options that include currently planned or limited use of ocean outfalls (alternatives I and II, respectively) reduce ocean discharge of nitrogen by up to 94% and phosphorus by up to 64% through a combination of effluent diversion to traditional reuse and application of nutrient control treatment technology. Limitation of phosphorus discharge under alternatives I and II is achieved exclusively through effluent diversion to reuse, since the secondary effluent phosphorus concentration of 0.8 mg/L is below the target effluent qualities of either the intermediate or full nutrient removal technologies. Discharge of nutrients to the ocean is decreased by 93–99% under alternative III and by 100% under alternative IV.

Public acceptance. The public acceptance of alternatives I and II is anticipated to be high since all freshwater savings are achieved through traditional reuse. A groundwater recharge level of 20% could result in a low-to-moderate level of public acceptance in alternative III. However, misgivings about groundwater recharge could be substantially mitigated by public education efforts and community participation in the planning process, boosting the acceptance level to the moderate-to-high range. Alternative IV has a similar level of groundwater recharge and is thus expected to receive the same level of public acceptance.

Cost-effectiveness. The costs under the first two alternatives range from $1.05 to $1.40/1,000 gal in 2005 under alternatives I and II and increase to the range of $1.65–2.40/1,000 gal in 2025. Under alternative II, in 2025, there is little variation in costs between treatment scenarios because most of the flow is reused. The costs under alternative IV range from $2.50 to $3.90/1,000 gal, decreasing from 2005 to 2025 because of increasing traditional reuse, which leads to less recharge. The costs under alternative III are slightly lower, since a small portion of the flow is discharged to the ocean.

Table 9-4. Summary of Projected Flow Allocations and Costs for Liquid Treatment, Disposal and Reuse for the Boca Raton WWTP

Alterna-tive	Year	WWTP	Ocean outfall	Flows (MGD) Trad. Reuse	GW recharge	Concen-trate	Cost ($/1000 gal) Scenario* A	C	E
I	2005	15.6	10.4	5.2	0	0	1.05	1.21	1.40
	2010	17.1	8.3	8.8	0	0	1.20	1.33	1.49
	2015	18.7	7.5	11.2	0	0	1.33	1.45	1.58
	2020	20.2	6.7	13.6	0	0	1.48	1.58	1.69
	2025	21.8	5.8	15.9	0	0	1.65	1.74	1.83
II	2005	15.6	10.4	5.2	0	0	1.05	1.21	1.40
	2010	17.1	11.1	6.0	0	0	1.05	1.22	1.42
	2015	18.7	9.1	9.5	0	0	1.20	1.33	1.48
	2020	20.2	2.2	18.0	0	0	1.99	2.04	2.08
	2025	21.8	0.5	21.3	0	0	2.35	2.37	2.38
III	2005	15.6	0.6	5.2	7.9	2.0	3.84	3.84	3.84
	2010	17.1	0.6	6.0	8.3	2.1	3.76	3.76	3.76
	2015	18.7	1.0	9.5	6.5	1.6	3.22	3.22	3.22
	2020	20.2	1.9	18.0	0.2	0.0	2.31	2.31	2.31
	2025	21.8	2.1	19.6	0.0	0.0	2.15	2.15	2.15
IV	2005	15.6	0	5.2	8.3	2.1		3.90	
	2010	17.1	0	6.0	8.9	2.2		3.83	
	2015	18.7	0	9.5	7.3	1.8		3.32	
	2020	20.2	0	18.0	1.8	0.4		2.57	
	2025	21.8	0	21.3	0.4	0.1		2.47	

*The scenarios for ocean outfall treatment requirements preceding basic level disinfection are: A--secondary, C--intermediate nutrient removal, and E--full nutrient removal. These scenarios are applicable to alternatives I, II, and III, which involve use of ocean outfalls.

Table 9-5. Outcomes of Indicators for Ocean Outfall Alternatives at the Boca Raton WWTP

		Treatment applied for ocean outfall discharge		
		A--Secondary treatment	**C**--Intermediate nutrient removal	**E**--Full nutrient removal
Alternative I-- Ocean outfalls used at current levels	N load reduction	59%	76%	93%
	P load reduction	59%	59%	59%
	Freshwater savings	59% (including 0% from groundwater recharge)		
	Public acceptance	High		
Alternative II-- Limited use of ocean outfalls	N load reduction	64%	79%	94%
	P load reduction	64%	64%	64%
	Freshwater savings	64% (including 0% from groundwater recharge)		
	Public acceptance	High		
Alternative III **O**cean outfalls as back up	N load reduction	93%	96%	99%
	P load reduction	93%	93%	93%
	Freshwater savings	82% (including 20% from groundwater recharge)		
	Public acceptance	Low-Moderate to Moderate-High		
Alternative IV-- No use of ocean outfalls	N load reduction	100%		
	P load reduction	100%		
	Freshwater savings	87% (including 23% from groundwater recharge)		
	Public acceptance	Low-Moderate to Moderate-High		

Summary. The benefits, costs and public acceptance of the ocean outfall alternatives for the Boca Raton WWTP are compared in Figure 9-2. The benefit is the average of percent freshwater savings and overall nutrient (N, P) load reduction. Public acceptance is rated on a scale of high = 97%, moderate = 71%, and low = 45%, as suggested by the survey from CDM (2004).

A benefit of up to 71% is achieved through various combinations of traditional reuse and nutrient control technology (alternatives I and II). These are also the alternatives with the highest public acceptance. The alternatives involving groundwater recharge (III and IV) achieve the highest benefits (88–93%), but are also most expensive and receive a lower level of public acceptance. The cost to achieve a benefit of 50% is \$1.00/1,000 gal. The cost to achieve a benefit of 75% increases to \$2.00/1,000 gal.

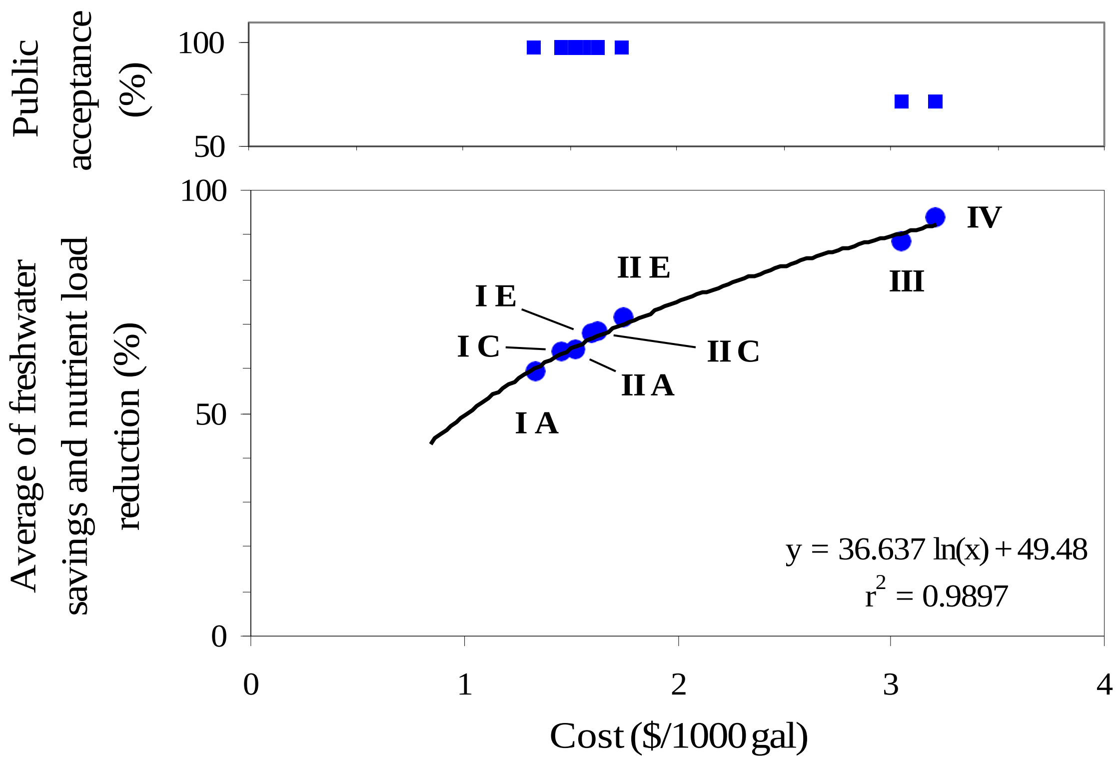

Figure 9-2. Public Acceptance and the Average of Percent Freshwater Savings and Nutrient Load Reduction versus Cost of Ocean Outfall Alternatives for the Boca Raton WWTP.

9.4 Broward/North WWTP

A summary of the projected flow allocations and costs for liquid treatment, reuse and disposal for the Broward/North WWTP is given in Table 9-6. A matrix of indicator outcomes over the years 2005–2025 is shown in Table 9-7.

Freshwater savings. Freshwater savings of 8–18% are achieved under alternatives I and II. The values of freshwater savings are expressed relative to the wastewater flow not discharged to Class I injection wells. The freshwater recovery under alternative III is 69%, which includes savings of 51% from groundwater recharge. The freshwater recovery under alternative IV is 71%, which includes savings of 52% from groundwater recharge.

Nutrient load reduction. Management options that include currently planned or limited use of ocean outfalls (alternatives I and II, respectively) limit ocean discharge of nitrogen by up to 83% and discharge of phosphorus by up to 37% through a combination of effluent diversion to traditional reuse and application of advanced treatment technology. The secondary effluent phosphorus concentration of the Broward/North WWTP averages 1.3 mg/L, which is less than the target effluent quality of intermediate nutrient removal technology and only slightly higher than the target effluent quality of full nutrient removal technology. Most of the phosphorus discharge limitation is therefore achieved through effluent diversion to reuse. Discharge of nutrients to the ocean is decreased by 98–100% under alternative III and by 100% under alternative IV.

Table 9-6. Summary of Projected Flow Allocations and Costs for Liquid Treatment, Disposal and Reuse for the Broward/North WWTP

		Flows (MGD)						Cost ($/1000 gal)					
			Ocean	UIC	Trad.	GW re-	Concen-	Scenario [2]					
Alt	Year	WWTP	outfall	wells [1]	reuse	charge	trate	A	B	C	D	E	F
I	2005	84.2	51.7	30.0	2.4	0	0	0.60	0.68	0.75	0.82	0.92	0.99
	2010	88.6	54.3	30.0	4.2	0	0	0.61	0.68	0.76	0.83	0.91	0.98
	2015	90.8	55.5	30.0	5.3	0	0	0.61	0.68	0.76	0.83	0.91	0.98
	2020	92.2	56.9	30.0	5.3	0	0	0.61	0.68	0.76	0.82	0.92	0.98
	2025	94.1	58.8	30.0	5.3	0	0	0.61	0.68	0.76	0.82	0.92	0.98
II	2005	84.2	51.7	30.0	2.4	0	0	0.60	0.68	0.75	0.82	0.92	0.99
	2010	88.6	54.3	30.0	4.2	0	0	0.61	0.68	0.76	0.83	0.91	0.98
	2015	90.8	51.3	30.0	9.4	0	0	0.66	0.72	0.79	0.85	0.94	1.00
	2020	92.2	46.6	30.0	15.6	0	0	0.77	0.83	0.89	0.95	1.02	1.08
	2025	94.1	41.1	30.0	23.0	0	0	1.01	1.07	1.11	1.17	1.22	1.28
III	2005	84.2	0.3	30.0	2.4	41.2	10.3	2.58	2.66	2.58	2.66	2.58	2.66
	2010	88.6	0.4	30.0	4.2	43.1	10.8	2.54	2.61	2.54	2.61	2.54	2.61
	2015	90.8	1.0	30.0	9.4	40.3	10.1	2.49	2.55	2.49	2.55	2.49	2.55
	2020	92.2	1.6	30.0	15.6	36.0	9.0	2.36	2.42	2.36	2.42	2.36	2.42
	2025	94.1	2.4	30.0	23.0	30.9	7.7	2.37	2.43	2.37	2.43	2.37	2.43
IV	2005	84.2	0	30.0	2.4	41.4	10.3	2.58 [3]			2.66 [4]		
	2010	88.6	0	30.0	4.2	43.5	10.9	2.54			2.61		
	2015	90.8	0	30.0	9.4	41.1	10.3	2.50			2.56		
	2020	92.2	0	30.0	15.6	37.3	9.3	2.38			2.44		
	2025	94.1	0	30.0	23.0	32.8	8.2	2.40			2.46		

[1] Class I

[2] The scenarios are defined in terms of ocean outfall treatment requirements preceding basic level disinfection (A, B--secondary; C, D--intermediate nutrient removal; E, F--full nutrient removal) and level of disinfection for discharge to Class I injection wells (A, C, E--none; B, D, F--high level). These scenarios are applicable to alternatives I, II and III, which involve use of ocean outfalls.

[3] No disinfection of effluent discharged to Class I UIC wells

[4] High-level disinfection of effluent discharged to Class I UIC wells

Public acceptance. The public acceptance of alternatives I and II is anticipated to be high because reclaimed water is used primarily for irrigation by larger users. The more substantial degree of freshwater savings due to groundwater recharge under alternatives III and IV will present a challenge in gaining public acceptance. However, misgivings about groundwater recharge may be substantially mitigated by public education efforts and community participation in the planning process. Thus, public acceptance is considered low-to-moderate for alternatives III and IV.

Cost-effectiveness. The costs range from $0.60 to $1.30/1,000 gal under alternatives I and II and $2.40 to $2.70/1,000 gal under alternatives III and IV. The Broward/North WWTP is the only facility of the six with Class I injection wells for effluent disposal in operation at the time the dataset for the present study was collected. Differences in costs between scenarios

A and B, C and D, and E and F represent an upgrade from no disinfection to high level disinfection for discharge to these wells. Accordingly, the costs increase somewhat between each pair of scenarios. Slight increments in the costs are also apparent as the degree of treatment for ocean-bound wastewater is increased from secondary (scenarios A and B) to intermediate nutrient removal (scenarios C and D) and finally to full nutrient removal (scenarios E and F). Under alternatives III and IV, costs are seen to decrease somewhat from 2005 to 2025. This is because the extent of traditional reuse increases with time, diminishing the flow that is recharged.

Table 9-7. Outcomes of Indicators for Ocean Outfall Alternatives at the Broward/North WWTP

		Secondary treatment for ocean outfall discharge		Intermediate nutrient removal for ocean outfall discharge		Full nutrient removal for ocean outfall discharge	
	Scenario*	**A**	**B**	**C**	**D**	**E**	**F**
Alt. I-- Ocean outfalls used at current levels	N load reduction	8%	8%	38%	38%	81%	81%
	P load reduction	8%	8%	8%	8%	29%	29%
	Freshwater savings	8% of wastewater not injected to Class I inection wells (including 0% from groundwater recharge)					
	Public acceptance	High					
Alt. II-- Limited use of ocean outfalls	N load reduction	18%	18%	45%	45%	83%	83%
	P load reduction	18%	18%	18%	18%	37%	37%
	Freshwater savings	18% of wastewater not injected to Class I injection wells (including 0% from groundwater recharge)					
	Public acceptance	High					
Alt III-- Ocean outfalls as backups	N load reduction	98%	99%	99%	98%	100%	100%
	P load reduction	98%	98%	98%	98%	99%	99%
	Freshwater savings	69% of wastewater not injected to Class I injection wells (including 51% from groundwater recharge)					
	Public acceptance	Low-Moderate					
Alt. IV-- No use of ocean outfalls	N load reduction	100%			100%		
	P load reduction	100%			100%		
	Freshwater savings	71% of wastewater not injected to Class I injection wells (including 52% from groundwater recharge)					
	Public acceptance	Low-Moderate					

*Scenarios: A, C, E--no disinfection for discharge to Class I injection wells; B, D, F--high level disinfection for discharge to Class I injection wells

Summary. The benefits, costs and public acceptance of the ocean outfall alternatives for the Broward/North WWTP are compared in Figure 9-3. The benefit is the average of percent freshwater savings and overall nutrient (N, P) load reduction. Public acceptance is rated on a scale of high = 97%, moderate = 71%, and low = 45%, as suggested by the survey from CDM (2004).

A benefit of up to 39% is achieved through various combinations of traditional reuse and nutrient control technology (alternatives I and II). These are also the alternatives with the highest public acceptance. The alternatives involving groundwater recharge (III and IV) achieve the highest benefits (84–85%), but are also most expensive and receive a lower level of public acceptance. The cost to achieve a benefit of 50% is $1.30/1,000 gal. The cost to achieve a benefit of 75% increases to $2.10/1,000 gal.

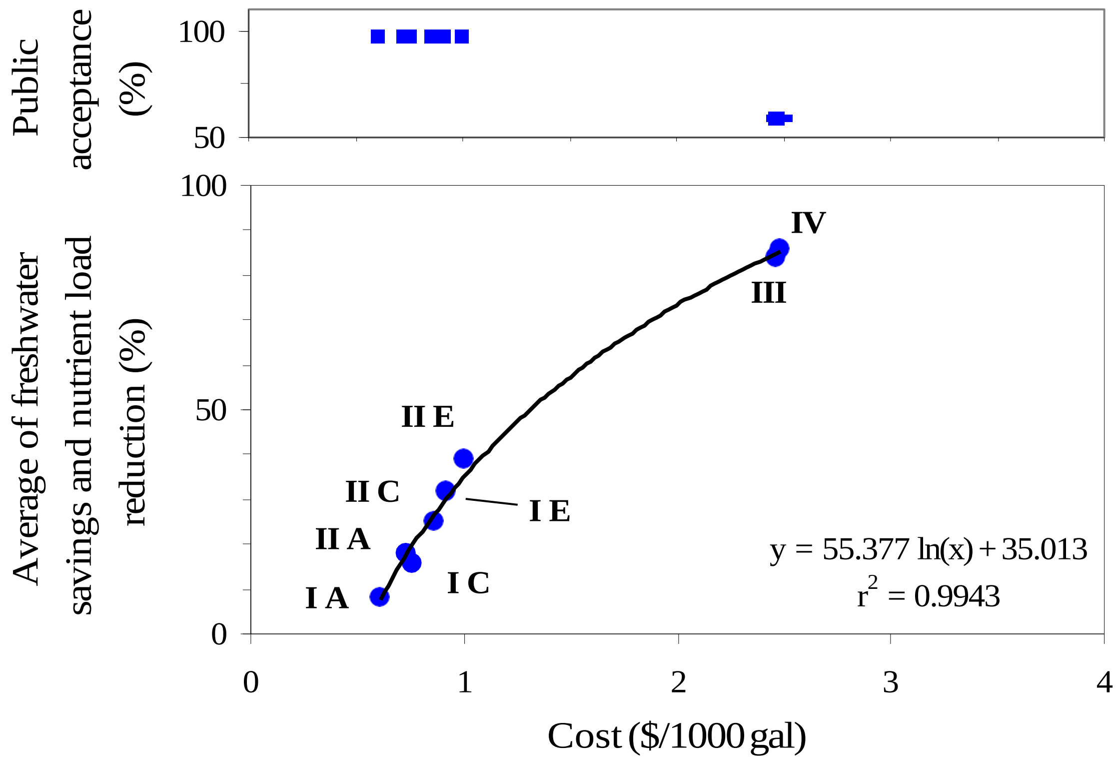

Figure 9-3. Public Acceptance and the Average of Percent Freshwater Savings and Nutrient Load Reduction versus Cost of Ocean Outfall Alternatives for the Broward/North WWTP.

9.5 Hollywood WWTP

A summary of the projected flow allocations and costs for liquid treatment, reuse and disposal for the Hollywood WWTP is given in Table 9-8. A matrix of indicator outcomes over the years 2005–2025 is shown in Table 9-9.

Freshwater savings. Freshwater savings of 9 to 10% are achieved under alternatives I and II, due mostly to the limited extent of traditional reuse. There is a modest level of groundwater recharge under these two alternatives, which also contributes to the freshwater savings. The freshwater savings under alternatives III and IV are 67%, which includes savings of 57–58% from groundwater recharge.

Nutrient load reduction. Management options that include currently planned or limited use of ocean outfalls (alternatives I and II, respectively) limit ocean discharge of nitrogen by up to 84%. The maximum limitation of phosphorus discharge for these alternatives is 18%, due to the limited extent of traditional reuse and the effluent total phosphorus concentration of 1.1 mg/L, which is only slightly higher than the target effluent quality for full nutrient removal technology. Discharge of nutrients to the ocean is decreased by 99–100% under alternative III and by 100% under alternative IV.

Table 9-8. Summary of Flow Allocations and Costs for Liquid Treatment, Disposal and Reuse for the Hollywood WWTP

Alterna-tive	Year	WWTP	Flows (MGD) Ocean outfall	Trad. Reuse	GW recharge	Concen-trate	Cost ($/1000 gal) Scenario* A	C	E
I	2005	40.0	37.4	2.6	0	0	0.62	0.95	1.17
	2010	43.5	39.9	3.6	0	0	0.62	0.93	1.15
	2015	47.2	43.5	3.6	0	0	0.61	0.92	1.14
	2020	50.9	46.3	3.6	0.75	0.19	0.72	1.01	1.23
	2025	54.5	46.3	3.6	3.6	0.9	1.08	1.36	1.53
II	2005	40.0	37.4	2.6	0	0	0.62	0.95	1.17
	2010	43.5	39.9	3.6	0	0	0.62	0.93	1.15
	2015	47.2	42.9	4.2	0	0	0.62	0.92	1.15
	2020	50.9	45.6	5.2	0	0	0.63	0.91	1.13
	2025	54.5	46.3	6.1	1.7	0.4	0.86	1.13	1.31
III	2005	40.0	0.3	2.6	29.7	7.4	3.96	3.96	3.96
	2010	43.5	0.4	3.6	31.6	7.9	3.86	3.86	3.86
	2015	47.2	0.4	4.2	34.0	8.5	3.81	3.81	3.81
	2020	50.9	0.6	5.2	36.1	9.0	3.72	3.72	3.72
	2025	54.5	0.6	6.1	38.2	9.5	3.66	3.66	3.66
IV	2005	40.0	0.0	2.6	29.9	7.5		3.96	
	2010	43.5	0.0	3.6	31.9	8.0		3.88	
	2015	47.2	0.0	4.2	34.3	8.6		3.84	
	2020	50.9	0.0	5.2	36.5	9.1		3.76	
	2025	54.5	0.0	6.1	38.7	9.7		3.71	

*The scenarios for ocean outfall treatment requirements preceding basic level disinfection are: A--secondary, C--intermediate nutrient removal, and E--full nutrient removal. These scenarios are applicable to alternatives I, II, and III, which involve use of ocean outfalls.

Public acceptance. The public acceptance of alternatives I and II is anticipated to be high because reclaimed water is used primarily for irrigation by larger users. The substantial degree of freshwater savings due to groundwater recharge under alternatives III and IV presents a challenge in gaining public acceptance. Accordingly, public acceptance is considered to be low-to-moderate for these two alternatives.

Cost-effectiveness. The costs under alternatives I and II range from $0.60 to $1.50/1,000 gal, while the projected costs for alternatives III and IV range between $3.70 and $4.00/1,000 gal. Increments in the costs are apparent as the degree of treatment for ocean-bound wastewater is increased from secondary to full nutrient removal. The inflow to the plant is projected to exceed the ocean outfall permitted capacity of 46.3 MGD sometime before the year 2015. The amount of inflow in excess of this value must be handled by a combination of traditional reuse and groundwater recharge. Projected traditional reuse flows will be insufficient to handle the excess towards the end of the projection period, necessitating a modest flow to groundwater recharge. The higher extent of traditional reuse projected under alternative II results in lowered costs for this alternative.

Table 9-9. Outcomes of Indicators for Ocean Outfall Alternatives at the Hollywood WWTP

		Treatment applied for ocean outfall discharge		
		A--Secondary treatment	**C--**Intermediate nutrient removal	**E--**Full nutrient removal
Alternative I-- Ocean outfalls used at current levels	N load reduction	10%	46%	84%
	P load reduction	10%	10%	18%
	Freshwater savings	9% (including 2% from groundwater recharge)		
	Public acceptance	High		
Alternative II-- Limited use of ocean outfalls	N load reduction	10%	46%	84%
	P load reduction	10%	10%	18%
	Freshwater savings	10% (including 1% from groundwater recharge)		
	Public acceptance	High		
Alternative III-- Ocean outfalls as back up	N load reduction	99%	99%	100%
	P load reduction	99%	99%	99%
	Freshwater savings	67% (including 57% from groundwater recharge)		
	Public acceptance	Low-Moderate		
Alternative IV-- No use of ocean outfalls	N load reduction	100%		
	P load reduction	100%		
	Freshwater savings	67% (including 58% from groundwater recharge)		
	Public acceptance	Low-Moderate		

Summary. The benefits, costs and public acceptance of the ocean outfall alternatives for the Hollywood WWTP are compared in Figure 9-4. The benefit is the average of percent freshwater savings and overall nutrient (N, P) load reduction. Public acceptance is rated on a scale of high = 97%, moderate = 71%, and low = 45%, as suggested by the survey from CDM (2004).

A benefit of up to 30% is achieved through various combinations of traditional reuse, groundwater recharge and nutrient control technology (alternatives I and II). These are also the alternatives with the highest public acceptance. The alternatives involving extensive groundwater recharge (III and IV) achieve the highest benefits (83%), but are also most expensive and receive a lower level of public acceptance. The cost to achieve a benefit of 50% is $1.90/1,000 gal. The cost to achieve a benefit of 75% increases to $3.25/1,000 gal.

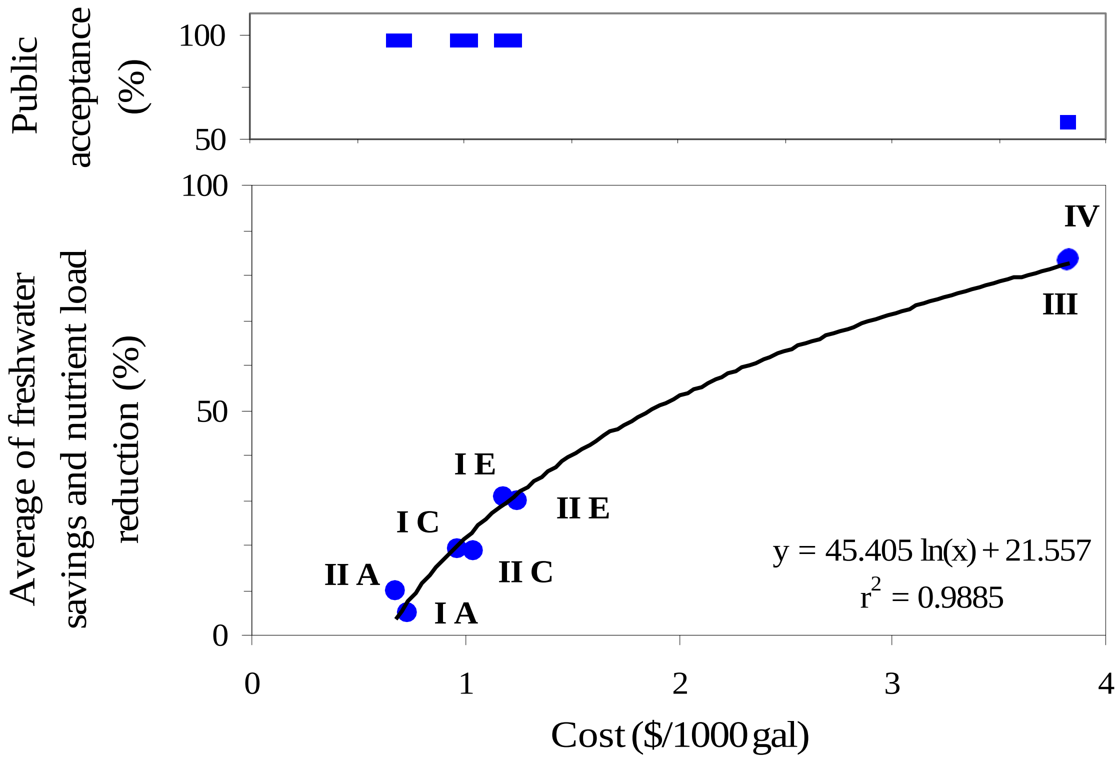

Figure 9-4. Public Acceptance and the Average of Percent Freshwater Savings and Nutrient Load Reduction versus Cost of Ocean Outfall Alternatives for the Hollywood WWTP.

9.6 Miami-Dade/North WWTP

A summary of the projected flow allocations and costs for liquid treatment, reuse and disposal for the Miami-Dade/North WWTP is given in Table 9-10. A matrix of indicator outcomes over the years 2005–2025 is shown in Table 9-11.

Freshwater savings. Modest freshwater savings of 3% under alternative I and 4% under alternative II are achieved, with half or more of the savings deriving from groundwater recharge. The freshwater savings under alternatives III and IV is 64–65%, which includes savings of 63% from groundwater recharge.

Pollutant load reduction. Management options that include currently planned or limited use of ocean outfalls (alternatives I and II, respectively) limit ocean discharge of nitrogen by up to 84% and discharge of phosphorus by up to 44%. Nutrient load reduction under alternatives III and IV is 100%.

Public acceptance. The public acceptance of alternatives I and II is anticipated to be high because of the very limited extent of water reuse. The substantial degree of freshwater savings due to groundwater recharge under alternatives III and IV poses a challenge to gaining public acceptance. However, a concerted public education efforts and community participation in the planning process could overcome this challenge. Thus, the degree of public acceptance is considered to be low-moderate for this alternative.

Table 9-10. Summary of Flow Allocations and Costs for Liquid Treatment, Disposal and Reuse for the Miami-Dade/North WWTP

Alternative	Year	WWTP	Flows (MGD) Ocean outfall	Trad. Reuse	GW recharge	Concentrate	Cost ($/1000 gal) Scenario* A	C	E
I	2005	107.9	107.8	0.1	0.0	0.0	0.55	0.84	1.08
	2010	111.9	111.8	0.1	0.0	0.0	0.54	0.83	1.07
	2015	116.6	112.5	0.1	3.2	0.8	0.68	0.97	1.19
	2020	121.3	112.5	0.1	6.9	1.7	0.84	1.11	1.32
	2025	126.3	112.5	0.1	10.9	2.7	0.96	1.22	1.43
II	2005	107.9	107.8	0.1	0.0	0.0	0.55	0.84	1.08
	2010	111.9	111.4	0.5	0.0	0.0	0.54	0.83	1.07
	2015	116.6	112.5	2.0	1.8	0.4	0.60	0.89	1.13
	2020	121.3	112.5	2.4	5.1	1.3	0.78	1.06	1.25
	2025	126.3	112.5	3.7	8.1	2.0	0.85	1.12	1.32
III	2005	107.9	0.0	0.1	86.2	21.6	3.15	3.15	3.15
	2010	111.9	0.1	0.5	89.1	22.3	3.10	3.10	3.10
	2015	116.6	0.2	2.0	91.5	22.9	3.05	3.05	3.05
	2020	121.3	0.3	2.4	94.9	23.7	3.00	3.00	3.00
	2025	126.3	0.4	3.7	97.7	24.4	2.95	2.95	2.95
IV	2005	107.9	0.0	0.1	86.2	21.6		3.15	
	2010	111.9	0.0	0.5	89.1	22.3		3.10	
	2015	116.6	0.0	2.0	91.7	22.9		3.05	
	2020	121.3	0.0	2.4	95.1	23.8		3.00	
	2025	126.3	0.0	3.7	98.0	24.5		2.95	

*The scenarios for ocean outfall treatment requirements preceding basic level disinfection are: A--secondary, C--intermediate nutrient removal, and E--full nutrient removal. These scenarios are applicable to alternatives I, II, and III, which involve use of ocean outfalls.

Cost-effectiveness. The projected costs under alternatives I and II range from $0.55 to $1.40/1,000 gal, whereas the projected costs for alternatives III and IV are in the range of $2.95 to $3.15/1,000 gal. Increments in the costs are apparent as the degree of treatment for ocean-bound wastewater is increased from secondary to full nutrient removal. The inflow to the plant is projected to reach the permitted capacity of the ocean outfall (112.5 MGD) by the year 2010. Flows in excess of 112.5 MGD must be handled by a combination of traditional reuse and groundwater recharge. The higher extent of traditional reuse projected under alternative II thus leads to somewhat lower costs.

Table 9-11. Outcomes of Indicators for Ocean Outfall Alternatives at the Miami-Dade/North WWTP

	Treatment applied for ocean outfall discharge		
	A--Secondary treatment	C--Intermediate nutrient removal	E--Full nutrient removal
N load reduction	5%	45%	84%
P load reduction	5%	5%	44%
Freshwater savings	3% (almost all from groundwater recharge)		
Public acceptance	High		
N load reduction	5%	46%	84%
P load reduction	5%	5%	44%
Freshwater savings	4% (including 2% from groundwater recharge)		
Public acceptance	High		
N load reduction	100%	100%	100%
P load reduction	100%	100%	100%
Freshwater savings	64% (including 63% from groundwater recharge)		
Public acceptance	Low-Moderate		
N load reduction	100%		
P load reduction	100%		
Freshwater savings	65% (including 63% from groundwater recharge)		
Public acceptance	Low-Moderate		

Summary. The benefits, costs and public acceptance of the ocean outfall alternatives for the Miami-Dade/North WWTP are compared in Figure 9-5. The benefit is the average of percent freshwater savings and overall nutrient (N, P) load reduction. Public acceptance is rated on a scale of high = 97%, moderate = 71%, and low = 45%, as suggested by the survey from CDM (2004).

A benefit of up to 34% is achieved through various combinations of traditional reuse, groundwater recharge and nutrient control technology (alternatives I and II). These are also the alternatives with the highest public acceptance. The alternatives involving extensive groundwater recharge (III and IV) achieve the highest benefits (82%), but are also most expensive and receive a lower level of public acceptance. The cost to achieve a benefit of 50% is $1.70/1,000 gal. The cost to achieve a benefit of 75% increases to $2.70/1,000 gal.

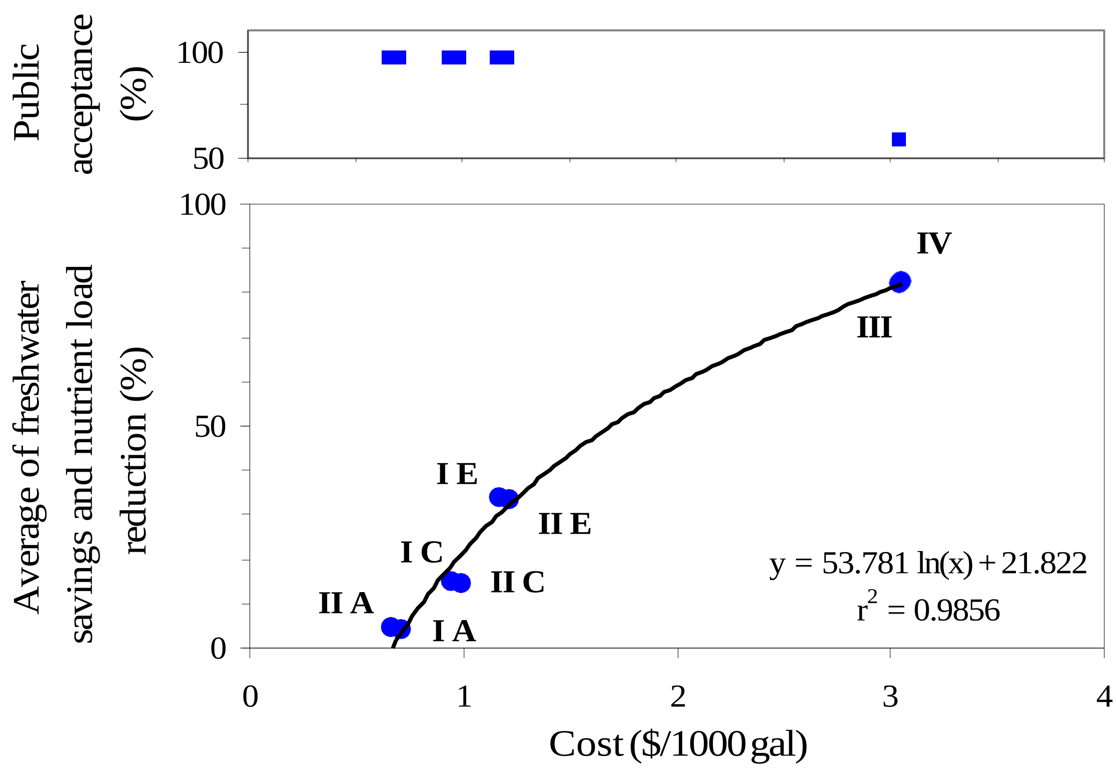

Figure 9-5. Public Acceptance and the Average of Percent Freshwater Savings and Nutrient Load Reduction versus Cost of Ocean Outfall Alternatives for the Miami-Dade/North WWTP.

9.7 Miami-Dade/Central WWTP

A summary of the projected flow allocations and costs for liquid treatment, reuse and disposal for the Miami-Dade/Central WWTP is given in Table 9-12. A matrix of indicator outcomes over the years 2005–2025 is shown in Table 9-13.

Freshwater savings. Very modest freshwater savings of 1% under alternatives I and II are achieved, due to the limited extent of traditional reuse. The freshwater savings under alternatives III and IV are 64%, which includes savings of 63% from groundwater recharge.

Pollutant load reduction. Management options that include currently planned or limited use of ocean outfalls (alternatives I and II, respectively) limit ocean discharge of nitrogen by up to 83% and discharge of phosphorus by up to 39%. Nutrient load reduction under alternatives III and IV is 100%.

Public acceptance. The public acceptance of alternatives I and II is anticipated to be high because of the very limited extent of water reuse. The substantial extent of groundwater recharge under alternatives III and IV presents a challenge in gaining public acceptance. Depending on the extent and success of the community involvement and public education efforts, a public acceptance of low-to-moderate could be expected.

Table 9-12. Summary of Flow Allocations and Costs for Liquid Treatment, Disposal and Reuse for the Miami-Dade/Central WWTP

Alterna-tive	Year	WWTP	Flows (MGD) Ocean outfall	Trad. Reuse	GW recharge	Concen-trate	Cost ($/1000 gal) Scenario* A	C	E
I	2005	129.4	129.4	0.0	0.0	0.0	0.50	0.87	1.12
	2010	134.1	134.1	0.0	0.0	0.0	0.50	0.87	1.12
	2015	139.8	139.8	0.0	0.0	0.0	0.49	0.86	1.12
	2020	145.4	143.0	0.0	1.9	0.5	0.54	0.90	1.15
	2025	151.3	143.0	0.0	6.7	1.7	0.60	1.00	1.25
II	2005	129.4	129.4	0.0	0.0	0.0	0.50	0.87	1.12
	2010	134.1	133.7	0.4	0.0	0.0	0.50	0.86	1.11
	2015	139.8	138.9	1.0	0.0	0.0	0.49	0.86	1.11
	2020	145.4	143.0	2.1	0.2	0.1	0.50	0.86	1.11
	2025	151.3	143.0	2.9	4.4	1.1	0.58	0.94	1.19
III	2005	129.4	0.0	0.0	103.5	25.9	3.96	3.96	3.96
	2010	134.1	0.1	0.4	106.9	26.7	3.90	3.90	3.90
	2015	139.8	0.1	1.0	111.0	27.8	3.82	3.82	3.82
	2020	145.4	0.2	2.1	114.5	28.6	3.77	3.77	3.77
	2025	151.3	0.3	2.9	118.5	29.6	3.72	3.72	3.72
IV	2005	129.4	0	0.0	103.5	25.9		3.96	
	2010	134.1	0	0.4	106.9	26.7		3.91	
	2015	139.8	0	1.0	111.1	27.8		3.83	
	2020	145.4	0	2.1	114.6	28.7		3.78	
	2025	151.3	0	2.9	118.8	29.7		3.72	

*The scenarios for ocean outfall treatment requirements preceding basic level disinfection are: A--secondary, C--intermediate nutrient removal, and E--full nutrient removal. These scenarios are applicable to alternatives I, II, and III, which involve use of ocean outfalls.

Cost-effectiveness. The costs under alternatives I and II range from $0.50 to $1.25/1,000 gal, whereas costs under alternatives III and IV range from $3.70 to $4.00/1,000 gal. Increments in the costs are apparent as the degree of treatment for ocean-bound wastewater is increased from secondary to full nutrient removal. The permitted ocean outfall capacity is 143 MGD. Projected traditional reuse will not be sufficient to handle flows in excess of this amount after the plant inflow reaches 143 MGD sometime between the years 2015 and 2020. Thus, a modest degree of groundwater recharge is required under alternative I and a lesser extent of groundwater recharge is required under alternative II.

Table 9-13. Outcomes of Indicators for Ocean Outfall Alternatives at the Miami-Dade/Central WWTP

		Treatment applied for ocean outfall discharge		
		A--Secondary treatment	C--Intermediate nutrient removal	E--Full nutrient removal
Alternative I-- Ocean outfalls used at current levels	N load reduction	2%	42%	82%
	P load reduction	2%	2%	39%
	Freshwater savings	1% (all from groundwater recharge)		
	Public acceptance	High		
Alternative II-- Limited use of ocean outfalls	N load reduction	2%	42%	83%
	P load reduction	2%	2%	39%
	Freshwater savings	1% (including 0.5% from groundwater recharge)		
	Public acceptance	High		
Alternative III-- Ocean outfalls as back up	N load reduction	100%	100%	100%
	P load reduction	100%	100%	100%
	Freshwater savings	64% (including 63% from groundwater recharge)		
	Public acceptance	Low-Moderate		
Alternative IV-- No use of ocean outfalls	N load reduction	100%		
	P load reduction	100%		
	Freshwater savings	64% (including 63% from groundwater recharge)		
	Public acceptance	Low-Moderate		

Summary. The benefits, costs and public acceptance of the ocean outfall alternatives for the Miami-Dade/North WWTP are compared in Figure 9-6. The benefit is the average of percent freshwater savings and overall nutrient (N, P) load reduction. Public acceptance is rated on a scale of high = 97%, moderate = 71%, and low = 45%, as suggested by the survey from CDM (2004).

A benefit of up to 31% is achieved through various combinations of traditional reuse, groundwater recharge and nutrient control technology (alternatives I and II). These are also the alternatives with the highest public acceptance. The alternatives involving extensive groundwater recharge (III and IV) achieve the highest benefits (82%), but are also most expensive and receive a lower level of public acceptance. The cost to achieve a benefit of 50% is $1.90/1,000 gal. The cost to achieve a benefit of 75% increases to $3.40/1,000 gal.

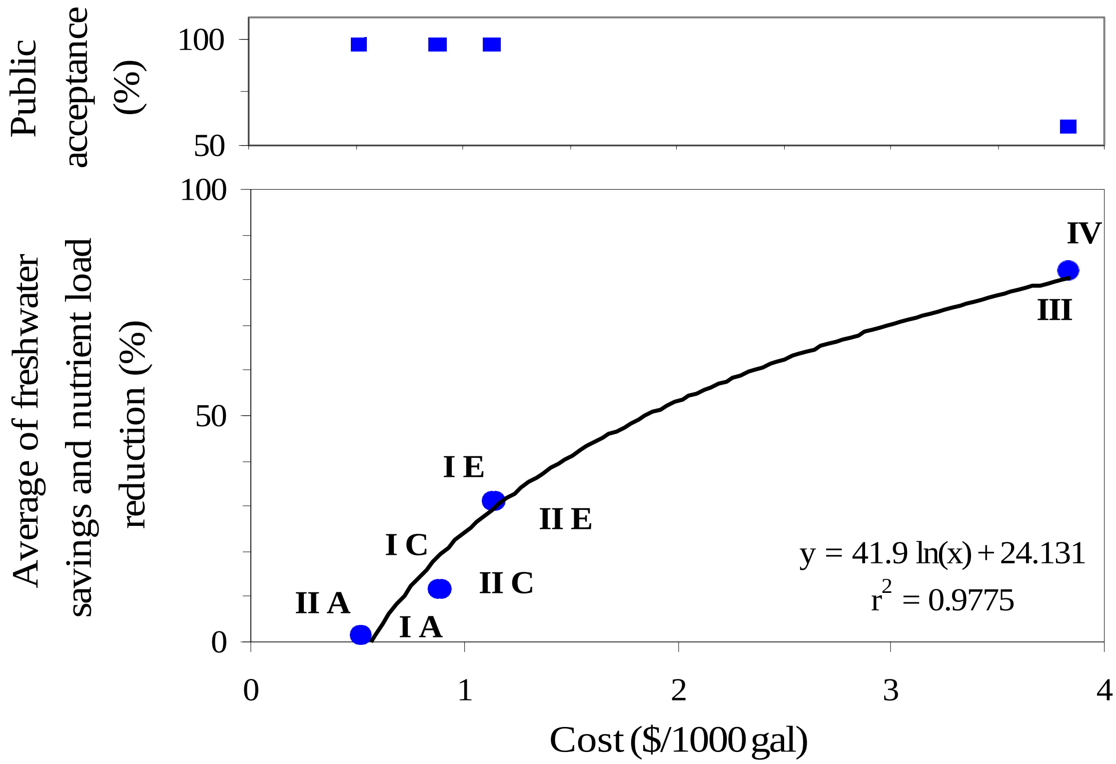

Figure 9-6. Public Acceptance and the Average of Percent Freshwater Savings and Nutrient Load Reduction versus Cost of Ocean Outfall Alternatives for the Miami-Dade/Central WWTP.

9.8 Comparison of Indicators among the Six WWTPs with Ocean Outfalls

Nutrient load reductions, freshwater savings and costs averaged over the 2005–2025 projection period are compared among the six WWTPs in this section. The Ocean Outfalls as Backups (Alt III) and No Use (Alt IV) alternatives have very similar values of these indicators. Therefore, values of the indicators under alternative IV are not discussed.

9.8.1 Nutrient Load Reductions

Reductions in nutrient load to the ocean are summarized in Figure 9-7 for three levels of treatment—secondary, intermediate nutrient removal and full nutrient removal—under the Currently Planned Use (Alt I), Limited Use (Alt II), and Use as Backups (Alt III) alternatives. Since the base case is defined on the basis of secondary treatment, nutrient reductions under the secondary treatment scenario are achieved by diverting flow from the ocean outfalls to reuse and are identical to the reuse percentages. The Boca Raton and Boynton-Delray WWTPs have the highest projected traditional reuse percentages and thus achieve the highest nutrient load reductions—57% and 64%, respectively, under alternative II (Fig. 9-7a, d). The Broward/North, Hollywood, Miami-Dade/North and Miami-Dade/Central WWTPs have lower projected traditional reuse percentages and therefore lower nutrient reductions—18% or less under alternative II. The results for alternative I are similar, but generally involve less reuse and therefore lower nutrient reductions.

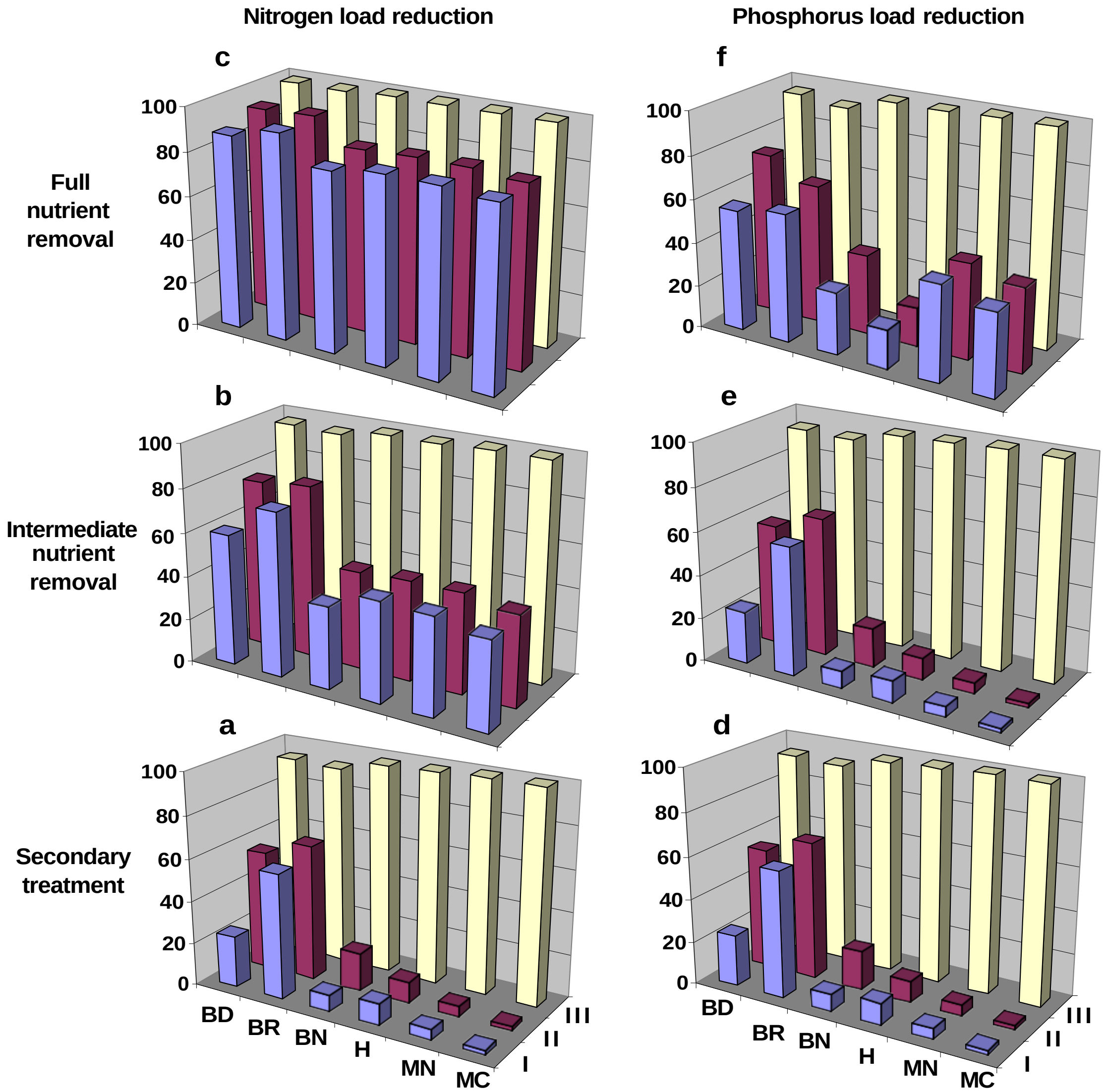

Figure 9-7. Percentage Reductions in Ocean Nutrient Load Achieved by Ocean Outfall Alternatives. I = currently planned use of ocean outfalls, II = limited use of ocean outfalls and III = ocean outfalls as backups; BD = Boynton-Delray, BR = Boca Raton, BN = Broward/North, H = Hollywood, MN = Miami-Dade/North, and MC = Miami-Dade/Central.

Intermediate nutrient control technology improves nitrogen load reductions at all the facilities relative to secondary treatment (Fig. 9-7b). Under alternatives I and II, the Palm Beach County facilities (Boynton-Delray, Boca Raton) reduce nitrogen loads by 77–79% whereas the Broward County (Broward/North, Hollywood) and Miami-Dade County (Miami-Dade/North, Miami-Dade/Central) facilities reduce nitrogen loads by 42–46%. Intermediate nutrient control technology does not improve phosphorus load reductions (Fig. 9-7e), since the effluent phosphorus levels in secondary effluents from all six facilities are below the concentration of 3 mg/L normally achievable by this technology.

Full nutrient removal technology brings the nitrogen load reductions at the Palm Beach County WWTPs to the range of 93–94% under alternatives I and II (Fig. 9-7c), which is comparable to that achieved under alternative III. Nitrogen load reductions at the Broward and Miami-Dade County facilities are somewhat lower—in the range of 83–84%—because of less traditional reuse. Phosphorus load reductions under alternatives I and II reach 64–74% at the Palm Beach County plants and 18–44% at the Broward County and Miami-Dade County plants (Fig. 9-7f).

9.8.2 Freshwater Savings

Freshwater savings relative to the base case, which has zero reuse, are summarized in Figure 9-8. Savings due to traditional reuse are highest at the Palm Beach County WWTPs, reaching 56–64% under alternatives II and III, compared to 18% or less under these alternatives at the Broward and Miami-Dade County WWTPs (Fig. 9-8a). Results for alternative I are similar, but involve less traditional reuse and therefore less freshwater savings. Groundwater recharge is negligible under alternatives I and II and accordingly there is little or no freshwater savings attributable to groundwater recharge under these alternatives (Fig. 9-8b). Groundwater recharge is extensive under alternative III, particularly at the facilities with limited traditional reuse. The Broward/North, Hollywood, Miami-Dade/North and Miami-Dade/Central WWTPs have freshwater savings of 51–63% due to groundwater recharge under alternative III, compared to 20–28% at the Boynton-Delray and Boca Raton WWTPs. The total freshwater savings are highest at the facilities with most extensive traditional reuse (Fig. 9-8c), ranging from 1% to 59% under alternative I, 1% to 64% under alternative II, and 64% to 82% under alternative III.

9.8.3 Costs

The costs of the various scenarios are compared among the six WWTPs in Figure 9-9. Under the Limited Use alternative (Alt II) and the secondary treatment scenario, costs vary in proportion to the extent of traditional reuse, ranging from $0.50 to $0.70/1,000 gal at the Broward County and Miami-Dade County facilities, where traditional reuse is least, to $1.50/1,000 gal at the Palm Beach County WWTPs, where traditional reuse is greatest (Fig. 9-9a). Costs under the intermediate nutrient removal scenario increase to $0.90–1.00/1,000 gal at the Broward County and Miami-Dade County facilities and $1.60–1.70/1,000 gal at the Boynton-Delray and Boca Raton facilities (Fig. 9-9b). Under the full nutrient removal scenario, costs increase to $1.00–1.20/1,000 gal at the Broward County and Miami-Dade County facilities and $1.80/1,000 gal at the Palm Beach County facilities (Fig. 9-9c). The results under alternative I are generally similar.

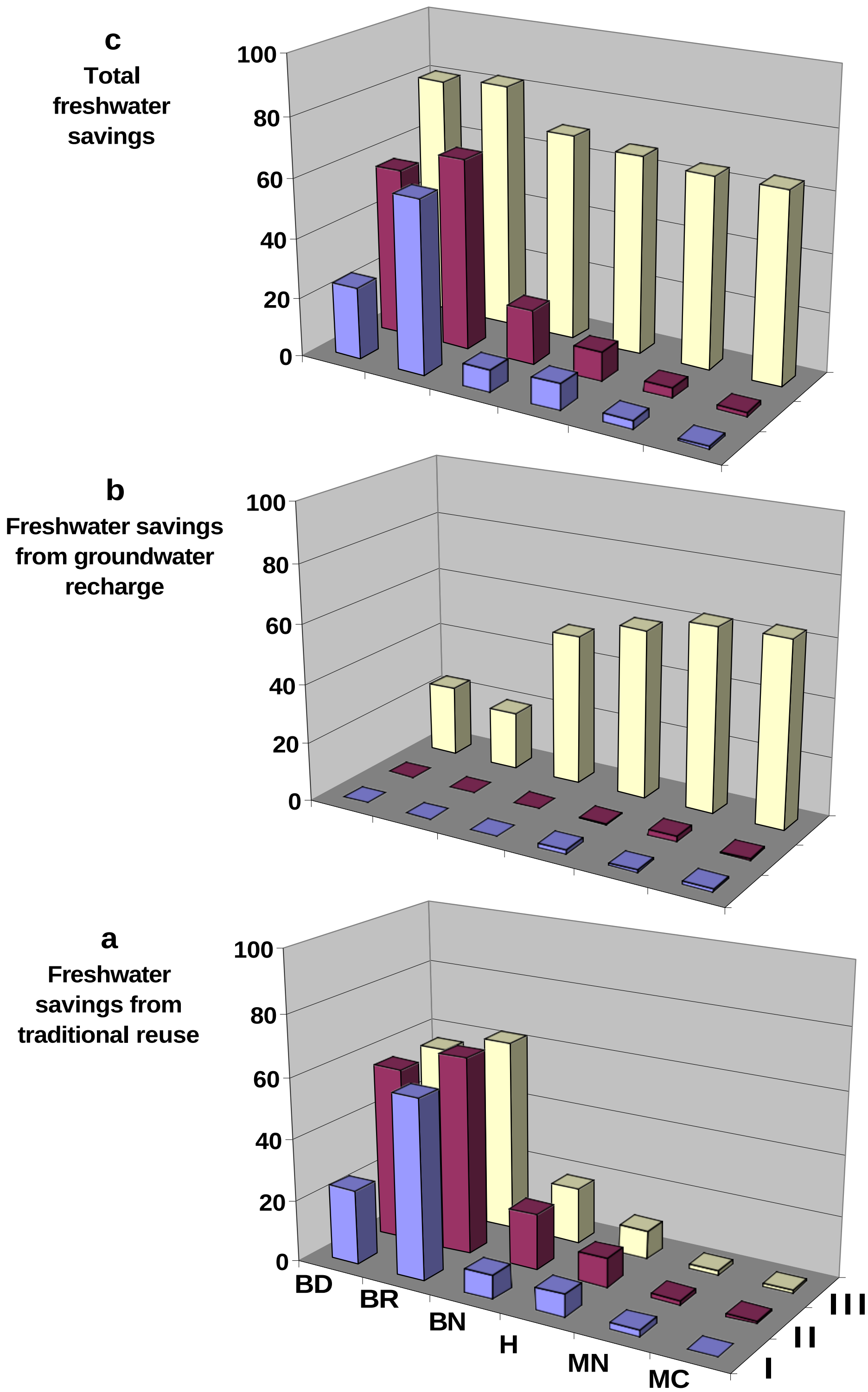

Figure 9-8. Freshwater Savings by Ocean Outfall Alternatives as Percent of Flow Treated. BD = Boynton-Delray, BR = Boca Raton, BN = Broward/North, H = Hollywood, MN = Miami-Dade/North, MC = Miami-Dade/Central. Alternatives are I–currently planned use of ocean outfalls, II–limited use of ocean outfalls, and III–use of ocean outfalls as backups. (Freshwater savings are expressed as percent of treated flow not discharged to Class I injection wells at the Broward/North WWTP.)

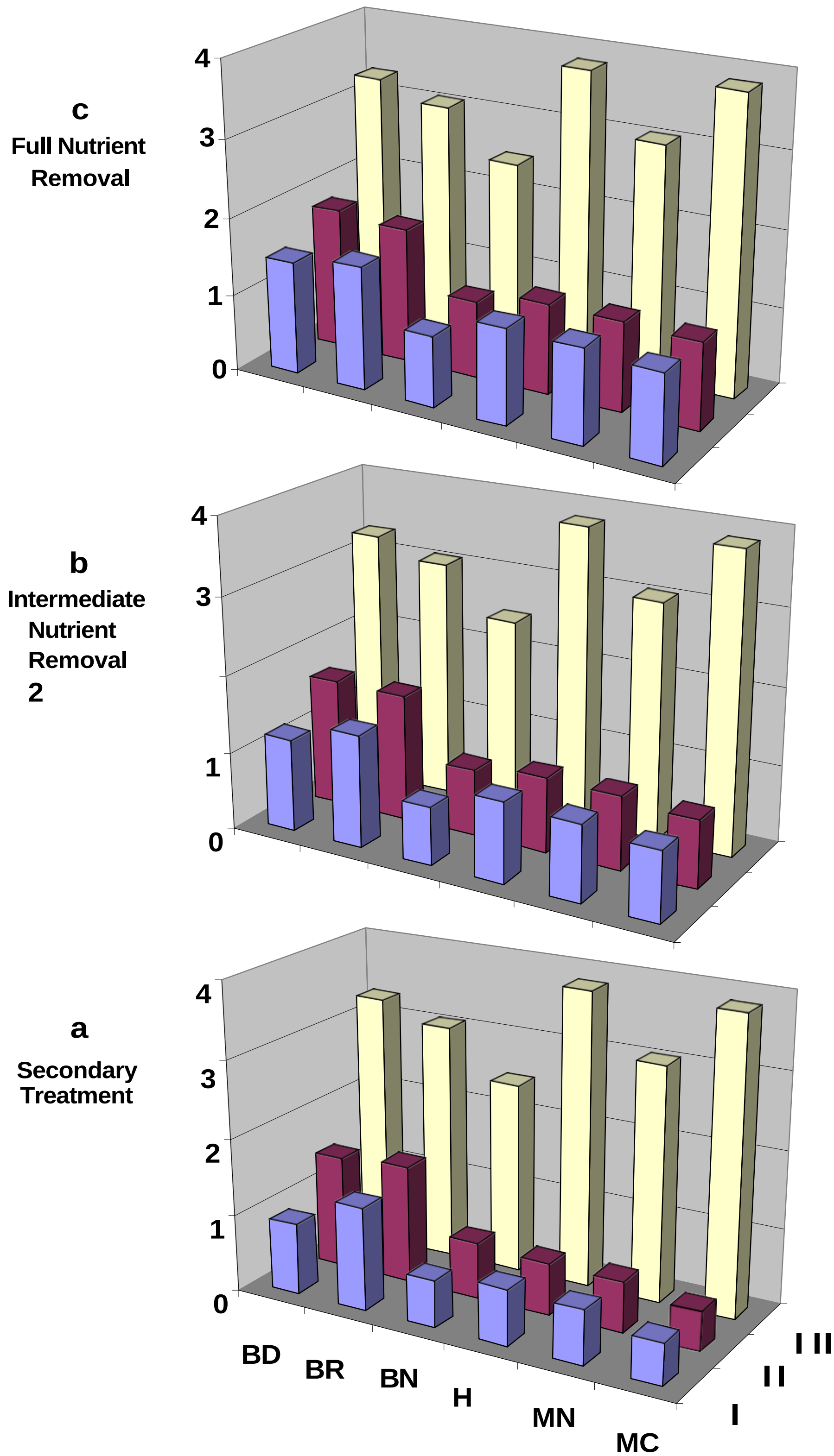

Figure 9-9. Costs for Ocean Outfall Alternatives in $/1,000 gal. BD = Boynton-Delray, BR = Boca Raton, BN = Broward/North, H = Hollywood, MN = Miami-Dade/North, MC = Miami-Dade/Central. Alternatives are I–currently planned use, II–limited use, and III–backup use.

Very little flow reaches the outfalls under alternative III; therefore, the costs of this alternative are only slightly influenced by the level of treatment applied for ocean outfall disposal. The costs are highest ($3.80/1,000 gal) at the Miami-Dade/Central and Hollywood WWTPs. Both of these facilities have limited traditional reuse; therefore, most of the flow is handled by groundwater recharge under alternative III. The sites of recharge are very far (up to 35 miles) from the Miami-Dade/Central facility and hence high reclaimed water transmission costs are incurred. The Hollywood facility has a long transport distance to the recharge site and also has relatively high costs for concentrate disposal. Costs at the Broward/North WWTP are relatively low ($2.50/1,000 gal) because of relatively close proximity of recharge sites and a moderate level of traditional reuse. Costs at the other three facilities are in the range of $3.10 to $3.30/1,000 gal.

As shown earlier, the full nutrient control scenario under alternative II can achieve nitrogen load reductions that are on the same order as those achieved by alternative III. It is therefore interesting to express the cost of this scenario relative to that of alternative III. Costs of the full nutrient removal scenario at the Broward and Miami-Dade County WWTPs range from 29–40% of the costs of alternative III, while achieving nitrogen load reductions of 83–84%. At the Palm Beach County plants, the full nutrient removal scenario has costs that are 55–57% those of alternative III, while achieving nitrogen load reductions of 93–94%. However, corresponding phosphorus load reductions are less impressive, ranging from 18 to 74% at the six WWTPs.

9.9 Summary

Four alternative ocean outfall strategies were examined under the defined scope of this study. Under the Currently Planned Use alternative (Alt I), ocean outfalls would be used at currently planned levels. Under the Limited Use Alternative (Alt II), ocean outfall disposal would be limited to flows remaining after traditional reuse options were maximized and underground injection flows reached full 2005 permitted capacity. Under the Ocean Outfalls as Backups alternative (Alt III), ocean disposal would only be used during wet weather periods to handle flow that would otherwise go to traditional reuse. Complete elimination of ocean outfalls was considered under the No Use alternative (Alt IV). Varying degrees of treatment (secondary, intermediate nutrient removal, full nutrient removal) were considered for wastewater that is destined for ocean disposal. Secondary treatment with no disinfection vs. secondary treatment with filtration and high-level disinfection was considered for disposal through Class I injection wells. Four indicators (performance measures) were evaluated for each alternative: 1) amount of freshwater saved relative to a base case with no reuse, 2) reductions in nitrogen and phosphorus discharged via ocean outfalls relative to the base case, 3) public acceptance, and 4) costs. The results are given in a series of 13 tables and 9 figures.

The following conclusions and recommendations were reached from evaluation of the ocean outfall alternatives:

- Traditional (public access) reuse for the Boynton-Delray and Boca Raton WWTPs could substantially reduce nutrient loads to the ocean. Substantial reduction of nutrient loads from the other four facilities can be achieved through groundwater recharge, since traditional reuse opportunities are more limited in these areas.

- Substantial reductions in nitrogen loads are achievable through intermediate and full nutrient removal technologies. Given the relatively low total phosphorus concentrations in effluents from the WWTPs, only full nutrient removal technology can reduce phosphorus loads. Substantial reductions in phosphorus load will require moving toward either traditional reuse or groundwater recharge.
- The average freshwater savings are essentially equal to traditional reuse volumes under alternatives I (currently planned use of ocean outfalls) and II (limited use of ocean outfalls) and range from 24 to 64% at the Boynton-Delray and Boca Raton WWTPs and from 1 to 18% at the other four facilities.
- Under alternatives III (use of ocean outfalls as backups) and IV (no use of ocean outfalls), average freshwater savings range from 64 to 87%.
- Public acceptance of alternatives I and II is expected to be high at all of the facilities because the reclaimed water is used primarily for irrigation.
- Public acceptance of alternatives featuring large-scale groundwater recharge could be moderate or lower. However, public education programs and community involvement throughout the planning, implementation, and continued use of water reuse projects should help mitigate public concerns.
- Trends between costs and the percent average of freshwater savings and nutrient load reduction indicate that alternatives emphasizing traditional reuse and nutrient control technology are somewhat more cost effective than those emphasizing groundwater recharge. The ability to generate revenues from traditional reuse further increases the attractiveness of this approach.
- At the facilities with lesser densities of consumptive use permittees (Hollywood, Miami-Dade/North and Miami-Dade/Central), extensive groundwater recharge would be required to achieve a 50% average of freshwater savings and nutrient load reduction unless industries and residential users are added to the reclaimed water customer base.
- The costs of liquid treatment, reuse, and disposal to achieve a 50% average of freshwater savings and nutrient load reduction would range from $1.00/1,000 gal at the Boca Raton WWTP to $1.90/1,000 gal at the Hollywood WWTP, averaging $1.50/1,000 gal. Increasing this average to 75% would raise the average cost to $2.60/1,000 gal.

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Reuse Coordinating Committee and the Water Conservation Initiative Water Reuse Work Group (2003) Water Reuse for Florida: Strategies for Effective Use of Reclaimed Water. Florida Department of Environmental Protection, Tallahassee, Florida. June 2003. Accessed 28 February 2006 at http://www.dep.state.fl.us/water/reuse/flprog.htm.

10. Summary and Conclusions

The purpose of the study was to evaluate the status and efficacy of effluent management options for the six municipal facilities in Florida's Palm Beach, Broward and Miami-Dade Counties that discharge secondarily treated wastewater through ocean outfalls (Fig. 10-1). Urban water requirements in this region are rising due to rapid population growth, while water supply problems loom due to uncertainties in the time-phasing and funding of water resources projects. Southeast Florida's natural and artificial reef resources—some located near the outfalls—provide habitat and protection for marine organisms and contribute over 61,000 jobs and $1.9 billion in yearly income for residents of the three counties. An underutilized water management option in the region is water reuse, which could help Southeast Florida meet its water requirements while decreasing or eliminating reliance on ocean outfalls. The State has a reuse capacity of 1.2 BGD and expects to reclaim and reuse 65% of all domestic wastewater by 2020, up from 40% today. The study reviewed previous work describing the effects of ocean wastewater disposal on ocean biota and human health risks as well as past examples of obstacles and successes of water reuse in Florida, the U.S. and abroad. Four alternative ocean outfall strategies—involving varying degrees of reuse, nutrient removal and ocean outfall use— were considered. The alternatives were evaluated at each wastewater treatment plant according to four performance measures: 1) amount of freshwater saved relative to a base case with no reuse, 2) reduction in nitrogen and phosphorus discharged via ocean outfalls relative to the base case, 3) public acceptance, and 4) costs. Management recommendations based on these evaluations are presented.

Figure 10-1. Florida Counties with Ocean Outfalls. Photo from Google Earth (2005).

Current and projected flows at the six wastewater treatment plants (WWTPs) are compared to their permitted capacities in Table 10-1. The 2025 wastewater influent flow exceeds the 2005 permitted capacity at each WWTP; thus all of the facilities face important decisions regarding their future wastewater management options. According to current plans of the utilities, 7% of the total wastewater handled by the facilities will be reclaimed for traditional (public access) reuse in 2025, up from 4% currently.

Table 10-1. Permitted, 2005, and Projected 2025 Flows at WWTPs with Ocean Outfalls

	Boynton-Delray	Boca Raton	Broward/ North	Hollywood	M-D/ North	M-D/ Central	Total
Permitted flow (MGD)	24.0	17.5	84.0	42.0	112.5	143.0	423
2005 flow (MGD)	19	16	84	40	108	129	396
2005 reuse[1] (MGD)	3.7	5.2	2.4	2.6	0.1	0	14
2005 reuse[1] (%)	19	33	3	7	< 1	0	4
2025 flow (MGD)	27	22	94	54	126	151	474
2025 reuse[1,2] (MGD)	7.5	15.9	5.3	3.6	0.1	0	32.4
2025 reuse[1,2] (%)	28	73	6	7	0.1	0	7

[1]Excluding onsite reuse for process

[2]Based on utilities' plans extending to 2025

The primary source of potable water in Palm Beach County is the Surficial or the Biscayne Aquifer and in Broward and Miami-Dade Counties it is the Biscayne Aquifer. Population growth in the region should lead to a continued upward trend in demands, resulting in an aggregate water demand of 606 MGD by the year 2025. The Lower East Coast Water Supply Plan developed options for meeting future water supply needs, including Everglades National Park as part of the Everglades restoration, but did not make a detailed evaluation of reuse options. Ideally, the planned update of the 2000 Plan will address reuse in more detail.

Each of the service areas within the three counties was analyzed to determine the future water demand in relation to the available and planned potable water design capacity. The difference between water demand and potential water supply (design capacity) for the study period is termed "new water" demand. New water is the water demand in excess of the existing or planned water supply (design capacity) of the water treatment facility.

Palm Beach County has sufficient water treatment plant design capacity to meet its needs until at least 2025 (Table 10-2). Broward County has insufficient design capacity to meets its 2025 water demand; however, the water utilities within the County are planning five improvement programs during the study period to increase the design capacity by 26.9 MGD for a total of 426.8 MGD by the year 2008, which is sufficient to meet water demands throughout the study period. After three planned improvements to increase its design capacity by 86.3 MGD for a total of at least 554 MGD by the year 2025, Miami-Dade County will still need to identify sources for an additional 26.7 MGD by 2025.

Table 10-2. Summary of Projected Water Demands and WTP Design Capacities for the Study Area

County	2005 Water Demand (MGD)	% of 2005 Total	2025 Water Demand (MGD)	% of 2025 Total	2005 Design Capacity (MGD)	2025 Design Capacity (MGD)	Demand in Excess of Capacity (MGD)
Palm Beach	62.5	13.3	87.4	14.4	124.0	124.0	0
Broward	167.3	35.7	226.7	37.4	399.9	426.8	0
Miami-Dade	238.9	51.0	292.4	48.2	467.7	554.0	26.7
Total	468.7	100.0	606.5	100.0	991.6	1104.8	26.7

The Southeast Florida Outfall Experiment I (SEFLOE I), initiated by utilities in Broward, Miami-Dade and Palm Beach Counties, characterized the impacts of ocean outfall wastewater disposal in Southeast Florida. Englehardt et al. (2001) present a comparative assessment of the human and ecological impacts from municipal wastewater disposal in Southeast Florida. Their assessment includes ocean disposal from the six WWTPs. Field investigations revealed that surfacing plumes were present at all six WWTP outfalls throughout the year (Englehardt et al. 2001). All of the outfalls are in at least 28 meters (92 ft) of water and 2 miles offshore. They are located in the westerly boundary of the strong Florida Current, a tributary of the Gulf Stream. Wanninkhof et al. (2006) evaluated farfield dilution of sewage outfall discharges in southeast Florida. Their studies indicate that the rapid dilution observed in the immediate vicinity of the outfall continues to occur in the 10 to 66 km (6 to 41 mi) downstream distances. These authors do not address issues of reef impacts or pollutant control. A 2003 US EPA relative risk assessment study involved deep well injection, aquifer recharge, discharge to ocean outfalls and surface waters as disposal options (US EPA 2003). One of the conclusions of this study was that:

> Human health risks are of some concern, both within the 400-m mixing zone and outside of it, primarily because treatment of effluent prior to discharge via ocean outfalls does not include filtration to remove *Cryptosporidium* and *Giardia*. The most probable human exposure pathways include fishermen, swimmers, and boaters who venture out into the Florida Current and experience direct contact, accidental ingestion of water, or ingest fish or shellfish exposed to effluent. Otherwise, there is a very small, but not nonzero, chance for onshore or nearshore recreational or occupational users to be exposed to effluent constituents, since there is a small (10%) chance that currents will change direction to east or west.

Natural and artificial reefs near the six ocean outfalls contribute significantly to the tourist business in South Florida (2001). Recent studies by Tichenor (2004a; 2004b) suggest that the outfall discharge at Boynton Beach may be having an adverse effect on Lynn’s Reef, but did not establish a link between pollutant discharges and the relative importance of pollutant concentrations at a specific reef. A biomarker study by Fauth et al. (2006) indicates that the reefs have been impacted in some cases. Based on $\delta 15N$ analyses of macroalgae, sponges and gorgonian corals recently collected from reefs in Palm Beach and Broward counties, Lapointe and Risk (undated) believe that sewage nitrogen is a contributor to the nitrogen pool in the area’s coastal waters. No complete report is available for this ongoing study. These recent and ongoing studies could provide valuable new insights into the extent of the cause-effect linkage between outfall discharges and impaired reefs in Southeast Florida and indicate whether or not current wastewater treatment levels are sufficient to protect water quality in general and the reefs in particular.

The highly urbanized nature of Southeast Florida has been cited as an obstacle to water reuse. However, successes of water reuse systems in large urban areas are well documented. The West Basin Water Management District in the Los Angeles area provides 118 MGD of reclaimed water for traditional reuse. The Irvine Ranch Water District in California has 300 miles of reclaimed water distribution piping in place. The Pinellas County, St. Petersburg, Florida, and Rouse Hill, Australia systems each have upwards of 10,000 connections to their reclaimed water distribution systems, while the City of Cape Coral, Florida has 33,000 residential customers—the world's largest residential reuse system. Orange County, California, is building a 62.5 MGD system to supply highly treated reclaimed water for groundwater augmentation and limitation of seawater intrusion. Satellite water reclamation facilities offer a cost-effective means of serving users that are distant from regional water reclamation facilities. They vary in size from the 100 MGD San Jose Creek Water Reclamation Plant in Los Angeles County to 0.01 MGD units demonstrated in Melbourne, Australia. Satellite facilities can achieve higher reclaimed water qualities than regional facilities—with the same degree of treatment—in collection systems impacted by saline groundwater.

Spatial analysis of the consumptive permit user database in Southeast Florida indicates that large users[1] with individual permits in Palm Beach County and northern Broward County have the highest demands for landscape irrigation. These large users are typically golf courses, parks, and other recreational areas. Miami-Dade County has the highest potential industrial demand. The Turkey Point Power Plant is an example of an industrial user not currently being supplied with reclaimed water. A case study of the area near the Broward/North WWTP indicates that reclaimed water can be cost effectively supplied to larger irrigation users within 12 metropolitan miles (measured along streets) of the reclamation facility. A relationship between reclaimed water flow for traditional reuse and cost was developed for this system. Expressions for the cost of transporting and injecting highly treated reclaimed water for groundwater recharge and for disposing of concentrate from reverse osmosis were also determined.

Four alternative ocean outfall strategies were examined under the defined scope of this study. Under the Currently Planned Use alternative (Alt I), ocean outfalls would be used at currently planned levels. Under the Limited Use Alternative (Alt II), ocean outfall disposal would be limited to flows remaining after traditional reuse options were maximized and underground injection flows reached full 2005 permitted capacity. Under the Ocean Outfalls as Backups alternative (Alt III), ocean disposal would only be used during wet weather periods to handle flow that would otherwise go to traditional reuse. Complete elimination of ocean outfalls was considered under the No Use alternative (Alt IV). Florida's 1.2 BGD reuse capacity clearly indicates that reuse is feasible within Florida and state statutes (403.064 and 373.250, F.S.) encourage and promote water reuse. Therefore, it was assumed that unaccounted for flows would be directed to reuse in alternatives that involve some level

[1] Users of 0.05 MGD more are categorized as large users for the purposes of this study.

of curtailment of ocean outfalls. The assumption was made that permitted capacities of the ocean outfalls would be maintained at 2005 levels and that no additional ocean outfalls would be permitted. It was also assumed that Class I injection control wells for effluent disposal would be held at 2005 permitted capacities and, furthermore, that Class I injection wells for effluent disposal that were in testing or under construction during 2005 would not receive permits. Current and potential treatment requirements employed in the evaluation of ocean outfall alternatives are summarized in Table 10-3. Generalized process trains capable of achieving these treatment requirements are shown in Figure 10-2.

Four indicators (performance measures) for the various alternatives at each of the WWTPs were evaluated: 1) amount of freshwater saved relative to a base case with no reuse, 2) reductions in nitrogen and phosphorus discharged via ocean outfalls relative to the base case, 3) public acceptance, and 4) costs. Indicators were evaluated based on the complete data set throughout the projection period.

Table 10-4 gives averages of flows, freshwater savings, public acceptance, and costs over the 20-year projection period (2005–2025) for all scenarios considered at the six WWTPs. Costs in the table include the costs of liquid treatment, reuse and disposal. Table 10-5 gives average values for nutrient loads to the ocean under the base case as well as in all scenarios considered for the WWTPs. Percentage reductions in nutrient load achieved in the scenarios are also given.

Table 10-3. Current and Potential Treatment Requirements of Wastewater Management Options*

Option	Treatment requirements	
	Current	**Potential**
Ocean outfalls	Secondary with basic-level disinfection (T2)	Intermediate or full nutrient control w/ basic-level disinfection (T4/T5)
Class I injection wells	Secondary with no disinfection (T1)	Secondary w/ filtration & high-level disinfection (T3)
Traditional reuse	Secondary w/ filtration & high-level disinfection (T3)	
Groundwater recharge	Full treatment and disinfection (T6)	

*Treatment trains (T1, T2, etc.) capable of meeting the requirements are described in Figure 10-2

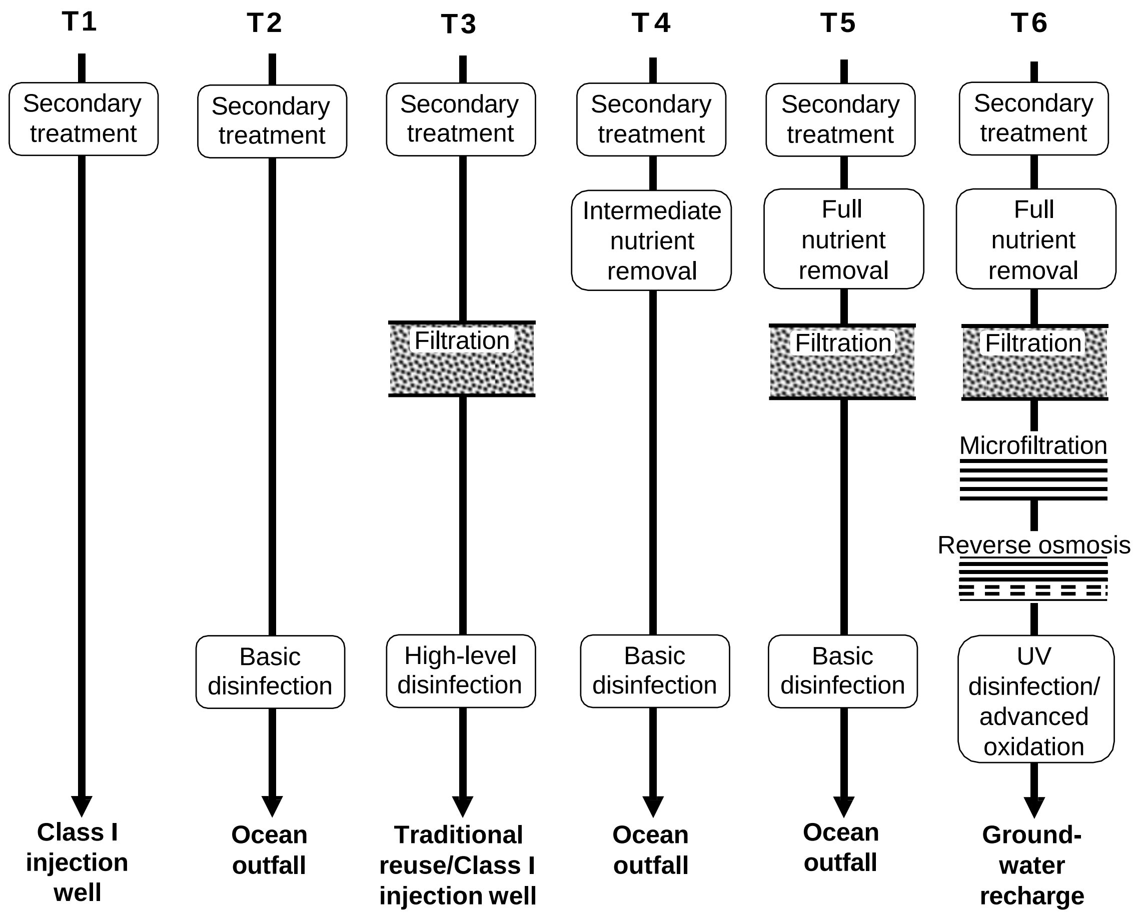

Figure 10-2. Generalized Process Trains Capable of Meeting Current and Potential Treatment Requirements of Wastewater Management Options

The averages of freshwater savings and nutrient load reductions and costs of the ocean outfall alternatives for the six WWTPs with ocean outfalls are compared in Figure 10-3. As the figure indicates, there are no maxima in the averages with respect to cost. Furthermore, the results for specific scenarios tend to lie near the general trend for each facility, indicating no substantial cost advantage of one scenario over another for a given level of freshwater savings and nutrient load reduction. The costs do not take into account the revenues that could be generated from providing reclaimed water to users as part of a traditional reuse system. When the potential for revenue generation is considered, scenarios emphasizing traditional reuse are likely to be more cost effective than those that do not.

The following conclusions and recommendations were reached from the present study:

- Water reuse (traditional and groundwater recharge) offers advantages to Southeast Florida—in terms of conserving water, augmenting available water resources, and reducing discharges to the ocean environment.
- Considering impending water shortages in Southeast Florida, continued use of ocean outfalls and deep injection wells for effluent disposal represents an unsustainable export of freshwater from the region.

Table 10-4. Flows, Freshwater Savings, Public Acceptance and Costs for Ocean Outfall Alternatives over the Period 2005–2025

WWTP	Inflow (MGD)	Alt	Flows as % of inflow: Ocean outfall	UIC wells[1]	Trad. Reuse	GW re-charge	Concen-trate	% Freshwater Savings: Total	From GWR	Public acceptance[2]	Cost ($/1000 gal) Scenarios[3]: A	C	E
Boynton-Delray	23.2	I	75.6	0.0	24.4	0.0	0.0	24	0	H	0.92	1.20	1.46
		II	43.5	0.0	56.5	0.0	0.0	56	0	H	1.46	1.65	1.82
		III	6.1	0.0	56.5	29.9	7.5	80	24	L/M to M/H	3.29	3.29	3.29
		IV	0.0	0.0	56.5	34.8	8.7	84	28	L/M to M/H		3.41	
Boca Raton	18.7	I	41.4	0.0	58.6	0.0	0.0	59	0	H	1.34	1.46	1.60
		II	35.7	0.0	64.3	0.0	0.0	64	0	H	1.53	1.63	1.75
		III	6.7	0.0	62.5	24.6	6.1	82	20	L/M to M/H	3.06	3.06	3.06
		IV	0.0	0.0	64.3	28.5	7.1	87	23	L/M to M/H		3.22	
Broward/ North	90.0	I	61.6	33.3	5.0	0.0	0.0	8	0	H	0.61	0.75	0.92
		II	54.5	33.3	12.2	0.0	0.0	18	0	H	0.73	0.86	1.00
		III	1.3	33.3	12.2	42.6	10.6	69	51	L to M	2.47	2.47	2.47
		IV	0.0	33.3	12.2	43.6	10.9	71	52	L to M		2.48	
Hollywood	47.2	I	90.4	0.0	7.2	1.9	0.5	9	1	H	0.73	1.04	1.24
		II	89.9	0.0	9.2	0.7	0.2	10	1	H	0.67	0.97	1.18
		III	1.0	0.0	9.2	71.8	18.0	67	57	L to M	3.82	3.82	3.82
		IV	0.0	0.0	9.2	72.6	18.2	67	58	L to M		3.83	
Miami-Dade/ North	116.8	I	95.4	0.0	0.1	3.6	0.9	3	3	H	0.71	0.99	1.22
		II	95.3	0.0	1.5	2.6	0.6	4	2	H	0.66	0.95	1.17
		III	0.2	0.0	1.5	78.7	19.7	64	63	L to M	3.05	3.05	3.05
		IV	0.0	0.0	1.5	78.8	19.7	65	63	L to M		3.05	
Miami-Dade/ Central	140.0	I	98.5	0.0	0.0	1.2	0.3	1	1	H	0.53	0.90	1.15
		II	98.3	0.0	0.9	0.7	0.2	1	1	H	0.51	0.88	1.13
		III	0.1	0.0	0.9	79.2	19.8	64	63	L to M	3.84	3.84	3.84
		IV	0.0	0.0	0.9	79.3	19.8	64	63	L to M		3.84	

[1] Class I [2] L = low, M = moderate, H = high

[3] The scenarios for ocean outfall treatment are: A--secondary, C--intermediate nutrient removal, and E--full nutrient removal. These scenarios are applicable to alternatives I, II, and III, which involve use.

Table 10-5. Averages for Nutrient Loads to the Ocean in Comparison to the Base Case over the 20-Year Projection Period

		Average Nutrient Loads to Ocean (tons/yr)								% Reductions in Nutrient Loads					
		Base case		Secondary		Inter. nut. rem.		Full nut. rem.		Secondary		Inter. nut. rem.		Full nut. rem.	
WWTP	Alt*	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP
Boynton-Delray	I	661	60	500	45	267	45	80	27	24	24	60	24	88	56
	II	661	60	287	26	154	26	46	15	56	56	77	56	93	74
	III	661	60	40	3.7	22	3.7	6.5	2.2	94	94	97	94	99	96
Boca Raton	I	480	20	199	8.2	118	8.2	35	8.2	59	59	75	59	93	59
	II	480	20	171	7.1	101	7.1	30	7.1	64	64	79	64	94	64
	III	480	20	32	1.3	19	1.3	5.7	1.3	93	93	96	93	99	93
Palm Beach County	I	1,141	80	698	54	385	54	115	35	39	33	66	33	90	56
	II	1,141	80	459	33	255	33	77	22	60	58	78	58	93	72
	III	1,141	80	73	5.0	41	5.0	12	3.5	94	94	96	94	99	96
Broward/ North	I	1,351	119	1,249	110	844	110	253	84	8	8	38	8	81	29
	II	1,351	119	1,104	97	746	97	224	75	18	18	45	18	83	37
	III	1,351	119	26	2.3	18	2.3	5.3	1.8	98	98	99	98	100	99
Hollywood	I	1,193	79	1,079	71	650	71	195	65	10	10	46	10	84	18
	II	1,193	79	1,072	71	646	71	194	65	10	10	46	10	84	18
	III	1,193	79	12	0.8	7.0	0.8	2.1	0.7	99	99	99	99	100	99
Broward County	I	2,543	198	2,328	181	1,494	181	448	149	8	8	41	8	82	24
	II	2,543	198	2,176	168	1,392	168	418	139	14	15	45	15	84	30
	III	2,543	198	38	3.1	25	3.1	7	2.5	99	98	99	98	100	99
Miami-Dade/ North	I	3,111	302	2,968	288	1,696	288	509	170	5	5	45	5	84	44
	II	3,111	302	2,966	288	1,695	288	508	169	5	5	46	5	84	44
	III	3,111	302	5.5	0.5	3.1	0.5	0.9	0.7	100	100	100	100	100	100
Miami-Dade/ Central	I	3,580	341	3,525	336	2,098	336	629	210	2	2	41	2	82	38
	II	3,580	341	3,518	335	2,094	335	628	209	2	2	42	2	82	39
	III	3,580	341	3.8	0.4	2.3	0.4	0.7	0.2	100	100	100	100	100	100
Miami-Dade County	I	6,691	643	6,493	624	3,794	624	1,138	379	3	3	43	3	83	41
	II	6,691	643	6,484	623	3,789	623	1,137	379	3	3	43	3	83	41
	III	6,691	643	9	0.9	5	0.9	2	0.9	100	100	100	100	100	100

*A nutrient load of zero and nutrient load reduction of 100% are achieved under Alternative IV at each WWTP

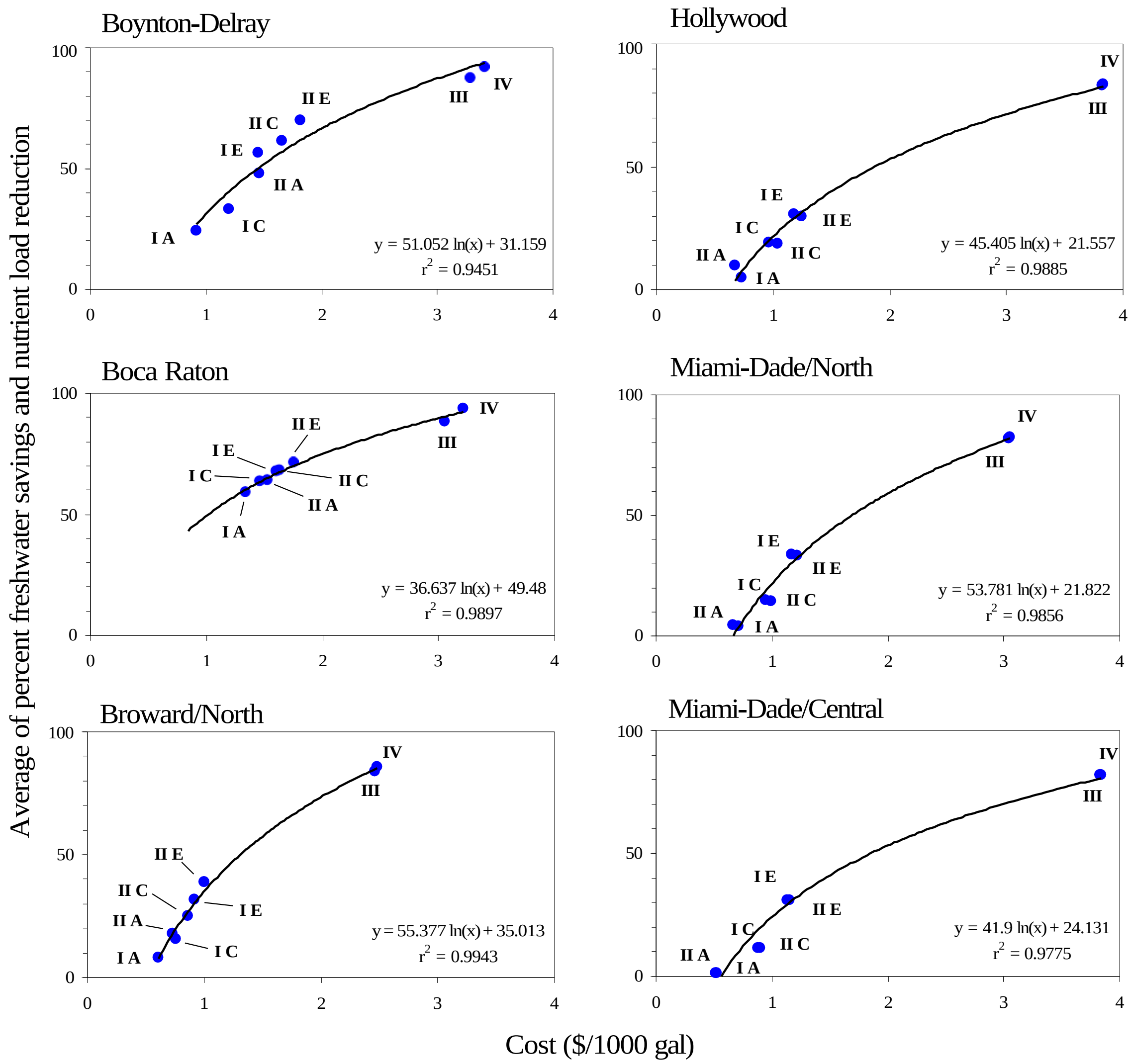

Figure 10-3. Averages of Percent Freshwater Savings and Nutrient Load Reduction versus Cost of Ocean Outfall Alternatives for WWTPs in Southeast Florida over the Period 2005–2025. Alternatives are Currently Planned Use (I), Limited Use (II), Ocean Outfalls as Backups (III) and No Use (IV). The scenarios for ocean outfall treatment are: A–secondary, C–intermediate nutrient removal, and E–full nutrient removal.

- The weight of indirect evidence of reef damage by ocean outfalls is cause for concern and justification for additional actions to address these issues.
- The success of water reuse in large urban areas in the U.S. and abroad indicates that difficulties to reuse posed by the highly urbanized nature of Southeast Florida can be overcome.
- Satellite water reclamation facilities can effectively serve distant users of reclaimed water in regional wastewater systems and improve reclaimed water quality in collection systems impacted by saltwater intrusion.

- Traditional (public access) reuse for the Boynton-Delray and Boca Raton WWTPs could substantially reduce nutrient loads to the ocean. Substantial reduction of nutrient loads from the other four facilities can be achieved through groundwater recharge, since traditional reuse opportunities are more limited in these areas.
- Substantial reductions in nitrogen loads are achievable through intermediate and full nutrient removal technologies. Given the relatively low total phosphorus concentrations in effluents from the WWTPs, only full nutrient removal technology can reduce phosphorus loads. Substantial reductions in phosphorus load will require moving toward either traditional reuse or groundwater recharge.
- The average freshwater savings are essentially equal to traditional reuse volumes under alternatives I (currently planned use of ocean outfalls) and II (limited use of ocean outfalls) and range from 24 to 64% at the Boynton-Delray and Boca Raton WWTPs and from 1 to 18% at the other four facilities.
- Under alternatives III (use of ocean outfalls as backups) and IV (no use of ocean outfalls), average freshwater savings range from 64 to 87%.
- Public acceptance of traditional reuse is expected to be high at all of the facilities because the reclaimed water is used primarily for irrigation.
- Public acceptance of alternatives featuring large-scale groundwater recharge could be moderate or lower. However, public education programs and community involvement throughout the planning, implementation, and continued use of water reuse projects should help mitigate public concerns.
- Trends between costs and the average of percent freshwater savings and nutrient load reduction indicate that alternatives emphasizing traditional reuse and nutrient control technology are somewhat more cost effective than those emphasizing groundwater recharge. The ability to generate revenues from traditional reuse further increases the attractiveness of this approach.
- At the facilities with lesser densities of consumptive use permittees (Hollywood, Miami-Dade/North and Miami-Dade/Central), extensive groundwater recharge would be required to achieve a 50% average of freshwater savings and nutrient load reduction unless industries and residential users are added to the reclaimed water customer base.
- The costs of liquid treatment, reuse and disposal to achieve a 50% average of freshwater savings and nutrient load reduction would range from $1.00/1,000 gal at the Boca Raton WWTP to $1.90/1,000 gal at the Hollywood WWTP, averaging $1.50/1,000 gal. Increasing this average to 75% would raise the average cost to $2.60/1,000 gal.

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