Design Alternatives for Expansion of the South Tampa Area Reclaimed (STAR) Project in Tampa

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The city of Tampa's rapid population growth has increased stress on the potable water supply. For its 2006-2007 Student Design Competition, the Florida Water Environment Association (FWEA), in conjunction with the Tampa Water Department, requested design alternative concepts for a Phase II expansion of the South Tampa Area Reclaimed (STAR) water system in order to service new customers who will provide the most cost-efficient offsets of potable water consumption in the South Tampa region.

Construction on the STAR system began in 2002. The first STAR (Phase I) customers received water in 2004, and in 2007 there were 2,400 customers connected (PBS&J, 2003; Vilagos, 2007). The system utilizes reclaimed water from the Howard F. Curren Advanced Wastewater Treatment Plant for irrigating residential and commercial properties. STAR's importance will increase as future restrictions are placed on the city by state and federal regulators.

It is projected that Tampa's water use permit for the city water supply will be capped at a specified maximum to prevent depletion of the Floridian Aquifer. Also, discharges from the Curren Plant to Hillsborough Bay will be halted to make best use of reclaimed effluent to supplement Tampa's water supply.

The Howard F. Curren Plant is located on a 250-acre site next to the Port of Tampa. It has a maximum capacity of 96 million gallons per day (MGD) but is currently operating between 53 and 74 MGD (City of Tampa, 2006). Less than 20 percent of the effluent from the plant is reclaimed for irrigation and industrial uses; the remaining effluent is discharged into Hillsborough Bay (City of Tampa, 2006).

The plant has a tertiary treatment system to ensure that the effluent meets reclaimed water standards. Reclaimed water is diverted from the effluent flow after chlorination, while the remaining effluent is dechlorinated with sulfur dioxide before discharge to the bay. The diversion of reclaimed effluent from the main flow has created several challenges at the plant, including overchlorinating effluent discharges to the bay.

In 2007 the demand of the STAR Phase I system was 1.4 MGD of reclaimed effluent from the Curren Plant, almost double the 0.8 MGD demand of the system's first year (City of Tampa, 2006). The system consists of 75 miles of ductile iron, PVC, and HDPE piping, ranging from 1.5 to 36 inches in diameter, which cost $28 million to construct (PBS&J, 2000). The main transmission line originates at the treatment plant; crosses Seddon Channel, Davis Island, and the edge of Hillsborough Bay; and follows an east-to-west route across Tampa, terminating near the Tampa International Airport. The South Tampa area was chosen because of its proximity to the Curren Plant, its high density of customers with irrigation meters, and its support for reclaimed water (PBS&J, 2000).

Challenges with Phase 1 included difficulties with directional boring, especially across the two water bodies at the Port of Tampa, as well as construction particulate matter trapped in the transmission main and plastic tailings from pipe connections, which required replacement of 1,300 feet of pipe. Because of the particulates in the distribution system and in-pipe biological growth from low chlorine residuals, water meters and sprinkler heads throughout the system were clogged and needed replacement (Vilagos, 2007).

Another challenge has been motivating industrial, commercial, and institutional (ICI) customers to connect to the network. This resistance is linked to a combination of factors, including the higher price of reclaimed water compared to groundwater and concerns about using reclaimed water in cooling towers (Vilagos, 2007).

Design Objectives

This project develops the following three alternative design concepts for expanding the STAR system while considering hydraulics, water quality, disinfection alternatives, potential users, and operation and maintenance (O&M) issues. From these options, a single design concept is recommended.

1. ***South Expansion Design*** – Considers pipe layout, modifications to the effluent chlorination system, recirculation stations, and a ground-level storage system.
2. ***Northwest Expansion Design*** – Considers pipe layout, modifications to the effluent chlorination system, recirculation stations, additional pumps, and a ground-level storage system.
3. ***South and Northwest Expansion Design*** – Considers pipe layout, modifications to the effluent chlorination system, recirculation stations, additional pumps, and a ground-level storage system.

The authors are members of the University of Florida's Student Design Team whose project won the statewide FWEA Student Design Competition at the 2007 Florida Water Resources Conference. John Sansalone is the University of Florida FWEA Student Chapter's faculty advisor.

Regulations

Florida and California are among the nation's leaders in adopting reuse standards. Regulations in Chapter 62-610 of the Florida Administrative Code (FAC) that apply to the STAR project, and in particular the STAR Phase II designs, are:

- Restricted Urban Access
- Public Access Areas, including Residential Irrigation
- Industrial Uses

For ***Restricted Urban Access*** use, the treated reclaimed water must, at a minimum, meet secondary treatment water quality standards and basic disinfection levels (FAC 62-610.410). If system storage is not required, it must be proven that reclaimed water flows will match the demand pattern during a diurnal cycle, and 20 years of climate data will be used and will account for all water inputs (FAC 62-610.414).

In addition to secondary treatment levels, reclaimed water use for ***Public Access Areas*** must include high-level disinfection. Florida's high-level disinfection is based on

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Table 1. FAC requirements (from EPA reuse guidelines)

Use	Treatment	BOD_5 [mg/L]	TSS [mg/L]	Turbidity (NTU)	Fecal Coliform (#/mL)
Unrestricted Urban Reuse	Secondary, Filtration & High-level Disinfection	20	5	NS*	75% Samples below detection (30 days) 75/100 (max)
Restricted Urban Reuse	Secondary, Filtration & High-level Disinfection	20	5	NS	75% Samples below detection (30 days) 75/100 (max)
Ag Reuse - Non Food	Secondary & Basic Disinfection	20 ($CBOD_5$)	20	NS	(200/100) (avg) (800/100) (max)
Industrial Reuse	Secondary & Basic Disinfection	20	20	NS	(200/100) (avg) (800/100) (max)

NS* = Not Specified by FDEP statutes

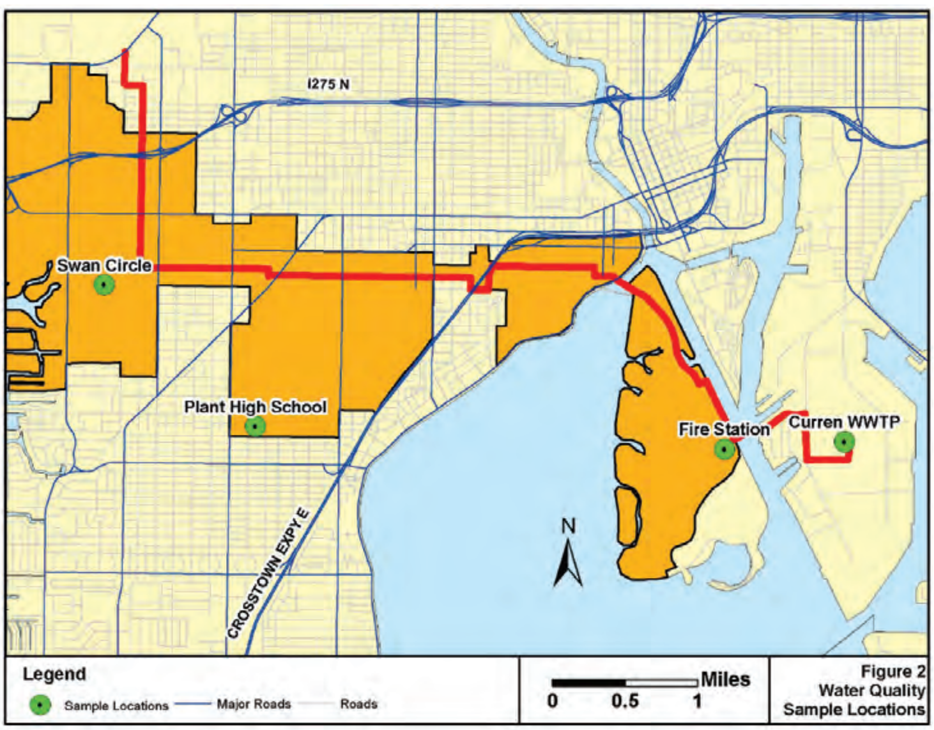

Figure 1. Map of STAR Phase I reclaimed effluent sampling locations

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fecal coliform and requires non-detectable samples for 75 percent of the monthly samples and a single-month upset value of 25 colonies per 100 mL (Elefritz Jr.). Also, if system storage is not required, not only must the reclaimed water flows match the demand pattern during a diurnal cycle, but the system volume must equal three times the portion of average daily flow of the total reuse capacity for which alternative reuse or disposal system is permitted (FAC 62-610.464).

Like Restricted Public Access use, ***Industrial Applications*** must adhere to secondary treatment and basic disinfection. Also, the code requires the use of best engineering practices to control biological growth (FAC 62-610.668). Table 1 summarizes the FAC standards for the reuse categories.

Besides adhering to state and federal standards, Tampa issued ordinance 2004-24, which amended the code for reclaimed water use to include the removal of any cross connections to the potable system, the removal of city-owned irrigation meters, and the final inspection of the system by a city official before use.

Methods

Water Quality Analysis

Water quality characteristics quantify the physical, chemical, and biological characteristics of water regarding potability, safety of human contact, and health of the ecosystem. Regulations for reclaimed water reuse vary considerably among states.

The most common water quality indices having limits are biochemical oxygen demand (BOD), measured as total suspended solids (TSS), and total or fecal coliform counts. Total and fecal coliform counts are used as indicators to determine the level of microbiological contamination and therefore the disinfection need. A turbidity limit is specified to monitor the performance of the treatment facility effluent (EPA, 2004).

To address water quality in the STAR Phase I system, reclaimed water sampling and analyses were performed for the distribution system. To examine water quality, three sampling locations in the distribution system and one sampling point at the Curren Plant discharge point were chosen, as illustrated in Figure 1.

At each location, samples were taken every two hours, including 10:15 a.m., 12:15 p.m., and 2:15 p.m. Sampling times and locations were based on the availability of city personnel, physical access points to the distribution system, and the requirement of timely water quality analysis. Each time at each location, two separate 1,000-milliliter (mL) samples were collected for laser-diffraction particle size distribution (PSD) analysis and gravimetric particulate matter measurement. A 500-mL sample was taken for general water chemistry measurements and a 500-mL sample was collected in a glass jar with zero headspace for chlorine residual analysis.

Sample collection and preservation followed Standard Method 1060 (APHA 1995). All water samples were collected in duplicates, stored on ice in coolers, and taken immediately to the University of Florida laboratories for further analysis. Travel time from Tampa to the laboratories was three hours, and samples were logged and tracked through a chain-of-custody.

Water temperature (°C) was measured immediately upon sampling in the field. Time-critical analyses such as total chlorine and free chorine were conducted immediately upon return to the laboratory. Other procedures that were less time-sensitive were performed within 24 hours of sampling. The following water chemistry parameters were tested:

- Temperature
- pH
- Dissolved oxygen (DO)
- Conductivity
- Total dissolved solids (TDS)
- Turbidity
- Total chlorine and free chlorine
- Total phosphorous (TP) and orthophosphate (PO43-)
- Total nitrogen (TN) and nitrate (NO3-)
- Particulate matter measured gravimetrically as total suspended solids (TSS)
- Particulate matter measured volumetrically as particle size distributions (PSD)

Determining Demands

Primarily, projected effluent flow from

the Curren Treatment Plant was determined as a proportional function of the population—a standard practice in projection methodologies that multiplies a projected population by a per-capita flow rate. For wastewater flows, a significant source of error with the per-capita methodology is introduced by inflow and infiltration (I&I), which is an inflow of stormwater runoff and/or infiltration of groundwater into compromised collection systems. Efforts were made to quantify these I&I parameters.

Population data from the 2006 county level report (Zwick, 2006) was combined with a city level report ("Florida," 2005), which gave the population for Tampa in 2005. Correlating the 1994, 2000, and 2005 county projections with the 2005 city level census resulted in the Tampa regional population projections.

The populations for 1994 were approximated linearly between the 1990 and the 2000 census data. The 1994 Tampa population approximation was necessary because of a lack of effluent flow data before 1994 from the Curren Plant. The error involved in this approximation was considered minimal. Tampa's population was then considered to grow at a proportional rate to the county population.

It is expected that the maximum urban load of Tampa will be met by the year 2030 (Zwick, 2006); therefore, 2030 was considered the end of the projection scenario. In addition to the temporal change in population during the planning period, population densities are expected to change spatially as a result of rezoning and urban revitalization projects. The spatial projections were not determined in this study. The errors introduced with omission of the spatial component are not significant to the increase in reuse effluent coming from the Curren Plant during the planning period, but will add significant error to future expansions of wastewater treatment and reuse distribution operations in Tampa.

A comparison of projected wastewater treatment plant data was made against data presented by the South Florida Water Management District in its 2006 Regional Water Supply Plan. The district data was given for the North Tampa Bay area of Hillsborough County. To calculate the Curren Plant flows, a proportion of year 2000 actual flows were multiplied against given projection data. To address I&I per capita, flows were calculated and a correlation was made between per capita flow and average annual rainfall. The results gave I&I trends normalized against population. This analysis aided in quantifying I&I peaks that may occur.

To determine the optimal reuse areas to be served by STAR Phase II, a geographic information system (GIS) model was created in ArcGIS 9.1 software from ESRI. The initial data shapefiles entered into ArcGIS were obtained online from the city of Tampa, Tampa Bay Water, and the South Florida Water Management District. Water meter data was integrated with water use permit (WUP) data and based on location within designated neighborhood associations.

The area for the neighborhoods was calculated using ArcGIS Xtools. The flows were normalized against the neighborhood area to create a demand density (gpm/acre). The centroid of the reuse neighborhood was calculated using ArcGIS Xtools. Optimal neighborhoods were determined by calculating linear distance from the existing STAR Phase I system to the centroid of the reuse neighborhood, then the distance was weighted against the demand density.

Three demand scenarios were modeled to show a minimum, median, and maximum demand. Variables used were:

- Metered irrigation data
- Irrigation efficiency factors
- Average metered data from WUPs above 0.1 MGD
- Maximum permitted daily average flows from WUPs.

The efficiency factor used was 1.45, a value that was adapted from potable water irrigation offset efficiencies presented by the water district.

For the minimum demand, metered irrigation data was added to average metered data from WUPs within each reuse neighborhood. For median demand, metered irrigation data was added to maximum permitted daily average flow from WUPs. For maximum demands, metered irrigation data was multiplied by the efficiency factor and then added to maximum permitted daily average flows from WUPs. The scenarios were compared at complete coverage of reuse neighborhoods and a 100 percent connection rate.

Diurnal demand fluctuations over a 24-hour period were modeled by acquiring hourly flow data over the year 2006. Diurnal demand was modeled in two categories: average and maximum. Average demand multiplier values were calculated as the geometric mean of the given hour divided by the average daily flow. Maximum demand multiplier values were calculated as the maximum values of the given hour divided by the average daily flow.

Chemical Treatment

Among disinfection methods, chlorination is the most commonly utilized disinfectant throughout the world. Its important advantages are economy, relative ease of use, a very high oxidizing and deodorizing ability, and stability. Important disadvantages are its safety and its ability to react with natural organic matter (NOM) to form disinfection byproducts (DBPs) that include trihalomethanes (THMs) and haloacetic acids (HAAs), many of which are classified as probable human carcinogens and environmental hazards (Metcalf and Eddy, 2003; Kawamura, 2000).

Overall, chlorine is an effective, well-established technology; the residual can be monitored and maintained; and a chlorine disinfection system is already present in the Curren Treatment Plant. To avoid increasing capital cost and chemical cost, chlorination is

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chosen as the disinfectant technology throughout the proposed designs.

Chlorine compounds used in wastewater treatment plants are chlorine (Cl_2), sodium hypochlorite (NaOCl), calcium hypochlorite [$Ca(OCl)_2$], and chlorine dioxide (ClO_2) (Metcalf and Eddy, 2003). The design recommendation is to keep using Cl_2 as the disinfection chemical.

Post aeration, chlorination, and dechlorination are provided to disinfect effluent and remove chlorine residuals before discharge into Tampa Bay. All the effluent treated at the plant is being chlorinated in one contact chamber to meet distribution system requirements for STAR. Currently, only 3 percent of the effluent from the plant is distributed into STAR. The result is an unreasonable chemical budget for chlorine and sulfur dioxide (SO_2).

Although one of the chlorinators is currently under repair, the availability of an unused dry contact chamber allows for a solution. The designs include a disinfection system where a percentage of flow, based on STAR demands, will be diverted to the unused contact chamber and chlorinated separately. Each post-aeration chlorination tank is 425 feet long and 25 feet wide, with an average water depth of 10 feet. The minimum contact time requirement is 15 minutes, but a time of 20 minutes was used for peak flow conditions.

The effluent discharged from the plant into Hillsborough Bay must undergo chemical dechlorination through treatment with SO_2 (City of Tampa, 2007). Chemical data from the plant was used to determine the approximate concentration of SO_2 required to dechlorinate the effluent, in addition to known sulfur dioxide/chlorine ratios. For this effluent stream, a 1:1 ratio of sulfur dioxide to chlorine was used and a safety factor of 2 mg/L sulfur dioxide was implemented to ensure that zero chlorine residual was being discharged into the bay (Palmer).

Planning and implementing a booster station depends on both the selection of the design and the flow into the system. Assigning an area for a booster station, as well as dosage requirements, was done under minimum flow conditions. Because of its chemical tracing capabilities and its built-in algorithms, EPAnet 2.0 was used for this procedure.

Each design was run and the concentration of chlorine residual leaving the Curren Plant was traced. The simulations were run for 300 hours to achieve stability in the system and identify points in the transmission main where residual concentrations fell below 1 mg/L. A first-order bulk decay rate equation with a bulk coefficient of –0.34 and a zeroth order wall reaction with a wall coefficient of –1.0 were used.

Two different conditions govern each node's fluctuation of concentration with time: the demand multipliers for the minimum demand condition manage flow in the system and the first order exponential model decay of chemical throughout time affects concentration.

In the model, the concentration leaving the booster station was set at 4 mg/L, despite demand multipliers. Cost estimates for booster stations were found through Guardian, a distributor of chlorine booster station components and equipment.

Recirculation is a practical, necessary component for preventive maintenance of the pipe distribution system. It is used to assess the condition of the system and increases chlorine concentrations throughout the system by decreasing residence time.

Recirculation will empty into the sanitary sewer system, at specific minimum flow locations, identified using EPANet 2.0. Modeling was done by giving demands at the recirculation points a flow pattern that was the inverse of the average flow models to keep the pumps working at optimal conditions.

Implementing recirculation takes away the need to install booster stations at low residual points. Recirculation points would remove sediments from the pipe system and improve the current water quality throughout STAR. Without regular recirculation, sediment buildup leads to clogged irrigation meters and sprinklers. Recirculation would also be an incentive to attract high users, such as cooling towers, whose owners sometimes avoid redistribution systems due to concerns with particulate matter in the system.

Hydraulic Modeling

Modeling the hydraulic system for STAR Phase II was done primarily in WaterCAD 4.5. The city's Phase I WaterCAD files were imported directly into the system and set on a roadway background layer. Based on areas of high demand and neighborhood roads, three water mains were mapped.

When transmission main routes were chosen, variables that were considered include traffic flow, easement size, and proximity to users. Streets with less traffic and large easements closest to large users were followed wherever possible.

The transmission mains are 25 to 18 in ductile iron pipe (DIP) with a Manning's roughness of 0.012. The diameters are largest where they connect to Phase I and taper downstream. The size of the mains accounts for added users, such as cooling towers, in Phase II and future expansions (Phase III).

Mains will be installed by a standard trench method. The lateral pipes are 100 psi rated HDPE with a Manning's roughness of 0.018. They will be installed through horizontal boring techniques because the proposed system will traverse a highly urban area. HDPE pipe was chosen for its flexibility and compatibility because of the construction process.

A higher pressure rating in Phase II was chosen for added strength and durability while installing pipe. When laying lateral pipe, east-west roads were favored over north-south ones within a neighborhood to reduce the number of connectors in the system.

All pipe lengths, main and lateral, were aligned directly over the roadway map in WaterCAD. Elevations were input based on a topographic map from the South Florida Water Management District. As previously mentioned, the peak flow pattern was used to run the system with all the secondary pipes having eight-inch diameters.

Water CAD performs a Hardy-Cross analysis to find flows in pipe networks. The peak flows from this initial run were applied to the continuity equation to determine the required diameter. These values were then rounded to the next-largest pipe size. This method was used because the flow through a pipe does not change with varying pipe sizes for pressurized systems.

The design velocity used for the diameter calculations was 4 feet per second (ft/s). The diameter ratio (DR) for 100 psi rated HDPE pipe is 17. The graph shows that for velocities lower then 4 ft/s, the working pressure of the pipe is 100 psi, but the pressure drops linearly for velocities over 4 ft/s (Polyethyline).

Once the pipe diameters were optimized, the model was run and checked for errors. Negative pressures occurred in the Northwest Region during peak flow, so pumps were added at the Phase I, Northwest Region connect-point. The flow through the main during the peak hour and the total head loss through the Northwest Region were used to select pump sizes.

Two pump models of similar maximum flows were found and compared by calculating a cost-to-maximum-flow ratio. The model with the lower ratio was chosen and three pumps were added to the system for redundancy. Phase I was designed with pipes that support a maximum pressure of 70 psi.

Final design options were optimized so that pressures in the system were within allowable ranges. Each design option was optimized separately though EPAnet2.0. EPAnet's rule-based controls allow linked status and settings to be based on a combination of conditions that might exist in the network over an extended-period simulation. Simulations were run over average demand conditions where multipliers were applied to simulate average hourly demands ranging from 0.218 at a minimum demand point, and 2.79 at peak demand. Viable pump locations and the number of pumps required were determined for maximum pressure conditions. Also, variable-speed pump settings were adjusted to meet system requirements.

EQ Storage

Currently the reclaimed water for STAR is drawn from the chlorination basin at the Curren Treatment Plant before dechlorination. Similar to other reclaimed water distribution systems, STAR Phase I has high peaks and sudden drops in flow from the daily pattern of early-morning irrigation. These fluctuations in flow cause spikes in the chlorine concentrations delivered to Hillsborough Bay.

Diurnal storage will provide a dependable, economic solution to equalizing the flow to STAR and will therefore help restore the water quality of the bay. The methods used to find the volume of storage required to balance the variations in daily flow were based on the flow equalization techniques developed in Metcalf and Eddy (2003).

A cumulative volume diagram was created to plot the cumulative volume versus the time of day. The average daily flow rate for STAR was plotted on the same diagram. A vertical line parallel to the linear average daily flow rate was set tangent to the volume curve at the farthest point from the daily flow rate line. This vertical distance equals the storage needed.

The flow pattern used was based on the known STAR average hourly flows. The increased demand for the growth of STAR Phase I and each proposed design option was found for the flow pattern by developing a multiplier that relates the STAR Phase I average and the designed system average.

A cumulative volume diagram was created for each design option and the storage necessary for each option was noted and tabulated. Along with diurnal storage, seasonal storage was considered but was found to be unnecessary in terms of the project lifetime of the designs.

Seasonal storage is important for reclaimed systems that are close to using 100 percent of the effluent from the supplying wastewater treatment plant (Metcalf and Eddy, 2003). Even with Phase II in place, reclaimed water will only use a third of the total effluent from HFCAWTP at peak conditions. If other reclaimed water systems are connected to STAR or draw from HFCAWTP, then seasonal storage would need to be implemented.

Cost Assessment

The construction costs associated with each design include cost for piping in the distribution system, plant upgrades such as modifying chlorination and establishing equalization at the end of treatment, and other elements such as booster stations. Cost for chlorination was calculated by using algorithms and costing indices provided by Capdet Works 2.1.

The database for the costing index was derived from MAS (Marshall and Swift equipment index), PIPE (Pipe, Valve and Fitting Cost index), and ENR (*Engineering News Record* 20-City Construction Cost Index). The values for the predefined costing indices are available monthly in *Engineering News Record* and *Chemical Engineering* journals. Because these were relevant to the year 2000, an interest rate of 19.91 percent (inflationdata.com) was used to bring the costs to the year 2007.

Chemical costs for chlorine were provided by the Curren Treatment Plant in addition to chemical usage data for 2005 and 2006 (Appendix 3). The unit cost for chlorine provided by Capdet Works was replaced with the rate of $430 per ton chlorine that is currently being spent.

Cost for chlorination depends on the amount of flow diverted to meet STAR demands. Demands for the system were summed up under peak flow conditions, which were then used to find the two percentages of flow that would be treated with different chlorine dosages.

The cost of the dechlorination system for the effluent stream into Tampa Bay was determined based on the average discharge and current costs for sulfur dioxide, available for $254 per ton (City of Tampa Wastewater Department, 2007). The cost for dechlorination will vary on a monthly basis because of fluctuating demands throughout the year; however, a base cost was determined from cost and average annual flows.

Construction costs were not taken into consideration when altering the chlorination system because a contact chamber and chlorinator are already available. Piping costs for each design were a function of diameter, material, length, and construction method. A unit cost for pipe diameter ranges per foot was set in place for 100 psi HDPE pipe (Standard DR 17) and ductile iron pipe (DIP). WaterCAD 4.5 was utilized to determine the total cost of the pipe layout in each design scenario.

Unit costs for both materials were found separately and include material cost, mobilization, pavement restoration, clearing and grubbing, service connections, and other items. HDPE pipe costs were taken from

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Water Chemistry	2006 Annual Mean
Ammonia (as N)	0.13 mg/L
Chlorides	245 mg/L
Dissolved Oxygen	6.94 mg/L
Hardness	305 mg/L
Nitrate + Nitrite (as N)	1.21 mg/L
Orthophosphate (as P)	3.5 mg/L
pH	7.07 pH units
Potassium	16.1 mg/L
Sodium	181 mg/L
Sulfates	180 mg/L
Total Dissolved Solids	890 mg/L
Total Nitrogen	1.35 mg/L
Total Phosphorus	3.6 mg/L
TSS*	0.8 mg/L
Turbidity*	0.88 NTU

Table 2. STAR water chemistry summary, *prior to disinfection (provided by city of Tampa, 4th Quarter 2006).

Table 3. Reclaimed water chemistry in STAR Phase I distribution system. Water samples were collected from four sampling locations at three different times and tested by University of Florida.

Site	Temperature (°C)			pH			DO [mg/L]		
	10:15	*12:15*	*14:15*	*10:15*	*12:15*	*14:15*	*10:15*	*12:15*	*14:15*
AWTP[d]	25.8±0.4[a]	25.1±0.0	25.1±0.0	7.7±0.1	7.7±0.0	7.7±0.0	5.9±0.7	5.1±1.2	4.2±0.6
FS[e]	24.8±0.1	25.4±0.1	24.6±0.1	8.1±0.0	8.1±0.0	8.1±0.0	5.2±0.1	5.2±0.0	5.2±0.1
PHS[f]	25.1±0.1	25.4±0.0	24.7±0.1	8.1±0.1	8.1±0.0	8.1±0.0	4.8±0.1	4.8±0.1	4.8±0.1
SP[g]	24.7±0.1	24.1±0.1	N/A[b]	7.9±0.0	8.0±0.0	7.9±0.0	4.8±0.0	4.7±0.0	4.8±0.0
Site	**Conductivity (μS/cm)**			**TDS [mg/L]**			**Turbidity (NTU)**		
	10:15	*12:15*	*14:15*	*10:15*	*12:15*	*14:15*	*10:15*	*12:15*	*14:15*
AWTP	1931±7	1887±1	1843±0	946±3	924±1	903±0	0.9±0.1	0.7±0.1	0.7±0.1
FS	1779±1	1967±1	1969±1	872±1	964±1	965±1	0.7±0.1	0.8±0.2	0.8±0.1
PHS	1676±2	1626±0	1618±1	822±1	797±1	792±0	4.0±1.8[c]	1.1±0.2	1.3±0.2
SP	1543±0	1547±1	1550±0	765±0	758±1	759±0	0.8±0.0	1.5±0.1	1.2±0.2
Site	**TSS [mg/L]**			**Total N [mg/L]**			**Nitrate [mg/L]**		
	10:15	*12:15*	*14:15*	*10:15*	*12:15*	*14:15*	*10:15*	*12:15*	*14:15*
AWTP	2.0±0.1	1.9±0.1	2.1±0.3	3.2±0.1	2.6±0.1	2.5±0.1	2.6±0.3	1.5±0.4	1.8±0.4
FS	2.3±0.1	1.9±0.3	1.8±0.01	2.4±0.2	2.2±0.2	2.0±0.1	1.5±0.3	1.5±0.6	1.3±1.0
PHS	7.1±3.2[c]	2.0±0.6	2.4±0.7	2.3±0.1	1.8±0.1	1.7±0.1	1.4±0.5	1.5±0.4	1.7±0.2
SP	1.8±0.3	2.6±0.0	1.9±0.2	2.2±0.2	2.2±0.1	2.2±0.2	1.9±0.1	1.8±0.4	2.0±0.3
Site	**Orthophosphate [mg/L]**			**Total Chlorine [mg/L]**			**Free Chlorine [mg/L]**		
	10:15	*12:15*	*14:15*	*10:15*	*12:15*	*14:15*	*10:15*	*12:15*	*14:15*
AWTP	10.7±0.3	10.4±0.2	11.1±0.4	1.0±0.1	1.1±0.02	0.9±0.01	0.06±0.01	0.1±0.01	0.05±0.0
FS	9.2±0.5	13.1±0.6	12.9±0.9	0.3±0.1	0.7±0.01	0.6±0.02	0.01±0.00	0.01±0.0	0.01±0.0
PHS	10.2±0.1	9.7±0.2	9.9±0.1	0.1±0.0	0.2±0.01	0.2±0.01	0.01±0.01	0.01±0.0	0.01±0.0
SP	8.0±0.4	7.8±0.4	7.7±0.2	0.1±0.0	0.2±0.01	0.2±0.01	0.01±0.00	0.02±0.01	0.02±0.0

Water Quality Indices	Effluent Quality Reported by AWTP	Water Quality in Distribution System
Temperature (°C)	N/A	24.1- 25.8
DO (mg/L)	6.94	4.2 - 5.9
pH (pH units)	7.07	7.7 - 8.1
TDS (mg/L)	890	759 - 964
TSS (mg/L)	0.8	1.8 - 2.6
Total Nitrogen (mg/L)	1.21	1.7 - 3.2
Orthophosphate (mg/L)	3.5	7.7 - 13.1
Conductivity (µS/cm)	N/A	1543 - 1969
Turbidity (NTU)	0.88	0.7 - 1.5
Total Chlorine (mg/L)	N/A	0.1 - 1.1

Table 4. Comparison of reclaimed water quality in STAR Phase I distribution system with effluent quality reported by the Curren Treatment Plant with University of Florida data analysis.

	10:15AM	12:15PM	2:15PM
	α, β	α, β	α, β
AWTP	8.44, 0.08	8.24, 0.09	3.62, 0.48
FS	1.85, 0.63	1.33, 0.66	2.90, 0.29
PHS	2.11, 7.23	2.69, 0.48	6.60, 0.12
SP	4.41, 0.20	8.24, 0.09	4.41, 0.20

Table 5. and values for each cumulative gamma distribution of PSDs.

Continued from page 47

PBS&J's Phase II planning report, which are based on Phase I bids, and were brought to the year 2007. Horizontal boring is expected to be used for all HDPE pipes. DIP costs were taken from a regional water plan.

The estimated price of the at-grade storage pond designed for the Curren Plant was based on a similar project: the Pasco County Wet-Weather Reclaimed Water Reservoir Project, which was designed to store 400 million gallons of surplus reclaimed water to help offset dry-season demands.

The net present value (NPV) for each design was calculated by subtracting total revenue from total present cost, both projected to 2030. To find the total present cost, capital costs such as construction fees for piping, storage, and pumps were added to present O&M costs.

Construction of STAR Phase II was expected to start in 2007 and end in 2012. These years were used to determine O&M present value costs, which were based on the 2007 O&M values brought to 2012 with 3 percent interest and then compounded to 2030. This future value was then brought back to 2007 using a discount rate of 5 percent to account for risk. The total present cost was then adjusted by a factor of 25 percent for contingency and 20 percent for technical fees, permitting fees, and other miscellaneous fees (McElroy, 2007).

Total revenue was calculated by adding the present value of the revenue made from reclaimed water to the grant money received from Southwest Florida Water Management District and other contributors. To calculate the revenue generated from STAR, the total yearly demand for each region was multiplied by the current reclaimed rate of $1.34/ccf and compounded from 2012 to 2030. The total revenue was then brought back to the 2007 using the same 5 percent discount rate that was used to determine O&M present value cost (Annual Report FY2006, Southwest Florida Water Management District).

Results & Discussion

Table 2 summarizes the average reclaimed water effluent chemistry in 2006 reported by The Curren Treatment Plant. A summary of reclaimed water chemistry in STAR Phase I distribution system is shown in Table 3. A comparison of water chemistry in STAR Phase I distribution system with the average reclaimed water effluent chemistry reported by the plant in 2006 is summarized in Table 4.

According to the data in Tables 3 and 4, no significant difference was found in terms of temperature, dissolved oxygen, pH, and total dissolved solids between reclaimed water in the STAR Phase I distribution system and effluent from the treatment plant; however, TSS, total nitrogen, and orthophosphate were higher in the STAR Phase I distribution system than reported by the plant.

TSS (7.1 mg/L) and turbidity (4.0 NTU) of water sampled from Plant High School (PHS) at 10:15 a.m. were much higher than water sampled at other sampling times and locations, probably due to lack of pipe flushing before sampling. These data indicate biological growth in the distribution system.

Phosphorous in the STAR Phase I distribution system is much higher than that reported by the Curren Plant, which may cause potential eutrophication in Tampa or Hillsborough Bay. Also, chlorine residual in the STAR Phase I distribution system is too low to protect from microbial growth, which justifies disinfection booster stations.

Figure 2 displays a comparison of particle size distribution at each sampling time from

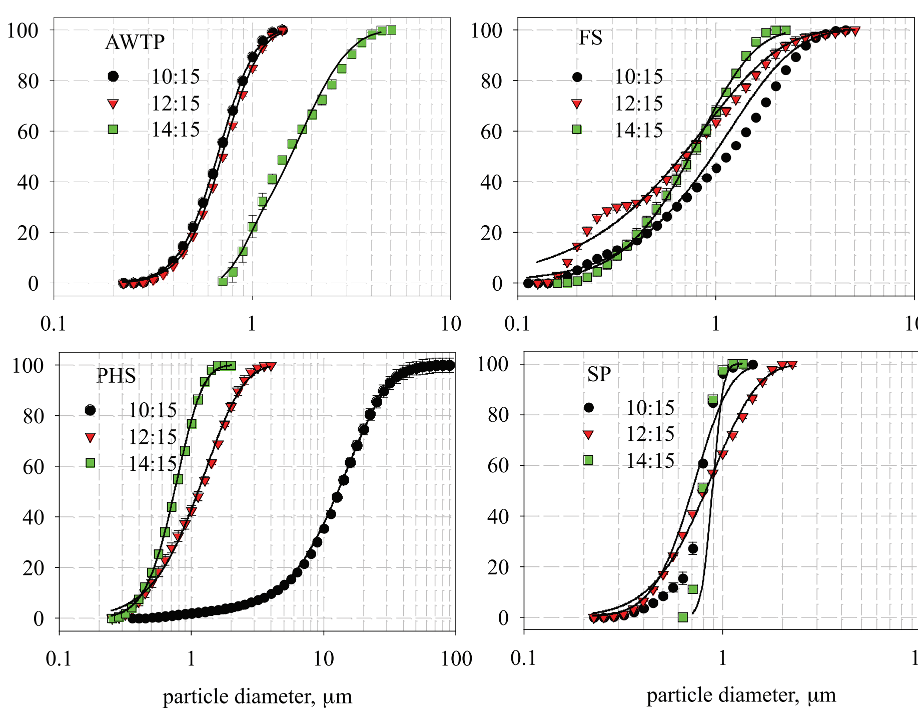

Figure 2. Comparisons of particle size distributions (PSDs) at each sampling time, from different sampling locations. PSD data were modeled by cumulative gamma distribution.

different sampling locations. Particle size distribution data were fit with a cumulative gamma distribution. Shape factor (α) and scale factor (β) were calculated as well. The shape factor α, represents uniformity of the particles, and the scale factor β, indicate the medium value of the particle size. Table 5 shows α and β values for each cumulative gamma distribution.

		Census	Projections					
Population	1994	2000	2005	2010	2015	2020	2025	2030
Hillsborough	910,000	998,948	1,132,000	1,249,000	1,355,000	1,460,000	1,561,000	1,654,000
Tampa	262,590	303,447	327,000	360,000	391,000	421,000	450,000	477,000
Flow MGD	56.6	48.5	57.2	66	72	77	83	88

Table 6. Year 2030 Projected flow from the Curren Plant, based on population.

Projection Scope	2000 actual flow MGD	Estimated 2000 to 2020 I&I reductions MGD	Estimated WWTP Flow Reductions 2000 to 2025(conservation) MGD	Projected % increase 2000 to 2025	Projected WWTP flow MGD
Hillsborough	92.95	4.32	0.61	60%	140.83
Curren Plant	48.5	2.25	0.32	60%	73.49

Table 7. Year 2025 Projected flow from the Curren Plant, based on flow ratio with Hillsborough County.

Projected Demands

The future supply of reuse water for the project depends directly on potable water conservation, the population served by the Curren Plant, and I&I in the wastewater collection area. The flows projected as a function of the population show the plant nearing capacity by 2030 with effluent flow reaching 88 MGD, shown in Table 6. Since there is a direct relationship to potable water used and wastewater treated, an alarming trend is indicated by these values.

The Southwest Florida Water Management District's 2006 Regional Water Supply Plan projected Hillsborough County wastewater flows to 2025, estimating reductions in inflow because of conservation and reductions in I&I. These projections were proportionally related to the Curren Plant, shown in Table 7.

If no conservation measures are undertaken, the projected flow going through the Curren Plant is predicted to increase over the 20-year life of the project with an approximate average daily flow of 88 MGD. The seasonal peak of the plant is typically 128 percent of the yearly average, giving a calculated peak of 112.64 MGD if no conservation measures are implemented. I&I could add significantly to this stress, as shown in Figure 3, especially if no reduction measures are implemented.

The results of the reuse neighborhood GIS in Figure 4 shows optimal demand densities in the following three regions:

➢ South of Phase I, including:
  - o Residential irrigation, Palma Ceia Golf and Country Club, and light Industrial, Commercial, and

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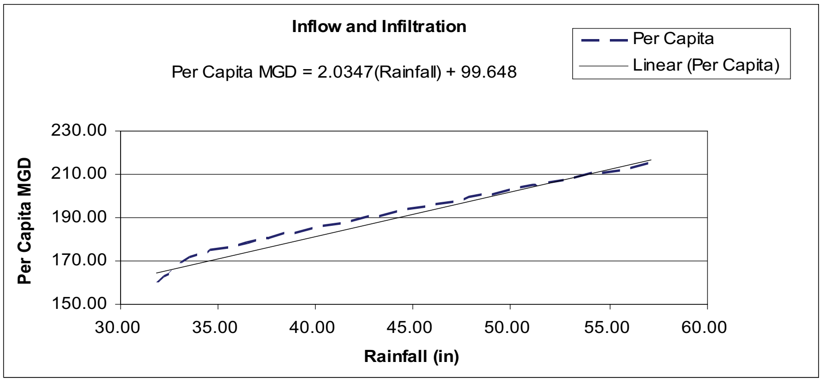

Figure 3. Inflow and infiltration normalized against population.

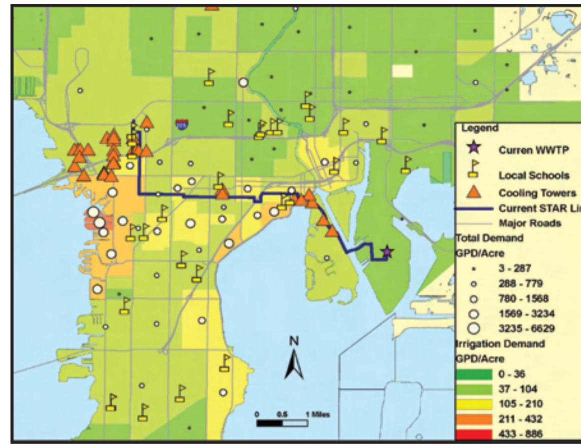

Figure 4. GIS map of potential reuse customers for STAR Phase II

Continued from page 49

Institutional (ICI) possibility.

➢ Northeast of Phase I, including:
   o ICI with minimal residential irrigation.

➢ Northwest of Phase I, including:
   o Residential irrigation, Tampa International Airport, and Rock Point Golf and Country Club, Raymond James Stadium and various ICI.

For design purposes pertaining to water quality ICI users are considered not to be reliable design demands, which leaves irrigation flow as the singular demand parameter.

The general trend produced on Table 8 for Phase II shows the most variability is due to WUPs that are located in the following neighborhoods:

➢ Lowry Park Central
➢ Golfview
➢ North Rocky Point
➢ Tampa International Airport

Analyzing Table 8 yields total median values showing a 4.74 percent increase in flow over the minimum values. Total maximum values show a 17.29 percent increase in flow over the median values. Variation in demand projections at the median level have an error of +/- 17.29 percent, which is the maximum percent difference of the demand range. A factor of safety can be maintained by applying this error to all the demand projections. The actual variation within each neighborhood would differ from +/- 17.29 percent. The most inaccuracy occurs for the lower bound of reuse neighborhoods without WUPs.

Important to note is that according to Phase I connection and irrigation water meter data (Vilagos, 2007), there were 9,000 potable irrigation meters at project start. Three years later, there were approximately 6,600 meters, suggesting that initial demand for Phase II will be only -27 percent of total design demand for the system. This value could increase to +17.29% of the design demand at maximum user connectivity.

Peak flows are shown at approximately 2 a.m. for both the average demand in Figure 5 and the maximum demands in Figure 6. All values are normalized as a percentage of the average daily flow going into STAR system.

Design Options

The three base expansion systems that were designed for STAR Phase II include a South system, a Northeast system, and a Northwest system. After creating these three base pipe networks, all

REUSE NEIGHBORHOOD	GPD Min Demand	GPD Median Demand	GPD Max Demand	GPM Min Demand	GPM Median Demand	GPM Max Demand
CARVER CITY/LINCOLN GARDENS	370,000	370,000	537,000	257	257	373
CORY LAKE ISLES	723,000	723,000	870,000	502	502	604
DREW PARK	217,000	217,000	266,000	151	151	185
EAST SIDE COMMERCIAL	164,000	164,000	217,000	114	114	151
EAST TAMPA BUSINESS & CIVIC	415,000	415,000	560,000	288	288	389
FOREST HILLS NEIGHBORHOOD	219,000	219,000	238,000	152	152	165
GOLFVIEW	593,000	1,017,000	1,190,000	412	706	826
HIGHLAND PINES	197,000	197,000	204,000	137	137	142
HUNTERS GREEN	1,760,000	1,760,000	2,095,000	1222	1222	1455
LOWRY PARK CENTRAL	269,000	336,000	353,000	187	233	245
NEW TAMPA	5,432,000	5,432,000	5,780,000	3773	3773	4014
NO REGISTERED NEIGHBORHOOD	3,559,000	3,888,000	5,192,000	2472	2700	3605
NORTH ROCKY POINT	859,000	907,000	1,292,000	596	630	897
NORTHVIEW HILLS	20,000	20,000	22,000	14	14	15
OLD SEMINOLE HEIGHTS	232,000	232,000	336,000	161	161	233
PALMA CEIA	199,000	199,000	281,000	138	138	195
PALMETTO BEACH	138,000	138,000	198,000	96	96	137
TAMPA HEIGHTS	120,000	120,000	167,000	83	83	116
TAMPA INTERNATIONAL AIRPORT	2,561,000	2,920,000	3,778,000	1779	2028	2623
TAMPA PALMS	2,208,000	2,208,000	2,635,000	1533	1533	1830
TERRACE PARK	2,965,000	2,965,000	3,058,000	2059	2059	2124
NORTH AIRPORT	1,477,000	1,477,000	2,081,000	1026	1026	1445
Total	24,700,000	25,930,000	31,350,000	17,000	18,000	22,000
Total MGD	25	26	31			

Table 8. Phase II demand ranges taken at 100% coverage and 100% connection

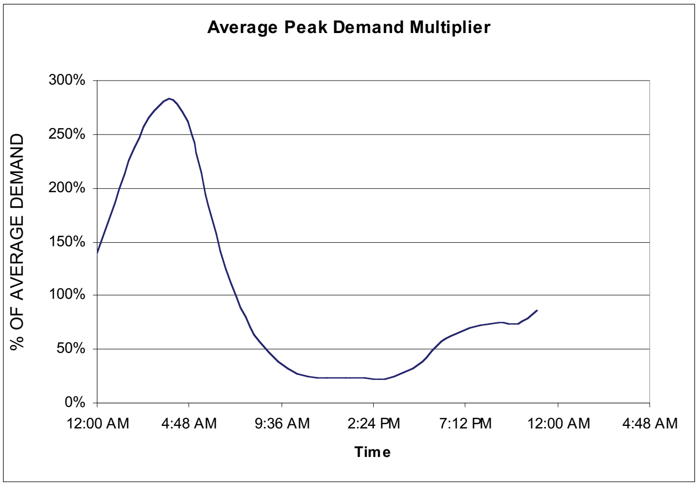

Figure 5. Average demand multipliers for determining hourly demands.

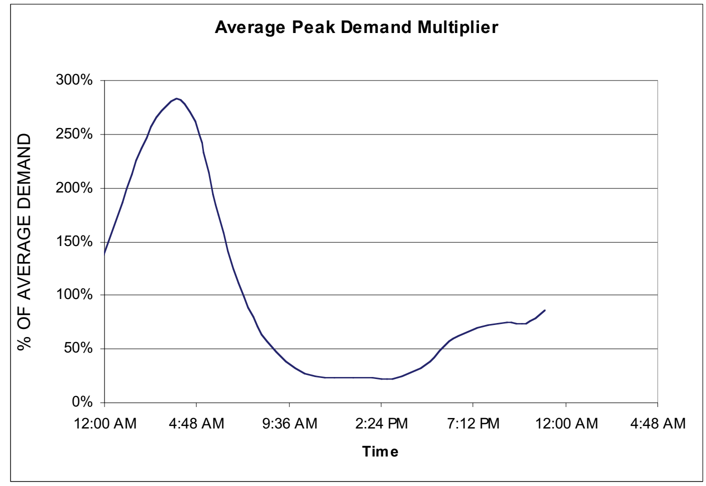

Figure 6. Maximum demand multipliers for determining hourly demands.

possible combinations of the Phase II systems were evaluated. A total of seven possible pipe network options were identified, which include the three base pipe networks by themselves and the four combinations of the base pipe networks, and are compared in Tables 9 and 10.

After all possible systems were established, cost summations of the pipe distribution systems were tabulated for each option and were used as part of the basis for narrowing down

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	Pipe Length (ft) for given Diameter					Total Flow	
Expansion Zone	**4.0 in**	**6.3 in**	**9.5 in**	**18 in**	**25.1 in**	**GPM**	**MGD**
South	511,000	0	0	0	56,000	2,400	3.5
NW	381,000	16,000	2,600	0	40,000	3,000	4.3
NE	93,000	0	0	32,000	0	400	0.6
South & NW	893,000	16,000	2,600	0	96,000	5,400	7.8
South & NE	605,000	0	0	32,000	56,000	2,800	4.1
NW & NE	475,000	16,000	2,600	32,000	40,000	3,400	4.9
South, NW & NE	986,000	16,000	2,600	32,000	96,000	5,800	8.4

Table 9. Pipe lengths, diameters, and total flows for seven design combinations.

Design	Pipe Cost ($M)	Demand (MG)	Ratio ($/gal)
South	$25.3	1,300	$0.0199
NW	$19.1	1,600	$0.0122
NE	$7.4	200	$0.0331
South & NW	$44.5	2,800	$0.0157
South & NE	$32.7	1,500	$0.0219
NW & NE	$26.5	1,800	$0.0148
South, NW & NE	$51.8	3,000	$0.0169

Table 10. Pipe layout design options with costs and demands.

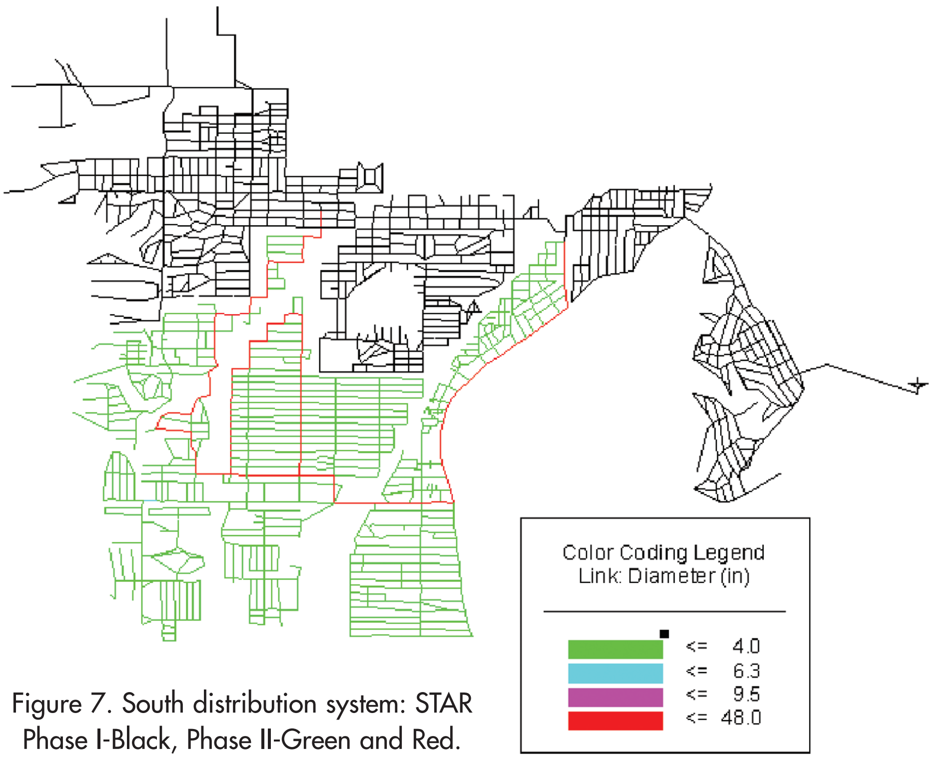

Figure 7. South distribution system: STAR Phase I-Black, Phase II-Green and Red.

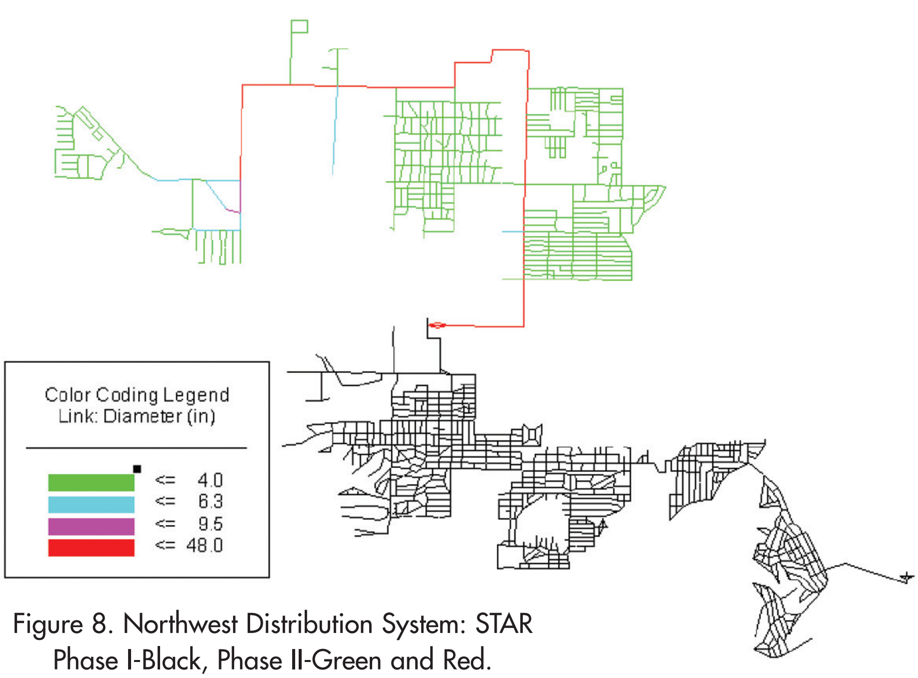

Figure 8. Northwest Distribution System: STAR Phase I-Black, Phase II-Green and Red.

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the original seven options to the final three.

Total daily demand flows for each possible distribution system were determined using WaterCAD 4.5 to evaluate each option. Using the total costs and the total demands for each option, a ratio of cost per gallon was found for each system. Using these cost-to-flow ratios, the Northeast system was eliminated as an unfeasible design option, as well as all other options that included the Northeast system. Based on the data seen in Table 10, the possible design options were narrowed down to three systems, which include the South system alone, the Northwest system alone, and a combination of the Northwest and South systems.

Each system consists of a modified effluent chlorination system, optimized flushing points, and storage basins calculated for each individual design. Specific demands, costs, and pipe characteristics vary for each system and can be seen in the tables that accompany the design options on the following pages.

EQ Storage Design

Table 11 shows the calculated volume of storage for Phases I and II for each design, based on flow. The storage is proposed to be located at the Curren Plant where the current unused sand drying beds are located.

South Design Option

The pipe distribution system for the South system consists of a DIP main and HDPE laterals, as seen in Figure 7 and Table 12. A 7.8-MG storage basin was designed for the South design based on the average peak demand. The South design system will implement the modified effluent chlorination design, which will consist of a separate chlorination basin for both the outfall and STAR effluents. This chlorination design will significantly reduce the total amount of chlorine and sulfur dioxide used in the chemical treatment of the reclaimed water and also will lower the cost of chemicals.

The South design will possess an average peak demand of 3.5 MGD, summarized in Table 9. After the system was evaluated, it was concluded that a 55-gpm flushing system distributed between three points would be needed. In addition to flushing points, two boost-

Volume of Storage Needed	
South Design	7.8 MG
Northwest Design	8.6 MG
Combined Design	12.3 MG

Table 11. Storage for each design option.

er stations would be required, creating a residual of 4.5 mg Cl_2/L at Station 1, and 2.0 mg Cl_2/L at Station 2 (Appendix 5).

Cost for each chlorine station is around $10,000, which is included in the overall costs (Cliborn, 2007). A total cost analysis for the South design is summarized in Tables 13 and Table 14. Complete specifications for the design are summarized in Table 15.

The cost analysis revealed an efficiency ratio of 0.0199 $/gal, which makes this design system the least efficient; however, it is still a viable option based on overall project cost.

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Diameter (in)	Length (ft)	Unit Cost ($/ft)	Total Cost
4	511,000	$23	$11,600,000
25.1	56,000	$245	$13,700,000
Total	567,000		$25,300,000

Table 12. Pipe breakdown of South system.

South Design	Costs
Pipe Layout	$25,300,000
Pump Station	$0
Booster Station (2)	$20,000
Storage Basin	$360,000
Chemical Treatment	$3,600,000
Contingency Factor	$7,300,000
Technical Fees	$5,900,000
Total Cost	$42,500,000

Table 13. Total present value costs through 2030.

South Design	Income/Revenue
Local Cooperators	$930,000
SWFWMD	$17,600,000
WPSTF	$1,800,000
Projected Revenue	$8,000,000
Net Present Value	$14,100,000

Table 14. Total present value revenues through 2030.

South Design	Specifications	
Split Effluent Chlorination		
Average Demand	3.5	MGD
Pipe Network	567,000	Ft
Flushing System	55	Gpm
Chlorine Booster (2)	4.5, 2.0	mg Cl_2/L
Main Pipe	25.1	Inch
Laterals	4	Inch
Storage Basin	7.8	MG
Efficiency Ratio	0.0199	$/gal
Total Cost (NPV)	14.1	Million $

Table 15. Summary table for design specifications of the South design.

Diameter (in)	Length (ft)	Unit Cost ($/ft)	Total Cost
4	381,000	$23	$8,700,000
6.3	16,000	$30	$500,000
9.5	3,000	$40	$100,000
25.1	40,000	$245	$9,900,000
Total	440,000		$19,100,000

Table 16. Pipe breakdown for Northwest system.

Table 17. Total present value costs through 2030.

Northwest Design	Costs
Pipe Layout	$19,100,000
Pump Station	$380,000
Storage Basin	$400,000
Chemical Treatment	$3,600,000
Contingency Factor	$5,900,000
Technical Fees	$4,700,000
Total Cost	$34,100,000

Table 18. Total present value revenues through 2030.

Northwest Design	Income/Revenue
Local Cooperators	$930,000
SWFWMD	$14,100,000
WPSTF	$1,800,000
Projected Revenue	$9,000,000
Net Present Value	$8,300,000

Table 19. Summary table for design specifications of the Northwest design.

Northwest Design	Specifications	
Split Effluent Chlorination		
Average Demand	4.3	MGD
Pipe Network	440,000	Ft
Flushing System	80	Gpm
Main Pipe	25.1	Inch
Laterals	4, 6.3, 9.5	Inch
Storage Basin	8.6	MG
Efficiency Ratio	0.0122	$/gal
Total Cost (NPV)	8.3	Million $

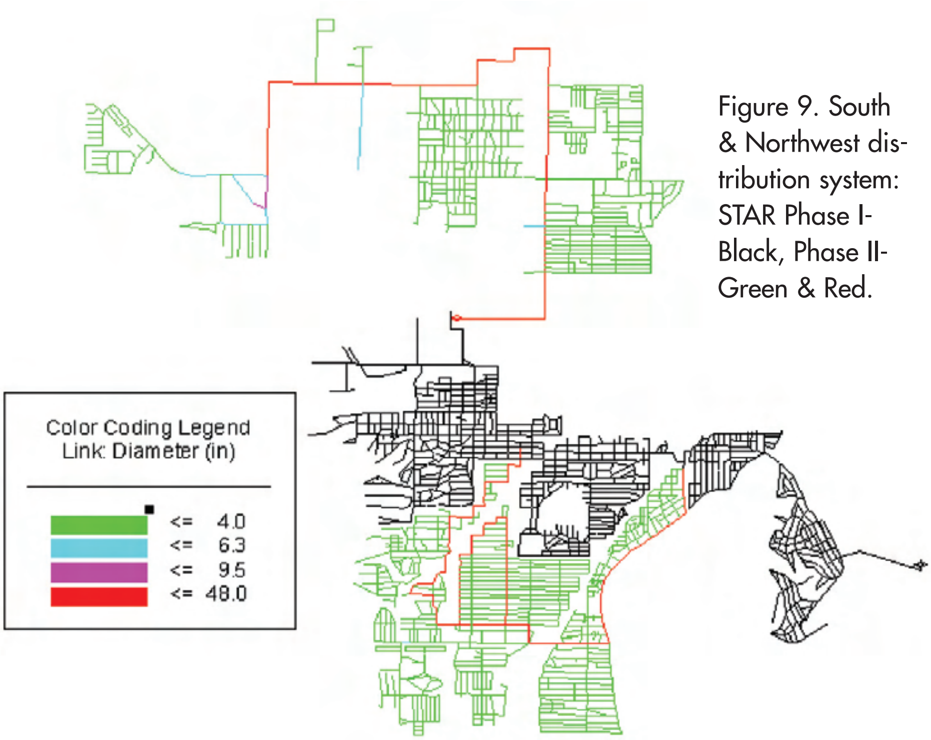

Figure 9. South & Northwest distribution system: STAR Phase I-Black, Phase II-Green & Red.

Continued from page 53

NorthWest Design Option

The Northwest design alternative, like the South, also contains the modified effluent chlorination system, which reduces the overall chemical and O&M costs. The average peak demand for the Northwest design is 4.3 MGD. A breakdown of pipe material, diameter, and cost is detailed in Figure 8 and Table 16.

The storage basin designed for this demand flow is 8.6 MG. The Northwest system will have two recirculation points both discharging 15 gpm. Also, it will discharge 50 gpm, as bulk interruptible flow, to the Rocky Point Golf Course. The summary of the cost analysis for the Northwest system is summarized in Tables 17 and 18. Complete specifications for the design are summarized in Table 19.

Based on the cost analysis data, the Northwest system is the most cost-effective solution with an efficiency ratio of .0122 $/gal. This option also has the lowest overall project cost, making it the optimal solution.

Combined Design Option

The combined design incorporates a summation of the characteristics of both the Northwest and South options; therefore, this system contains the same effluent chlorination scheme. The total peak average demand for the combined system is 7.8 MGD, which requires a storage basin with a volume of 12.3 MG. The pipe distribution characteristics are shown in Figure 9 and Table 20, and the cost analysis breakdown for the combined system is detailed in Tables 21 and 22.

The flushing system for this design is designed to be 135 gpm, which is a combination of the previous designs. The system would also include the design specifications of the chlorine booster stations in the South design. The complete specifications for the combined design are summarized in Table 23.

The combined design is the second most cost-efficient design; however, the total cost of the project is beyond the limits of the projected budget.

Final Design Evaluation

The three feasible design options can be rated based on total cost, potable offset, and their overall efficiency ratios. Using an efficiency ratio of cost per gallon, the Northwest expansion was determined to be the most efficient. The second most efficient design was the combined South and Northwest expansion design, and the least efficient design was the South expansion design, but differences in efficiency ratios among the three systems were minor.

According to cost calculations, the combined design is nearly double the cost of both the South and Northwest expansions. The

South design was also significantly more expensive than the Northwest design. The Northwest expansion is capable of offsetting 4.3 MGD of potable water, the South expansion can offset 3.5 MGD, and the combined design offsets 7.8 MGD. When comparing and analyzing the calculated cost and flow values in Tables 24 and 25, the Northwest system is determined to be the optimal solution.

In addition to the costs of STAR Phase II, the proposed chlorine effluent modifications will save money at the Curren Plant by decreasing the amount of chemicals purchased. Table 26 compares the current 2007 budget for chemicals and the calculated amounts needed for each design option.

Recommendations

Proposed Design

All three designs are potentially viable, but budget limitations have eliminated the possibility of implementing a combined pipe layout including both the South and Northwest systems. After the remaining two designs were evaluated, considering the available budget for STAR Phase II, the design team recommends that the city of Tampa implement a Northwest expansion to the current STAR Phase I distribution system.

This design expansion will offset 4.29 MGD in addition to the current offset of STAR Phase I. The expansion will require a total net present value cost of $8.3 million, which is feasible under the projected budget for STAR Phase II. The addition of a Northwest expansion will also help reduce stress on the Tampa area water resources, and will allow the city to maintain a reputation of environmental innovation and stewardship.

Future Considerations

Adjusting water-billing rates to change customer usage habits is a common practice among water supply districts. If a water source is under-priced, customers will use their resource inefficiently. If the supply is over-priced, the water supply district risks losing customers or facing public protest. Reclaimed water adds a new dimension to assigning water rates because of its auxiliary nature. A careful balance has to be found between charging too much or too little for reclaimed water use, especially for large users.

In a comparison of water districts in areas surrounding the city of Tampa, the city was found to charge about 50 percent less than its neighboring districts for residential users. The average potable water rate for each district was found by averaging their current potable water tier scales.

It is recommended that Tampa raise its residential potable water rates to 1.35 times

Continued on page 56

Diameter (in)	Length (ft)	Unit Cost ($/ft)	Total Cost
4	893,000	$23	$20,300,000
6.3	16,000	$30	$500,000
9.5	3,000	$40	$100,000
25.1	96,000	$245	$23,600,000
Total	1,008,000		$44,500,000

Table 20. Pipe breakdown for combined system.

Combined System	Costs
Pipe Layout	$44,500,000
Pump Station	$380,000
Booster Station (2)	$20,000
Storage Basin	$570,000
Chemical Treatment	$3,800,000
Contingency Factor	$12,300,000
Technical Fees	$9,800,000
Total Cost	$71,400,000

Table 21. Total present value costs through 2030.

Combined System	Income/Revenue
Local Cooperators	$930,000
SWFWMD	$29,500,000
WPSTF	$1,800,000
Projected Revenue	$17,000,000
Net Present Value	$22,100,000

Table 22. Total present value revenues through 2030.

Combined System	Specifications	
Split Effluent Chlorination		
Average Demand	7.8	MGD
Pipe Network	1,008,000	Ft
Flushing System	135	Gpm
Chlorine Booster (2)	4.5, 2.0	mg Cl_2/L
Main Pipe	25.1	Inch
Laterals	4, 6.3, 9.5	Inch
Storage Basin	12.3	MG
Efficiency Ratio	0.0157	$/gal
Total Cost (NPV)	22.1	Million $

Table 23. Summary table for design specifications of the combined design.

	Flow (MGD)	Cost	Ratio ($/gal)
South	3.5	$14,100,000	0.0199
Northwest	4.3	$8,300,000	0.0122
Combined	7.8	$22,100,000	0.0157

Table 24. Comparison of three optimal design solutions: potable water offset, total cost, efficiency ratio.

Design	Max Phase II Flow	Max Phase I Flow	Total
South	6.2	7.2	13.4
Northwest	7.7	7.2	14.9
Combined	13.9	7.2	21.1

Table 25. Maximum peak conditions for STAR Phase I and Phase II.

Costs	SO_2	Cl_2	O&M	Total
Current	$82,000	$407,000	$121,000	$610,000
South	$66,000	$178,000	$98,000	$243,000
Northwest	$65,000	$181,000	$100,000	$246,000
Combined	$61,000	$196,000	$107,000	$257,000

Table 26. Annual chemical and O&M savings at the Curren Plant

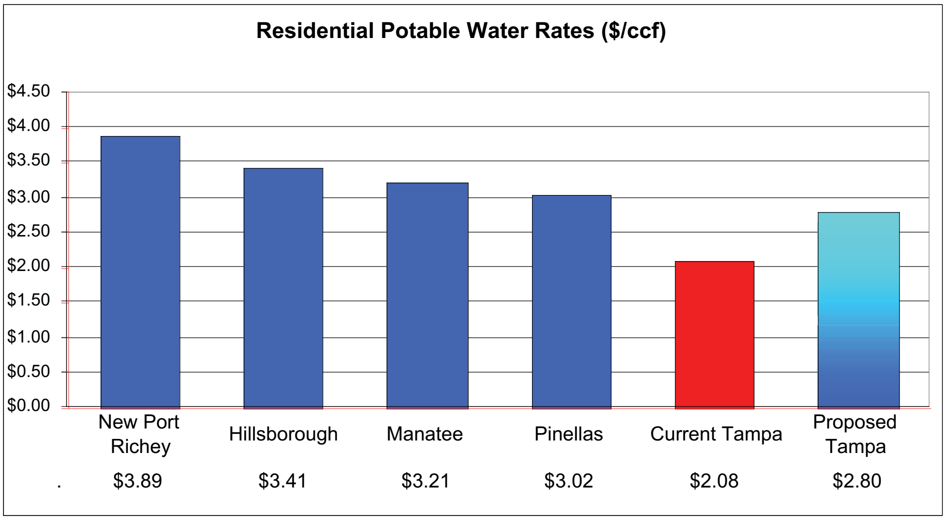

Figure 10. Proposed and current residential potable water rates in cost per ccf (2007).

City of Tampa Potable Water Rates			
	Residential Class	Current Rate	Proposed Rate
Tier 0	0 to 5 ccf per month	$1.07 per ccf ($1.43 per TG)	$1.44 per ccf ($1.93 per TG)
Tier 1	6 to 13 ccf per month	$1.24 per ccf ($1.66 per TG)	$1.67 per ccf ($2.24 per TG)
Tier 2	14 to 26 ccf per month	$2.08 per ccf ($2.78 per TG)	$2.81 per ccf ($3.75 per TG)
Tier 3	27 to 45 ccf per month	$2.78 per ccf ($3.72 per TG)	$3.75 per ccf ($5.02 per TG)
Tier 4	Over 46 ccf per month	$3.21 per ccf ($4.29 per TG)	$4.33 per ccf ($5.79 per TG)

Table 27. Comparison of current and proposed potable water rates (2007).

Table 28. Proposed Tier System for STAR.

STAR Residential Reclaimed Water Rates		
Tier 1	0-15 ccf per month	$0.94 per ccf ($1.26 per TG)
Tier 2	15-20 ccf per month	$1.34 per ccf ($1.79 per TG)
Tier 3	Over 20 ccf per month	$1.74 per ccf ($2.33 per TG)

Table 29. Proposed residential irrigation schedule for STAR.

STAR Residential Irrigation Schedule	
Addresses ending in 1-3	Water between 1-3 a.m.
Addresses ending in 4-6	Water between 4-6 a.m.
Addresses ending in 7-9	Water between 7-9 a.m.
Do NOT water on Wednesdays.	

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the current rate in order to be in the same range as surrounding districts, but not to exceed the other districts. This would bring the city's average rate from $2.08 per ccf of potable water up to $2.80 per ccf. Figure 10 below shows the average proposed rate alongside other district averages.

Raising the potable water rates and maintaining the average reclaimed rate for residential users should facilitate more efficient offset of potable water. Residential customers would value both sources of water more and therefore use the reclaimed water instead of potable water for irrigation. Table 27 details the recommended rate increase within the potable water tier scale.

In order to ensure efficient use of reclaimed water among residential customers and maximum potable water offset, a reclaimed tier rating scale is recommended. Scaling of the reclaimed rates is important for the long-term success of STAR as more customers join the network and the use of effluent from the Curren Plant for reclamation approaches full capacity.

Tampa currently charges a flat rate of $1.34 per 100 cubic feet ($1.79 per 1,000 gallons) for unlimited use of reclaimed water. The new reclaimed tier scale should include three tier levels with an average rate of $1.34, as seen in Table 28. A residential customer using potable water for irrigation averages 11.2 ccf (8,400 gallons). If that same customer used reclaimed water without tier rates, the monthly average would be 16.8 ccf (12,600 gallons) (Andrade, 2007). The tier system, seen in Table 4-2, follows these averages by encouraging customers to maintain the same amount of irrigation usage for reclaimed water as that of potable water.

Another recommendation for STAR residential customers is an irrigation schedule. Currently there are irrigation restrictions for potable water but none for reclaimed water. An irrigation schedule for STAR would be another component to maintain efficiency of reclaimed water use, attenuate the peaks in daily flow, and allow for a maintenance day. The flow in STAR usually peaks around 3 a.m.-4 a.m., which causes problems with chlorination and hydraulic delivery. Also, a maintenance day built into the weekly schedule would provide time for flushing the system and repairing any broken or damaged pipes and meters. The recommended irrigation schedule for residential STAR customers is detailed in Table 29.

In addition to the suggested STAR Phase II design, other projects should be considered for using reclaimed water from the Curren Plant. First, it is recommended to increase demands within the existing pipe network by targeting additional large users. New construction and urban revitalization should be pursued as potential new users. Pipes can be installed during construction or renovation and applied to both irrigation and air conditioning. Also, potential industrial, commercial, and institutional (ICI) customers who currently use potable water for cooling towers should be persuaded to connect.

There are many benefits to adding customers with cooling towers or other large air conditioning units. Customers with cooling towers would provide a steady base flow throughout the day and have less variation in demand during the year, compared to wet and dry season irrigation. They are also a consistent revenue source and would bring more profit per connection than residential users. ICI customers with cooling towers maximize potable water offset by using the same amount of reclaimed water as potable water in their cooling towers as opposed to irrigation customers who tend to use more water when they irrigate with reclaimed water.

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Table 30. Proposed reclaimed water rates for ICI customers.

STAR Commercial, Industrial, and Institutional Reclaimed Water Rates	
Priority customer	$0.60 per ccf ($0.80 per TG)
Interruptible customer without storage	$0.40 per ccf ($0.53 per TG)
Interruptible customer with storage	$0.20 per ccf ($0.27 per TG)

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It is recommended that a series of strategies be implemented in order to influence ICI customers with cooling towers to join the program. The two major factors hindering the use of reclaimed water in cooling towers are its cost and the presence of higher total dissolved solids (TDS) in reclaimed water. It is recommended that the reclaimed water rate for ICI customers be significantly below their potable water rates and tiered to include rates for interruptible customers. Currently, the average potable water rate for ICI customers is $2.33 per ccf. The proposed average cost of the reclaimed tier for these customers is $0.40. The recommended rates are listing in Table 30.

With the proposed reclaimed water rates in place for ICI customers, STAR connections with cooling towers should increase significantly because of the sharp increase in savings. Also, the added cost of TDS-reducing chemicals needed for cooling towers using reclaimed water would be more than recovered with the proposed rates.

It is recommended that an educational campaign be pursued in order to advertise the lower rates to ICI customers and provide them with information about the new chemicals they would need to purchase. This campaign should include pamphlets, seminars, and a city representative to guide the transition from potable to reclaimed water for these valued customers.

Another large potential user that should be considered is Pinellas County's reclaim system. A main extending from the Northwest system could easily reach the county border. Once these large users connect to STAR, the need for seasonal storage should be evaluated. Types of storage could include surface impoundments on golf courses and elevated storage tanks.

Finally, the phosphorous and nitrogen loading rate into the Tampa Bay can not be ignored. Currently, 0.8 metric tons of phosphorus is being added to the bay daily. A plan of action for reducing this loading rate must be devised. Also, reduction of N and P and other pollutants such as endocrine disrupting compounds and metals is required before introduction into the reuse system. Much of the reuse becomes irrigation water and nutrient pollutant becomes part of the urban hydrologic cycle.

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