Water Transmission and Energy/Storage Optimization Study

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The Florida Keys Aqueduct Authority (FKAA) authorized Atkins Global to update and calibrate the Innovyze InfoWater hydraulic model of its water transmission system (WTS), which was previously done by Atkins (formerly PBS&J) in 2009. As part of this effort, an extensive amount of WTS background data were collected and compiled, including water meter records and connections to a transmission system consisting of pressure-reducing valve stations (TAP), spatial disaggregation of service area water demands, booster and distribution system pump station historical log charts, booster and distribution system pump station supervisory control and data acquisition (SCADA), and a pump station energy cost summary.

An updated hydraulic model was developed exclusively for the FKAA WTS, including parallel sections of transmission mains from Florida City to Key West, five major booster pump stations (BPS), and all TAPs located along the transmission system. The model was originally created in steady state; the updated model was enhanced by making TAP water demand assumptions to develop an extended period simulation of 24 hours along the WTS. A discussion of how varying diurnal demands were applied to different kinds of TAPs is presented.

The local water distribution systems, including storage tanks and small booster pumps, were not modeled as part of the WTS and are simulated by the TAP demands. The updated FKAA WTS model was initially calibrated utilizing two sets of data: a period from February 2-4, 2011, was considered an average-day supply-and-demand scenario; and during Memorial Weekend in May 2011, a condition reflecting some of the highest water demands recorded over the past several years was considered a maximum-day scenario. Additional calibrations of the scenarios were performed to refine and update a few facilities based on November 2012 SCADA information provided by FKAA. The calibrated hydraulic model was then used to evaluate optimal energy operating procedures and location of additional WTS emergency storage.

Summary of Water Transmission System Model Update and Calibration

The hydraulic model has been recalibrated and updated to represent the current water system operation and demand conditions based on recent water meter TAP data, SCADA, and log sheets supplied by FKAA.

Water Demands

Two consecutive years (2010-2011) of TAP data, supplied per water meter, were used to update the WTS to current demands. The TAP water demands for the model have been updated to reflect the current lower average-day demands, as well as a lower peaking factor on the system. As a comparison, the 2005 annual average TAP demands included in the previous hydraulic model totaled 16.69 mil gal per day (mgd). The recent two-year TAP data resulted in an annual average demand of 15.05 mgd, which resulted in an annual average demand decrease of approximately 11 percent. This decrease is likely due to current economic conditions directly affecting population decreases and reduced water consumption per capita. In addition, FKAA's water loss along the WTS was evaluated and applied appropriately to the model to account for the total production at the Florida City Water Treatment Plant (WTP) and WTS pressure losses. The WTS is segmented into five areas that extend from Key West to Florida City (Areas I-V). The TAP data also include demands for the United States Navy and the recent system privatization and modifications made by FKAA. Table 1 summarizes the historical rolling annual average demand quantities for the years 2010 and 2011.

During this timeframe, it is estimated that the WTS experienced a total loss of approximately 10 percent, based on the difference between the average supply recorded at WTP and the average TAP demands. The water loss is over approximately 125 mi, resulting in an average water loss of an estimated 12,000 gal per day (gpd) per mi. The WTP distributed an average daily flow (ADF) of 17.1 mgd and a maximum daily flow (MDF) of 20.2 mgd, under recent demand conditions. There is also a reported additional water loss of approximately 10 percent in the local water distribution system downstream of the TAPs, which FKAA continues to work on reducing through review of meter accounting, meter testing, water audit programs, and other maintenance activities. In 2011 and 2012, FKAA identified and repaired a WTS leak reportedly contributing to a major portion of the WTS loss on North Roosevelt.

Diurnal Demand Patterns

The WTS model consists of two different types of connections that must be modeled appropriately (at input nodes) to simulate the

Table 1. Florida Keys Aqueduct Authority Water Transmission System Annual Average Water Demand

Area	Annual Average Water Demand (mgd)
I	4.71
II	1.24
III	3.02
IV	1.94
V	3.51
Navy	0.63
TOTAL	**15.05**

1. Two-year rolling average from 2010 and 2011.

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varying water demands at the TAPs: 1) tank demands that are TAP connections that only directly fill a distribution system tank, and 2) TAP demands that are direct feeds into the distribution system served by either a tank or no tank. Approximately 45 percent of the demand on the WTS consists of tank demand nodes, which directly supply a local distribution system generally consisting of a tank and a small booster pump station. These TAPs have a more constant demand due to a more controlled filling rate of a distribution tank and do not follow a typical daily demand pattern as the nontank-supplied demands along the WTS. Therefore, the tank TAPs were assigned a unique diurnal pattern, including a nighttime period where the tanks are full. To develop this diurnal pattern for the tank demand during an extended period simulation, SCADA was provided for two distribution areas served by tanks where tank-level data were recorded over 24 hours during assumed average-day demands. It was apparent from the SCADA that, from midnight to 6:00 a.m., the distribution tanks were full and the small pump stations were off. The low nighttime demand was being supplied by the smaller TAPs in the service area.

Figure 1 illustrates the tank diurnal demand curve assumed for the WTS model. The nontank-supplied TAPs were reviewed by the service area to understand their contributions in the water distribution system. For the most part, these TAPS are smaller meter connections that either feed isolated areas or supplement the area when the pump stations are off at night or meet a local peak demand. Since some are controlled by pressure, it makes it difficult to accurately simulate unless the local distribution system is fully added to the model. A diurnal pattern for direct demand nodes was estimated based on slightly adjusting the average demand above during the day (to model higher demands) and below average for nighttime, also shown in Figure 1.

The FKAA currently does not have remote flow metering of the TAPs and therefore cannot currently provide hourly demand patterns for each of the TAPs. Future installation of automated meter readers (AMRs) at the TAPs would provide valuable hourly flow data off the WTS and help in further managing and optimizing pumping operations.

Figure 1. Florida Keys Aqueduct Authority Water Transmission System Tank and Demand Node Diurnal Flow Patterns

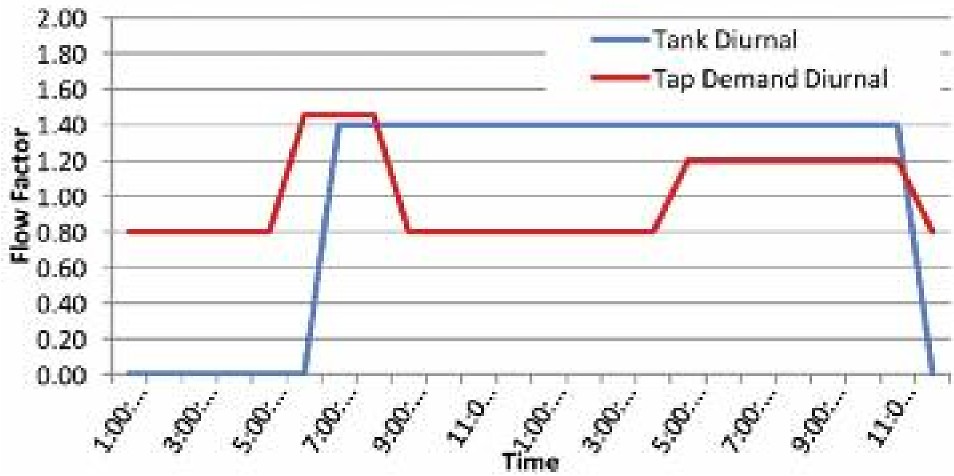

Table 2. Florida Keys Aqueduct Authority Water Transmission System Booster Pump Station Operations

Pump Station	Average Daily Demands		Maximum Daily Demands	
	Flow (mgd)	Pressure (psi)	Flow (mgd)	Pressure (psi)
Florida City	17.1	212	20.6	237
Key Largo[1]	15.9	-	18.6	-
Long Key	11.8	155	12.9	178
Marathon	9.8	180	11.3	178
Ramrod[1]	7.9	-	8.5	-

1. Key Largo PS and Ramrod PS are not in operation.

Water System

Since the hydraulic model was created in 2009, the Key Largo pump station has been the major addition to the WTS, although the pump station is not currently in use due to a decrease in projected maximum-day system water demands. This pump station includes two 700 horsepower (Hp) pumps, with a pumping capacity of 16,660 gpm (24 mgd) and 291 total dynamic ft of head. Additionally, the Marathon pump station has been upgraded to feature two new double suction pumps rated at 5,500 gpm (7.9 mgd) and 280 total dynamic ft of head.

The new pump curves have been imported into the current model to reflect current-day operation. The FKAA has replaced approximately five mi of the 36-in. pipeline between MM 93 and MM 98 with a similar size pipeline. Previously, this pipeline constrained operations of the WTS by limiting the discharge pressure at the WTP. Several short sections of the parallel 18-in. pipeline have been permanently abandoned.

As mentioned previously, two sets of log sheets were supplied by FKAA: one set was logged data from three days in February 2011, which was used as an example of average day booster pump station operation and controls; and the second set of log sheets supplied was from three days in May 2011, which was an example of maximum-day booster pump station operations and controls. The log sheets were used to understand the varying suction and discharge pressure for a 24-hour period for each booster pump station during each demand scenario. Table 2 summarizes a daily average of the booster pump station operation, based on system controls as provided on the log sheets.

Supervisory Control and Data Acquisition

The FKAA has implemented a detailed SCADA system for managing pump operations for the entire WTS and continues to expand and make refinements to further reduce energy costs. The SCADA system records numerous pieces of data and information at the booster pump stations, including electrical use, flow rates, efficiencies, pressures, motor speeds, etc. The FKAA has developed the programming to estimate hourly and daily energy costs to assist the WTS operators in decision making. In the future, it will be valuable data for FKAA to implement SCADA at the major TAPs supplying tanks to even better understand WTS operations. A few distribution tanks have been connected to the SCADA system.

The SCADA was supplied by FKAA for a seven-day period for each WTS booster pump station to incorporate into the hydraulic model for the purposes of hydraulic and energy calibration. The following discusses the SCADA that was used to assist in calibrating the pump stations in the model.

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Calibration

As previously mentioned, the log sheets noting hourly system pressures, metering facilities, and pump operations were used to assist in calibrating the model for a three-day period in February 2011 and May 2011. The hydraulic model calibration consisted of an evaluation of the pump station operations, storage tank filling rates at tank TAPs, and diurnal demands at other TAPs (junctions). Continuity checks were performed at junctions to ensure that continuity of flow was maintained.

Pump station operations were compared to SCADA for seven days in November 2012 supplied by FKAA to verify and calibrate the hydraulic model. As part of this planning effort, an energy analysis was conducted for the major water booster pump stations to estimate annual energy costs and compare them to actual costs. The energy module feature of the hydraulic model was utilized to calibrate the FKAA WTS hydraulic model to power consumption, based on the available power schedules and historical usage data. Table 3 shows a daily average of flows through each of the booster pump stations and average pressures following SCADA calibration.

Utilities

There are three utilities that currently provide the WTS electricity to power the booster pump stations: the WTP is served by Florida Power and Light (FP&L) and the areas along the Keys served by Florida Keys Coop and Key Energy Services. The new calibrated energy model was therefore used to predict power consumption on the WTS under various pumping and demand scenarios.

The FKAA provided electric utility bills for the WTS booster pump stations; the estimated utility and rates are provided in Table 4. The actual utility rate schedules are fairly complex and include variable and fixed charges; for the purposes of this study, average kilowatt-hour (kWh) costs were estimated for each utility based on the historical data. The FKAA operations staff continues to review and work with each utility to better understand pricing structure to ensure that the system is performing at the most optimum system cost.

The largest kWh cost is billed by Key Energy Services, which supplies the Ramrod pump station, but it is not usually operated under average demand conditions, similar to the Key Largo pump station. Based on limited billing data for the Key Largo pump station, the average kWh cost is high due to the infrequency of operation. In the months that the pump station is run consistently, an average $0.13/kWh was estimated; the months that the pump station is run in peak events, a cost of $0.33/kWh was estimated. This high kWh charge is assumed to be due to running the booster pump station during electric utility peak-hour demand charges.

Annual Costs

Based on the energy cost data provided and reviewed, the annual booster pump station costs are approximately $1.74 million for the WTS. The average-day scenario in the hydraulic model was simulated utilizing the energy module during an extended period of 24 hours for the pump operations calibrated in previous steps. The model predicted an annual average booster pump station energy cost of $1.73 million. The Florida City and Marathon pump stations did not include a full year of data; for these pump stations, the total average data for the missing months was averaged from previous months. The model predicted slightly lower cost, which may be due to the missing monthly energy data for the Florida City and Marathon pump stations. A summary of estimated annual energy costs for the three major booster pump stations under average annual demands is as follows:

- Florida City pump station : $1.18 million
- Long Key pump station: $280,000
- Marathon pump station: $300,000

The Key Largo and Ramrod pump stations were assumed off during average demands for cost-estimating purposes. A more detailed monthly analysis could be performed that considers the few times these facilities operate; however, for this planning effort, the primary focus was evaluating the Key Largo pump station and its future operations.

Model Simulations and Optimization Analysis

Current Conditions

The FKAA WTS is generally designed to operate and convey maximum daily demand (MDD) flows. Local storage and distribution pumping can be used to meet peak-hour demands for a majority of the connections off the WTS; however, there are direct service connections and TAPs served by the WTS, with no booster pumping or storage that must be supplied with adequate pressure during MDD and peak-hour demands. These customers may dictate the minimum operating pressure of the WTS.

Based on the log sheets and discussions with FKAA staff, the current operating conditions are as follows:

- WTS: Maximum 240 pounds per sq in. (psi) and minimum 70 psi (minimum 45-50 psi in Key West only)
- BPS: Maximum discharge 240 psi and minimum suction 50-70 psi
- WTS pipeline during MDD: Desired headloss =1 ft to 2.5 ft per 1000 ft; desired velocities = between 2-5 ft per second (fps)

During the timeframe reviewed, the WTP distributed an average daily flow (ADF) of 17.1 mgd and a maximum daily flow (MDF) of 20.2 mgd, including unaccounted-for water. Table 5 summarizes the typical booster pump station op-

Table 3. Average Booster Pump Station Flow and Pressure

Pump Station	Average Daily	
	Flow (mgd)	Pressure (psi)
Florida City	15.4	212
Key Largo[1]	15.4	159
Long Key	8.6	150
Marathon	9.2	196
Ramrod[1]	7.9	134

1. Key Largo pump station and Ramrod pump station are not in operation.

Table 4. Florida Keys Aqueduct Authority Electric Utilities

Pump Station	Utility	Annual Average kWh Costs ($/kWh)
Florida City	FP&L	$0.06-$0.08[1]
Key Largo	Florida Keys Coop	$0.11
Long Key	Florida Keys Coop	$0.11
Marathon	Florida Keys Coop	$0.11
Ramrod	Key Energy Services	$0.16

1. Estimated FP&L charges over the past five years.

eration during ADF and MDF conditions. Currently, FKAA does not operate the Key Largo or Ramrod pump stations during ADF or MDF conditions.

The new Key Largo pump station was constructed in anticipation of an increased MDF of approximately 24 to 25 mgd, which made it necessary to construct an intermediate pump station between WTP and the Long Key pump station due to predicted lower suction pressures. At the time, the FKAA service area was experiencing steady increases in water demands associated with increased permanent and transient populations. This trend has reversed in the past five years, due in part to a downturn in the economy and successful water conservation programs, and thus, FKAA continues to see reduced water use on the WTS system, including its recent fixes to reduce water loss.

As a result, with the reduced water usage on the WTS and resulting increase in WTS pressures, FKAA is now challenged to maintain and operate the Key Largo pump station that is not currently needed to meet average or maximum day demands. This station, with an estimated $7 million capital investment, potentially could become a stranded capital asset, until maximum-day demands rebound or significantly increase. As a comparison, existing maximum-day demands are only about 20-21 mgd, where about 23 mgd would warrant the use of the station. However, population forecasts still indicate that, at some time in the future, it is anticipated that maximum-day demands would increase to require the use of the station in the WTS.

One of the challenges for FKAA is to maintain the Key Largo pump station in a standby mode so the facility could be called upon at any time and also ensure future reliable operations when critical maximum-day demands are reached and require the pumping capacity. One option for FKAA is that the WTS system could be re-operated by modifying the high-service pump station with a lower head (at the WTP) and bring the Key Largo pump station on-line today. This opportunity is presented in the next section.

Florida City Water Treatment Plant and Key Largo Pump Station Re-Operation Scenario

The re-operation scenario consists of lowering the supply pressure at the WTP's high-service pump station, which will lower the WTS operating pressure and then use the Key Largo pump station to increase the WTS pressures back to pressures currently experienced on the WTS between the Key Largo and Long Key pump stations. The benefit of re-operation includes maintaining the Key Largo pump station in a normal opera-

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Table 5. Average and Maximum Day Pump Station Operation

Pump Station	ADF		MDF	
	Flow (mgd)	Pressure (psi)	Flow (mgd)	Pressure (psi)
Florida City	17.1	229	20.1	237
Key Largo	OFF		OFF	
Long Key	10.5	159	12.6	181
Marathon	8.5	175	9.8	207
Ramrod	OFF		OFF	

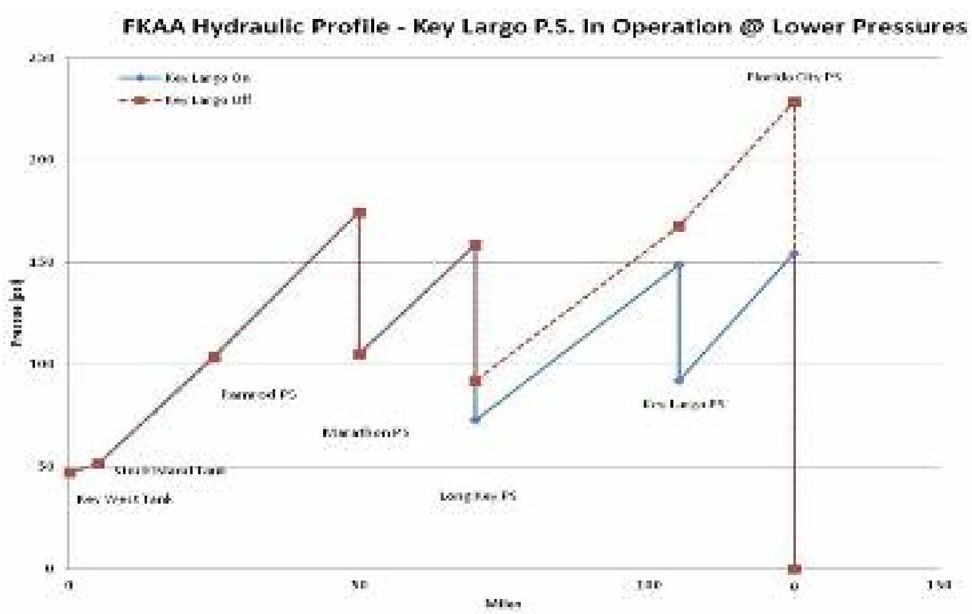

Figure 2. Florida Keys Aqueduct Authority Water Transmission System Hydraulic Profile

Table 6. Florida City and Key Largo Pump Station Lower Head Operation

Location	Pressure Location	Miles	Scenario 1: "Base Case" Pressure (psi)	Scenario 2: Key Largo On Pressure (psi)
Florida City PS	*Discharge*	125	229	155
	Suction	125	-	-
Key Largo PS	*Discharge*	105	168	149
	Suction	105	168	92[1]
Long Key PS	*Discharge*	70	159	159
	Suction	70	92	73
Marathon PS	*Discharge*	50	175	175
	Suction	50	105	105
Ramrod PS	*Discharge*	25	104	104
	Suction	25	104	104
Stock Island	*Tank Inlet*	5	51	51
Key West	*Tank Inlet*	0	47	47

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tional basis and reducing a high-pressure operation between WTP and the Key Largo pump station, thereby potentially reducing risks for pipeline failures and water loss. Furthermore, the opportunity exists to reduce energy costs as well.

Two energy scenarios were simulated utilizing the hydraulic model and energy module during an extended period of 24 hours. The first scenario includes the "base case," reflecting current WTS average-day pumping operations; the second scenario evaluates re-operations and lowering pressures at WTP high-service pump stations and operating the Key Largo pump station.

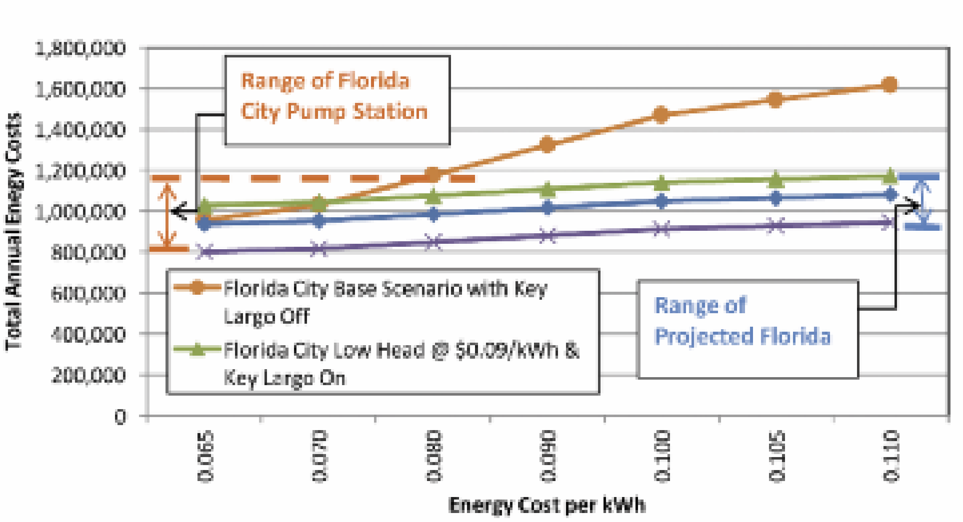
The re-operation of the Key Largo pump station would involve lowering the discharge pressure approximately 60 psi. This could potentially be accomplished by removing pump stages to the desired head; however, this would result in a lowering of the design flow rate. Under re-operations, the Key Largo pump station would then be used to provide the required suction pressure at the Long Key pump station; the WTS operations would remain the same downstream of the Long Key pump station. Figure 2 illustrates the hydraulic grade line for each of these scenarios.

Table 6 presents the operating pressures for each pump station during both scenarios, with the Key Largo pump station on and the base case when Key Largo pump station is not in operation.

Table 7. Florida City and Key Largo Pump Station Energy Analysis

Pump Station	Unit No.	Scenario 1: Key Largo Off	Scenario 2: Key Largo On
Florida City	4	$1,300.00	-
	7	$1,100.00	$1,150.00
	8	$820.00	$840.00
Key Largo	1	-	$440.00
	2	-	$530.00
	3	-	$45.00[2]
Long Key	1	$410.00	$550.00
	2	$360.00	$620.00
Marathon	1	$810.00	$820.00
	2	-	-
Total Daily Energy Costs		***$4,800.00***	***$4,995.00***
Estimated Additional Daily Energy Costs with Key Largo On			***$195.00***
Estimated Additional Annual Energy Costs with Key Largo On			***$71,175.00***

Figure 3. Florida City and Key Largo Pump Stations Energy Cost Evaluation



The model predicts an average daily power consumption based on the current time-of-use schedules from the utility companies. Table 7 presents a comparison of operating the Key Largo pump station (Scenario 2) to current base-case operations (Scenario 1). The annual additional cost associated with operating the Key Largo pump station was estimated to be $71,175. Based on an average annual demand scenario and energy cost assumptions, there appears to be some savings of not operating the Key Largo pump station. In addition, this cost comparison assumes that the high-service pump station could be modified and re-operated. The analysis does not consider the annualized cost to fund pump modifications and upgrades at the high-service pump station.

The FKAA has budgeted and is proceeding with high-service pump-station upgrades (with similar pumping units) due to the age and reduced efficiencies of several pumping units. Once this project is completed, FKAA may see some savings associated with these improvements. A more detailed financial analysis and life cycle cost analysis would need to be performed between the two options prior to making a final decision. The extent and acceptance of lowering pressures at the high-service pump station would need to be further detailed, including capital cost estimates.

Based on a preliminary assessment, it is apparent that the FKAA's ability to obtain lower electrical rates from FP&L (30 to 40 percent lower) favors continued use of the high-service pump station under the higher head conditions. However, should FKAA have an opportunity to obtain lower rates from Florida Keys Corp., Scenario 2 may become more feasible. A sensitivity analysis was conducted comparing the energy costs of the Florida City and Key Largo pump stations under Scenarios 1 and 2, as shown in Figure 3. The primary goal was to determine the "break even" electrical rate at the Key Largo pump station to make Scenario 2 comparable from an energy cost standpoint.

Referring to Figure 3, Scenario 1 is shown in orange and represents the base-case costs, with varying electrical rates from $0.065 to $0.11 (x-axis). The y-axis shows the total energy costs at Florida City (high-service pump station), with the Key Largo pump station off. As long as unit rates remain low from FP&L ($0.60 to $0.70), total pumping costs are around $1 million or less. The purple, blue, and green lines represent unit electrical cost variations from FP&L on Scenario 2 (lower pressure at the high-service pump station), with variable unit costs from Florida Keys Corp. For example, the blue line assumes FP&L provides $0.08 unit cost for a low-head high-service pump service operation.

Following the blue line along the x-axis, the impact of varying unit costs for the Key Largo pump station operations is shown. At $0.11 costs, the total costs would be about $1.15 million (y-axis), much greater than the base case. If the Key Largo pump station could be reduced to about $0.10 in this option, the energy costs would be similar for Scenario 1 and Scenario 2.

One conclusion from this analysis is the sensitivity of varying electrical rates on both high-service and Key Largo pump stations. Referring to the orange line in Figure 3, once unit costs exceed about $0.09 at a high-service pump station, even at $0.11, the Key Largo pump station becomes favorable to operate under Scenario 2 assumptions. However, given the recent consistent lower electrical rates for high-service pump stations, it is apparent that the annual cost benefit for FKAA is to continue with current operations. A significantly lower rate would be needed at the Key Largo pump station of about $0.08 to make Scenario 2 a viable option.

Table 8. Water Transmission System Emergency Storage Analysis

Service Area	Average Annual Demand	Total Storage Required [a] [b]	Existing WTS Storage	Existing Distribution Storage	Total Storage	Surplus (Deficit)	Storage Analysis per Area
Tanks	mgd	MG	MG	MG	MG	MG	
Existing Florida City WTP							FKAA may want to consider an additional 5.0-MG WTP storage tank for WTP operations.
WTP Storage Tanks	15.7	15.7	5.0	-	5.0	(3.70)	
			5.0	-	5.0		
			1.0	-	1.0		
			1.0	-	1.0		
Area V - Florida City WTP - Tavernier							Area IV and V emergency storage requirements could be supplied by storage at Key Largo PS or at Marathon PS.
-	3.51	3.51	0	2.5	2.5	(1.01)	
Area IV - Tavernier to Conch Key							
-	1.94	1.94	0	1.5	1.5	(0.44)	
Area III - Conch Key to Mile Marker No. 40							Area III emergency storage requirements could be supplied by Marathon PS.
Marathon	3.02	3.02	3.0 [d]	2.5	5.5	2.48	
Area II - Mile Marker No. 40 to Stock Island							Area I and II emergency storage requirements supplied by Back PS at Stock Island. FKAA may not need to rehab existing 5 MG tank out of service.
-	1.24	1.24	0	1.2	1.2	(0.04)	
Area I - Stock Island to Key West							
Stock Island[c]	4.71	4.71	10.0	-	10.0	12.29	
Stock Island Desal			5.0	-	5.0		
Key West			2.0	-	2.0		

[illegible]

Emergency Storage Analysis

The emergency back pump operation consists of the Stock Island back pump station, with its 20-mil-gal (MG) storage facilities (Stock Island and Desal tanks), although a 5-MG tank is currently out of service, and the Marathon Booster pump station, with its 3-MG storage tank. These facilities provide FKAA with the ability to back-pump into the transmission main in the event of an emergency along the transmission route from pipeline rupture or other failure. The FKAA uses the Stock Island back pump station, the Marathon Booster pump station, the storage tank, and the emergency reverse osmosis (RO) treatment plants at Stock Island and Marathon, if necessary, to back-pump water up the Keys toward the WTP, while maintaining pressures until an emergency scenario is resolved.

The Stock Island back pump station includes one diesel horizontal split-case pump, rated at 2,450 gpm (3.50 mgd) with 170 ft of total dynamic head. The back pump station has in the past been able to pump all the way to WTP and provides nearly 25 percent on an average-day demand. As part of the emergency storage analysis, the WTS water demands were assumed to be 30 percent of average-day demands, which represents a likely condition under extreme water conservation requirements. Based on a back pump model simulation, the storage tanks can supply approximately 5.58 days of 30 percent average-day demands in current conditions.

In order to evaluate WTS storage needs for emergency operations, a preliminary storage evaluation was performed, considering both WTP storage needs and the location of storage by service area. Currently, most of the FKAA-treated water storage is at the Florida City WTP or at the end of the WTS. Depending on the location and the extent of the emergency, there may be benefits to locating more storage in the middle of the WTS. An assumed storage goal of one average day of storage was assumed for WTP operations and the WTS system, respectively. Table 8 summarizes a possible storage scenario by service area that highlights the benefits of additional storage in the middle portion of the WTS, such as at the Marathon pump station. For this analysis, the distribution tanks were included in the evaluation, since this storage would likely be used in an emergency.

Several scenarios were evaluated for back-pump operation to assess the benefits of additional storage along the WTS by service area:

- The first scenario included an additional 3 MG of storage at the Marathon pump station, with storage totaling 6 MG at this location. The model simulation concluded an approximate water supply during 30 percent ADD of 5.63 days.
- The second scenario included an additional 5 MG of storage at Stock Island, with storage totaling 25 MG at this location. The model simulation concluded an approximate water supply of 7.04 days.
- A third scenario included 5 MG of new storage assumed at the Key Largo pump station. The model simulation concluded an approximate water supply of 9.8 days.

Referring to Table 8, Areas IV and V have the largest storage deficiency, which would suggest having new storage at either the Marathon or Key Largo pump station sites; however, the existing status of the Key Largo pump station would play into the decision to locate storage at that site. It has also been reported that the existing 3-MG Marathon tank is to be in need of rehabilitation; one option for FKAA would be to replace the existing 3-MG tank with a larger tank on the site.

Water Quality

A water-age scenario was simulated with the WTS model during average-day demands for an extended-period simulation of 10 days. Initially, all water in the WTS is zero days old, and the simulation must be carried out until water has traveled to the farthest point in the WTS system and the storage tanks have reached equilibrium. Once equilibrium, with respect to water age, has been reached, a daily pattern is established, and carrying the simulation out for additional days will not increase the age of water. Although no regulatory requirements exist for water age, general industry guidelines indicate that it should not exceed five days in the system to maintain good water qual-

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ity. The maximum water age in the WTS was 110 hours, or approximately 4.58 days at the end of the system in Key West. This analysis does not include the age of water in the distribution system.

Given the length of the FKAA WTS and travel time, the age of the water is well within the general industry criteria for the WTS. The Key West distribution model may want to be reviewed for age of water or integrated with the WTS to better understand the water age at the end of the Key West water distribution system.

Recommendations

Based on the study findings and technical analysis, the following recommendations were made:

- The ability of FKAA to obtain lower electrical rates from FP&L favors continued use of the high-service pump station under high-head operations.
- The Key Largo pump station should be kept in a standby mode and exercised periodically, as the facility will be needed when maximum-day demand increases toward 23-24 mgd on the WTS system or during an emergency scenario.
- The FKAA should continue discussions with Florida Electric Corp. regarding potentially obtaining lower energy rates and the standby mode of the Key Largo pump station.
- Should FKAA have an opportunity to obtain lower rates from Florida Keys Corp., Scenario 2 may become more feasible. A preliminary engineering report would need to be conducted to evaluate improvements at the high-service pump station to convert to a lower-head operation and the need to operate the Key Largo to Ocean Reef distribution pumping.
- In order to improve emergency storage along the WTS, it is recommended that storage be located at the Marathon site to support Areas IV and V along the WTS. A preliminary feasibility study for 4-6 MG of storage at Marathon is recommended, with consideration to replace the existing 3-MG tank.
- The FKAA should continue to expand SCADA and remote metering to the TAPs to better understand demand patterns off the WTS to further optimize water operations.

In summary, it has been concluded that the re-operations of the high-service pump station is highly dependent on the utility electrical rates. It is important for FKAA is to maintain the Key Largo pump station in a standby mode over the next several years, as this station will need to be utilized as maximum days approach to provide minimum pressure and minimum suction pressure of 70 psi.