Going Beyond Steady-State Wastewater System Modeling in Sarasota County: A Case for Extended-Period Simulation

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Before 1990, roughly 116 wastewater treatment facilities (WWTFs) existed in Sarasota County. Outside of city limits, private companies owned and operated all of the WWTFs. In the early 1990s, the County initiated a consolidation effort, which has now reduced the number of WWTFs to just less than 40. Consequently, the County now owns and operates complex and extensive wastewater collection/transmission systems comprised of around 83,700 sewer connections, over 700 conventional lift stations (LSs) with 300 mi of force mains, over 1,000 mi of gravity sewer mains, several alternative wastewater collection systems, and four WWTFs.

The County contracted with Jones Edmunds to develop dynamic hydraulic models of the County's existing conventional wastewater lift station and force main systems using SewerCAD™. At the time the models were initially developed, the County owned 10 WWTFs; later, some of them were decommissioned. The purpose of the models is to develop a useful planning tool that represents the existing systems to the extent practical and identify potential deficiencies within the system.

The consultant modeled nearly all County-owned conventional lift station and force main systems, which were given designated LS numbers as of November 2007; gravity sewer mains, which connect cascading conventional lift stations and force main systems; and gravity sewer interceptors, which connect conventional lift station and force main systems to WWTFs. A small number of LSs (e.g., WWTF drain LSs) were not modeled, as they have no impact on the systems. Alternative wastewater systems (e.g., low-pressure systems, vacuum systems, septic tank effluent pumping systems, etc.) were not modeled, but were included as point flows into the conventional lift station and force main systems.

These conventional lift station and force main systems discharged to 10 WWTFs, with certain WWTFs having interconnections. Due to the size and complexity of the overall system, 10 independent hydraulic models were developed, some of which have subsequently been updated to reflect more current system conditions.

The models were calibrated to reflect actual field conditions and used to determine the adequacy of the current lift station and force main systems to support growth, identify potential system deficiencies under the future flow conditions, and evaluate proposed wastewater improvement alternatives.

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Model Development

Data Collection

To develop realistic models, County staff and the consultant gathered physical, operational, and maintenance records for system LS pumps, force mains, gravity sewer mains, and WWTFs.

Acquisition of accurate data from the LSs was critical in assessing the capacity of the sewer system and providing the necessary data to create the hydraulic models. Because of this, a field investigation, including LS drawdown tests, was conducted. Not all of the County's LSs were field-verified; only those stations that had a critical role in the overall systems were field-tested.

County staff and the consultant conducted drawdown tests to determine actual pump capacity versus total head performance. Lift stations were tested using the wet well drawdown method, and the following information was gathered at the time of testing:

- Wet well dimensions
- Pump on and off levels
- Discharge pressure readings before (pump off), during (pump on), and after (pump off) drawdown
- Fill time immediately before drawdown
- Pump down time
- Fill time immediately after drawdown

In addition, the County has supervisory control and data acquisition (SCADA) records, including pump run times. This information was used for model development and calibration after sufficient field-testing, data acquisition, and processing.

Model Network

The model network layout is primarily based on the wastewater geodatabase (GDB) developed as part of the County's geographic information system (GIS) mapping project. Portions of the County's wastewater GDB were updated by the consultant's GIS Department before it was used as a basis for the model GDB. In addition, the County provided additional LS information, including LS type (triplex, duplex, etc.), wet well dimensions, force main and gravity main diameters and routing, and elevations. The two sets of data were reviewed and processed to prepare the input files needed to develop the Sarasota County wastewater transmission system models. The consultant spatially rectified numerous record drawing documents, including scanned as-builts and digitized facility data to achieve a final wastewater GDB suitable for developing a wastewater model.

Once a model GDB was created using the collected data, the consultant ran various hydraulic model connectivity subroutines to locate potential connectivity issues. Subsequently, questionable areas were reviewed and further refined by comparison to the most current wastewater atlas and information provided by the operations and maintenance staff. All discrepancies found were brought to the County for review and were updated based on County comments. The final model GDB with all revisions incorporated was converted to a SewerCAD model.

Within SewerCAD, hydraulic properties were estimated and incorporated within each pipe segment, including the Hazen-Williams C coefficients for force mains and Manning *n* values for gravity pipes.

Sewersheds

An area where sewer flows are conveyed mainly through gravity mains (and sometimes through force mains) to a common lift station is called a sewershed. Each lift station was assigned a sewershed based on the extent of the gravity system records.

The consultant delineated and updated the sewersheds based on knowledge of sanitary flow patterns and County-provided data. These data included the original sewersheds developed by the County, the wastewater GDB, water-meter shapefiles, record drawings, and the wastewater atlas. The County reviewed the results of this effort and final revisions were made accordingly. Figure 1 presents the sewersheds associated with one of the smaller wastewater systems.

Boundary Conditions

The WWTFs were modeled as outlets and LSs were modeled as pump stations. Each LS was explicitly modeled by converting the original GDB LS point to multiple points and lines. This resulted in a full representation of LS components, as listed in a County LS summary

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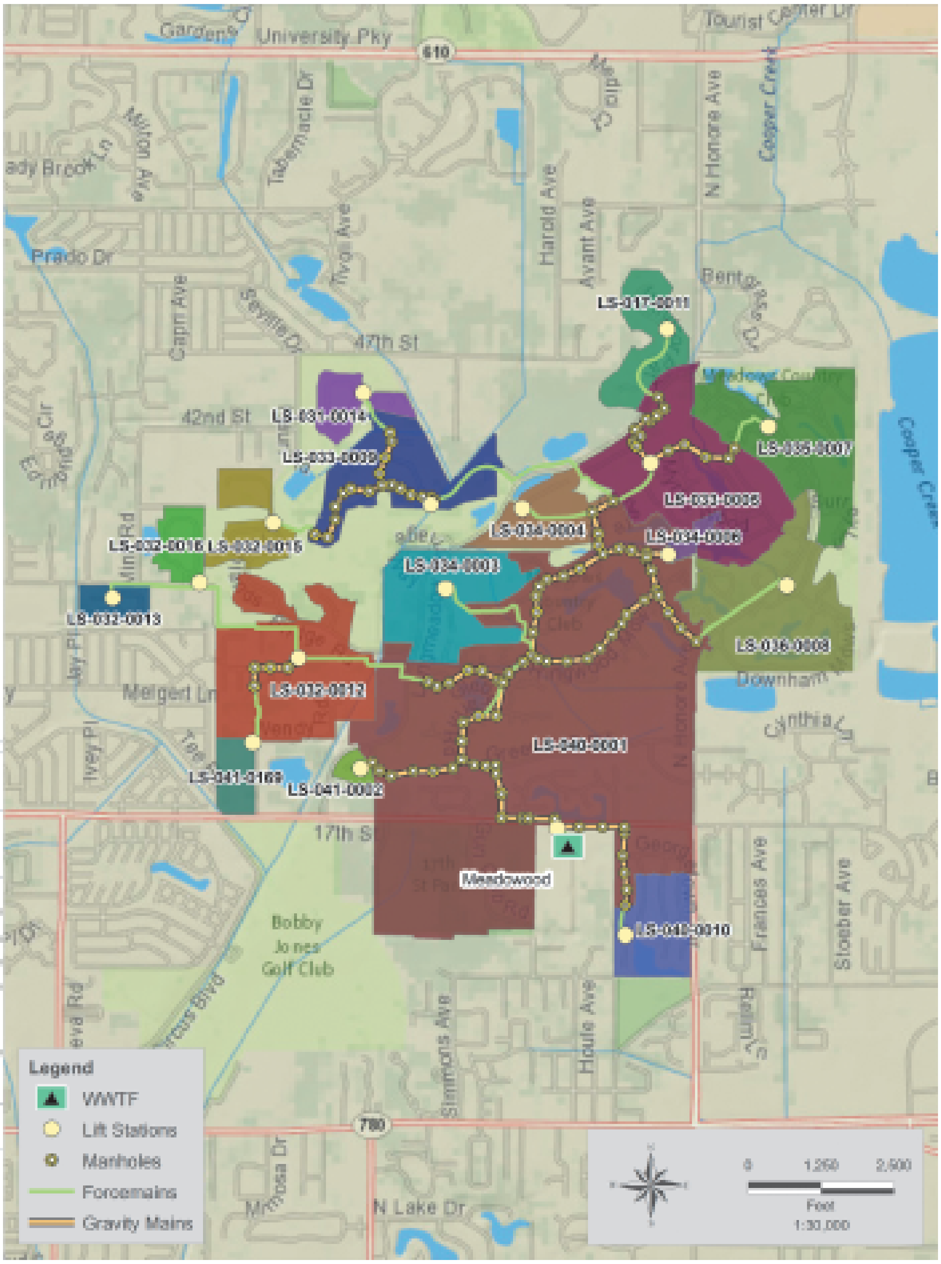

Figure 1. Meadowood Service Area — Sewersheds

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spreadsheet and shown on record drawings.

The consultant developed pump curves for each modeled LS from County-provided information, coupled with manufacturer's pump curves and/or information gathered during drawdown tests. Each pump curve was incorporated into the model using a multiple-point pump curve where available.

Level controls were incorporated into the model for each lift station. The level controls were based on information provided by the County and information gathered during drawdown tests. If no data were available, the level controls were estimated based on standard design philosophy.

Flows

The wastewater flow at an individual LS is made up of sanitary flow from customers, infiltration, and inflow. The following three information sets were used as the basis for developing the wastewater flow for each LS:

- Sewershed delineations
- Wastewater customer water meter locations
- Water meter customer records for winter months

Table 1. Wastewater Treatment Facility Flow Summary
(June 2006–May 2007)

Wastewater Treatment Plant		AADF (MGD)	MDF (MGD)
1	Aqua Inc. WWTF[1, 2]	-	2.971
2	Atlantic WWTF	0.294	0.826
3	Bee Ridge WWTF	1.428	2.365
4	City of Venice WWTF[1]	2.804	5.085
5	CCU WWTF	2.464	3.314
6	Gulf Gate WWTF	1.221	3.081
7	Meadowood WWTF	0.488	0.751
8	Siesta Key WWTF	1.179	2.341
9	Southgate WWTF	0.905	2.124
10	Venice Gardens WWTF	1.852	3.197

(1) WWTF only partially used by the County.

(2) AADF not available.

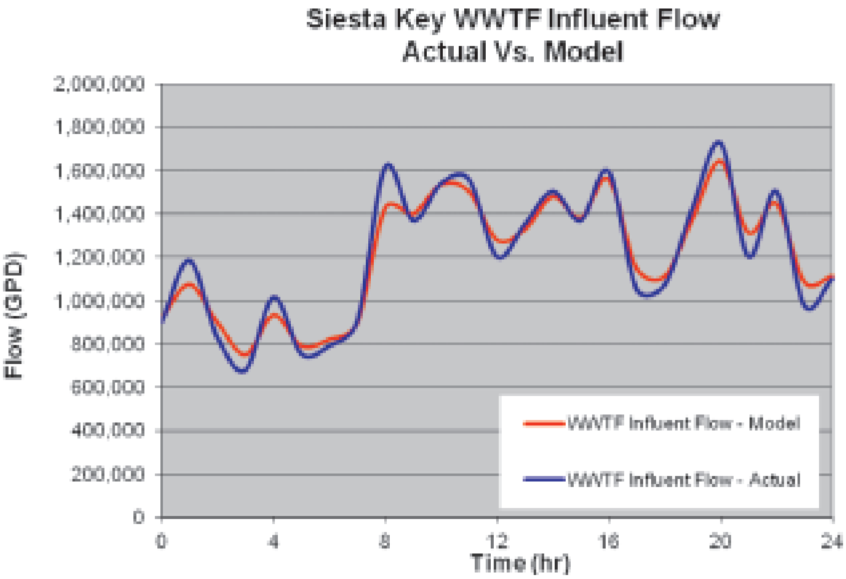

Figure 2. Example Wastewater Treatment Facility Influent Flows – Actual Versus Model

Water meter spatial information and flow (winter months) information was assigned to sewersheds to estimate current sanitary flows. Each meter was spatially assigned by address or other geographic assignment to a particular LS sewershed. Then, the sanitary flow was generally estimated using the sum of each wastewater customer's water-meter records for the lowest-flow winter month. Each of the summed flows specific to a sewershed was then loaded into the model.

Three components of the wastewater flow loading (sanitary flow, infiltration, and inflow), using a method that relies on the following correspondences, were established:

- Infiltration = Annual Average Daily Flow (AADF) – Minimum Monthly Average Daily Flow (MinMADF)
- Sanitary Flow = MinMADF
- Inflow = Maximum Monthly Average Daily Flow (MaxMADF) – AADF

Table 1 shows the summary of the WWTF flows based on the daily monitoring reports provided by the County.

Model Calibration

Two 24-hour extended-period simulation (EPS) scenarios were performed for each model: AADF and Peak Daily Flow (PDF). The County provided circular charts or digital readings data for the development of each WWTF daily flow pattern for the specified days. Diurnal patterns for each model scenario and for each WWTF were used for model calibration.

The County-provided historical SCADA records included actual LS run times for a number of selected days. The consultant correlated each hydraulic model by adjusting model parameters (inflow hydrographs, LS pump control elevations, Hazen-Williams *C* factors, etc.) to achieve agreement, to the extent practical, between model and actual LS run times and available WWTF inflows.

Where LS run-time correlation could not be achieved, the possible reasons for the discrepancies were reviewed and discussed with the County. Correlation issues associated with LSs that have a significant impact on the systems were resolved to the extent practical.

Figure 2 shows an example comparison of actual versus model WWTF influent flows. Figure 3 shows an example comparison of actual versus model lift station run times.

Comparison of Next-Generation Radar Rainfall Data Versus Lift Station Run Times

The consultant used a novel approach to ascertain if any LS sewersheds appeared to have significant infiltration and inflow problems. This approach involved obtaining next-generation radar (NEXRAD) polygons for the entire County and overlaying those polygons on the sewersheds polygon in an effort to link each sewershed to a specific NEXRAD polygon. The NEXRAD polygons consisted of 2-KM (~1.25-mi-sq) grids. The NEXRAD rainfall data were processed to yield hourly and daily rainfall totals within each polygon for an approximately one-and-a-half-year time period. The hourly and daily rainfall totals were then compared with LS run times for the same time period to ascertain the influence of rainfall on each LS.

Figure 4 presents an example of a lift station that was found to likely have an infiltration problem. Upon inspection of Figure 4 it can be seen that the periodic large rainfall events do not have a major impact on the LS's run times. However, when large rainfall events become more frequent, the LS's run times increase, likely due to infiltration associated with an increased groundwater level.

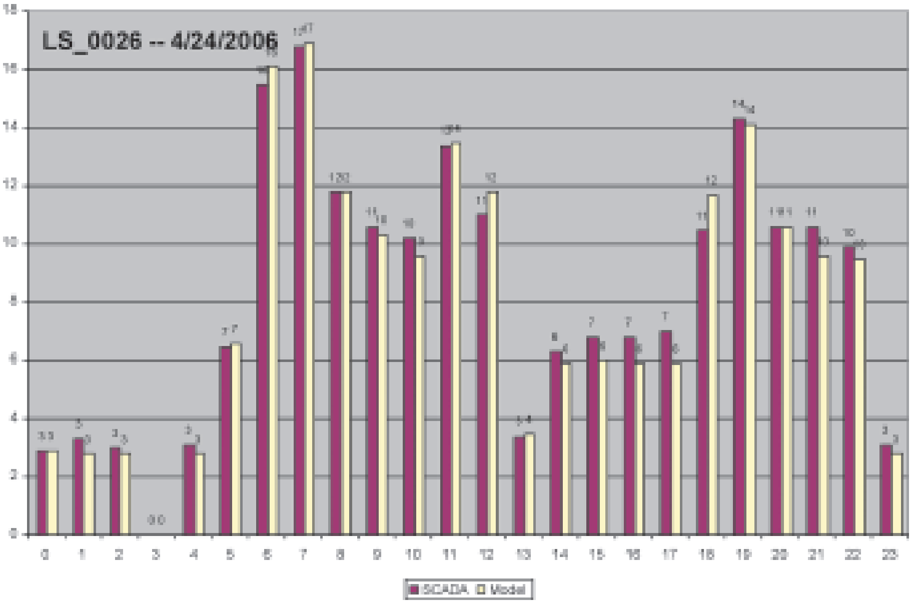

Figure 3. Example Lift Station Run Time – Actual Versus Model

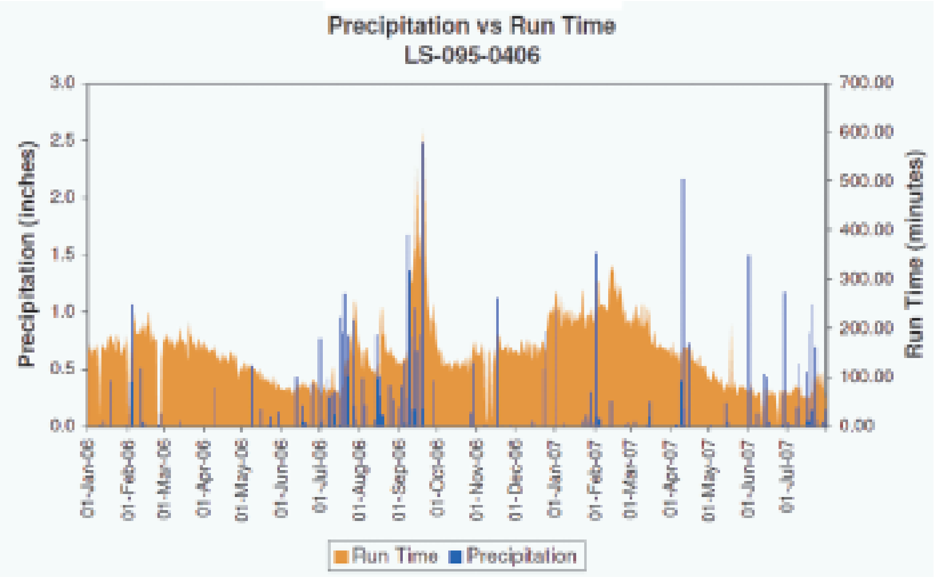

Figure 4. Example Lift Station Run Time Versus NEXRAD Polygon Precipitation

System Deficiencies

Due to the extent of the manifolded lift station/force-main systems within critical portions of the County's wastewater systems, several LSs periodically experience reduced capacities or deadhead conditions during high-flow periods. For large systems such as this, upgrading the system to eliminate all potential deadhead conditions, as determined through steady-state modeling, is rarely an economically viable solution. In addition, for large systems, selecting which pumps to model as "on" within a steady-state modeling scenario can be time-consuming and is ultimately based on the judgment of the individual, which can be risky. By developing a detailed model that reasonably represents the physical components and performance of the actual system, and that contains all LS pumps and controls, it is possible through EPS to force the model to sequence pumps on/off as done in an actual system. By developing these detailed models and loading 24-hour diurnal flow patterns for given flow days, it is possible to utilize a more realistic approach to assess system deficiencies that are expected to occur. For this project, what constitutes a system deficiency was agreed on by the County and the consultant. Some system deficiencies used for this project are presented below:

- LS pump deadheads
- LS standby pump on
- LS high level alarm on
- Overflow (LS or manhole)
- Pipe velocity never achieving 2 ft per second
- Pipe velocity exceeding 8 ft per second

System deficiencies were assessed using extended-period simulation of average daily flow and peak daily flow conditions. Figure 5 presents the system deficiencies identified for one of the service areas during future peak daily flow conditions.

The table presented in Figure 5 indicates which LS experienced a deadhead condition, the number of deadhead events experienced, and the duration of each deadhead condition. The table also indicates the maximum depth reached in a given wet well after its high-water alarm was activated. The fact that deadhead conditions or high-water alarms are occurring in highly manifolded lift station/force main systems may not necessarily justify an improvement. For this reason, the deficiencies (e.g., the number and duration of deadhead events, the maximum depth achieved in the wet well after its high-level alarm is activated, etc.) should be reviewed in detail, and then a decision should be made as to which system deficiencies should be resolved.

System Improvements

For this project, the County and the consultant discussed and agreed on the system deficiencies to be resolved. Improvements such as upgrading the County's Home Depot

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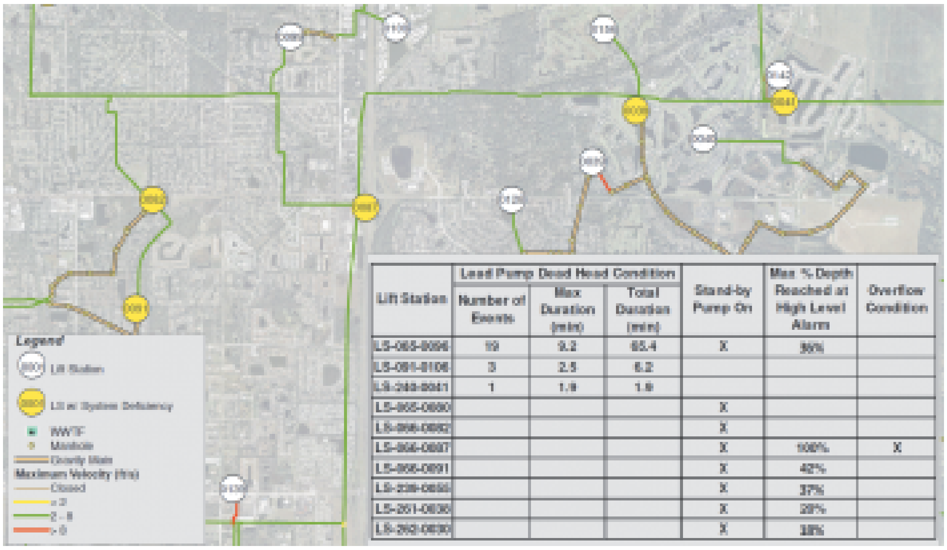
Master Lift Station (066-0087) capacity from 722 gallons per minute (gpm) to 1,000 gpm, upgrading the force main size from 12 in. to 16 in. from Cattlemen Road to Bent Tree Boulevard, and upgrading the force main size from 18 in. to 20 in. from Bent Tree Boulevard to Iona Road were incorporated into the model, and the 24-hour extended-period simulations were repeated. At the end of each simulation, the system deficiencies were reviewed. This process was repeated until the established goals were achieved. Figure 6 presents system deficiencies expected to occur in the improved system under future day flow conditions. Note that some tolerable system deficiencies are still predicted to occur in the system; however, no overflows will occur, and the total number of high-level alarm events has been reduced. The deadhead conditions were deemed tolerable.

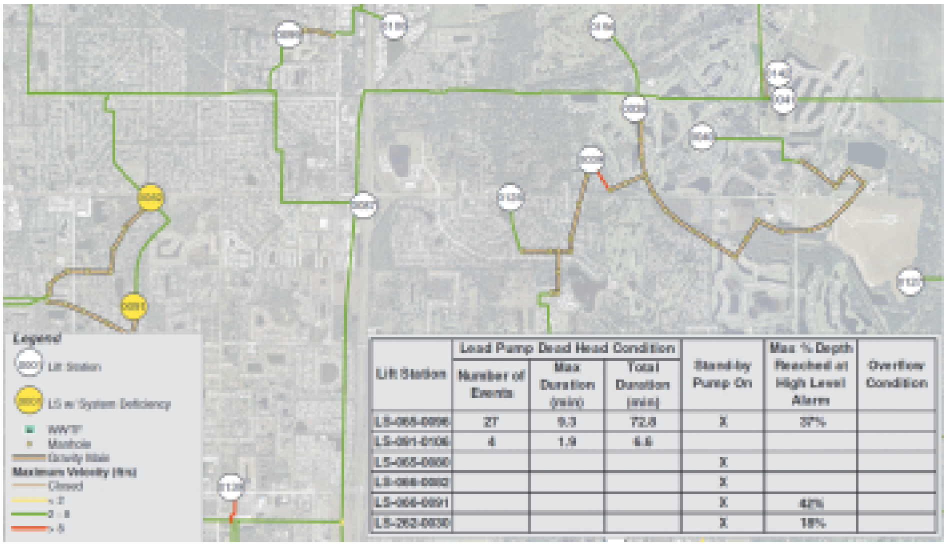
Summary

Jones Edmunds successfully developed hydraulic models of Sarasota County's complex and extensive wastewater collection/transmission systems. This comprehensive model development process involved data collection, GDB updates to establish a suitable network, sewershed delineation, boundary-condition representation, and flow-data processing and attribution. Once developed, the hydraulic models were calibrated.



Lift Station	Lead Pump Dead Head Condition			Stand-by Pump On	Max % Depth Reached at High Level Alarm	Overflow Condition
	Number of Events	Max Duration (min)	Total Duration (min)			
LS-065-0096	19	9.2	65.4	X	56%	
LS-091-0106	3	2.5	6.2			
LS-240-0041	1	1.9	1.9			
LS-065-0080				X		
LS-066-0082				X		
LS-066-0087				X	100%	X
LS-066-0091				X	42%	
LS-239-0055				X	37%	
LS-261-0036				X	20%	
LS-262-0030				X	18%	

Figure 5. Example System Deficiencies Expected to Occur in Current System During Future Peak Daily Flow



Lift Station	Lead Pump Dead Head Condition			Stand-by Pump On	Max % Depth Reached at High Level Alarm	Overflow Condition
	Number of Events	Max Duration (min)	Total Duration (min)			
LS-065-0096	27	9.3	72.8	X	37%	
LS-091-0106	4	1.9	6.6			
LS-065-0080				X		
LS-066-0082				X		
LS-066-0091				X	42%	
LS-262-0030				X	18%	

Figure 6. Example System Deficiencies Expected to Occur in Improved System During Future Peak Daily Flow

Model calibration was achieved by matching model-predicted WWTF influent flows and lift-station run times to actual measurements. Adequate correlation was observed, justifying the use of the hydraulic models to predict system deficiencies. At this point, predictive EPS model simulations were developed based on diurnal data and projected future flows.

The EPS model simulations were found to provide specific advantages over steady-state model simulations. While both types of model simulation can identify system deficiencies, the former also provides insight into the degree to which a deficiency is affecting actual system performance. For example, EPS model simulation results not only identify that a deficiency is likely to occur, but also how often or how long it will occur, as in the duration of a deadhead condition, or how far it exceeds established limits, as in the maximum depth achieved in a wet well after the high-water alarm is triggered. These findings were valuable to the County, because this additional information allowed it to define focused improvements that solved its most relevant deficiencies.

The consultant was able to successfully model improvements and determine that any remaining deficiencies were within tolerable limits due to the use of EPS model simulations. This is critical because using a steady-state model could lead to costly—and unnecessary—improvements to address deficiencies that may have been determined to be within tolerable limits if the EPS model had been used.

Acknowledgements

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References

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- Cardno/TBE, Jones Edmunds & Associates Inc., et.al., Bee Ridge Road Preliminary Design Report, Sarasota County, 2011.