The LIFT Intelligent Water Systems Challenge Final Solution Submission Team 4

The Team

This partnered team consists entirely of members from Clean Water Services (CWS), the watershed utility for Washington County, Oregon and headquartered in Hillsboro, Oregon, USA.

- Chris Maher, Operations Analyst II (Team Lead), maherc@cleanwaterservices.org
  - Coordination, Report Authoring, Report Submission, Facility Operation Evaluation
- Perry Sunderland, Principal Engineer, sunderlandp@cleanwaterservices.org
  - Solution Management, Project Design, Modeling
- Tonya Zinzer, Energy Project Engineer, zinzert@cleanwaterservices.org
  - Solution Management, Project Design, Energy Savings Evaluation, Data Analysis
- Brandon Wick, Senior Automation Engineer, wickb@cleanwaterservices.org
  - Instrument Selection, Control Loop Development, Programming
- Jeff Van Note, Information Systems Manager, vannotej@cleanwaterservices.org
  - Data Stream Identification, Data Analysis, QA/QC, Programming, Software Engineering
- Ryan Sandhu, Field Operations Manager, sandhur@cleanwaterservices.org
  - Data Stream Identification, Collections System Modeling, Instrument Selection

The team includes individuals from different departments across the District with the individual and combined skills to identify, analyze and communicate the information needed to execute an intelligent water system solution. The team would like to recognize here the efforts of all District staff and the support of the project sponsors:

Nate Cullen, Waste Water Treatment Department Director
Nora Curtis, Conveyance Department Director
Diane Taniguchi-Dennis, General Manager

Opportunity Statement

The drive toward a business minded approach to utility management involves cost effective and sustainable practices that includes in large part reducing operational and maintenance (O&M) cost. Energy efficiency is especially key to utilities with stringent permit limits that require more treatment unit processes. To continue to find energy efficiency opportunities, CWS encourages the creativity in staff to challenge current process and operation. These opportunities generally have an associated risk because they involve reducing operating cushions and safety factors as well as narrowing permit compliance margins. To make changes to current processes, risk must be assessed and risk mitigation strategies need to be developed and evaluated. These strategies can be informed by better, leveraged, or new, data.

The Rock Creek Advanced Waste Water Treatment Facility operates an influent pump station (IPS) that lifts the incoming wastewater approximately 70 feet to the screening process. The influent wet well is operated on level control and the level setpoint is set to provide free flow (less than full pipe) from the collection system trunk to the wet well. This is to reduce the risk of sanitary sewer overflow (SSO) in the collection system during high flow events. Informing and mitigating this risk could afford the opportunity to increase the level setpoint to decrease pump energy consumption, improve pump hydraulic conditions, and reduce O&M costs. The suction conditions at the current setpoint are less than ideal leading to frequent “rag-ball” formation and reduced pumping capacity. The consequence for O&M is a daily pump flushing procedure.

Challenges Statement

The potential energy efficiency benefit of this opportunity is a simple engineering problem, while the assessment of risk is subject to interpretation of data and institutional perceptions. The major risks are summarized as risk of overflow, risk of blockage, and risk of odors. The risk of sanitary sewer overflow due to either a wet weather event or blockage of the conveyance system is elevated because of a reduced safety factor. The risk of overflow due to influent pump equipment failure is elevated because of a reduced operating cushion. Settleable or floatable solids may accumulate in the conveyance system due to full pipe hydraulics. Odors generated by those solids may become a public nuisance or staff safety issue, as well as causing system corrosion. Still, data can be identified, analyzed, and leveraged to inform these risks.

Organizational challenges are probably as common in the industry as influent pump stations. In the “black box” or “inside and outside the fence” concept, a hard line is drawn around the treatment plant, with the influent pump station on the inside. Not only does this opportunity require a change to a long standing operating strategy and greater risk, it offers a benefit to one department (treatment) at the detriment of another (conveyance). The greatest challenge to overcome may well be for one department to learn the data streams of the other, for conveyance to take some ownership of the influent pump station, for production to take some ownership of the conveyance system, and to blur the line between the two departments.

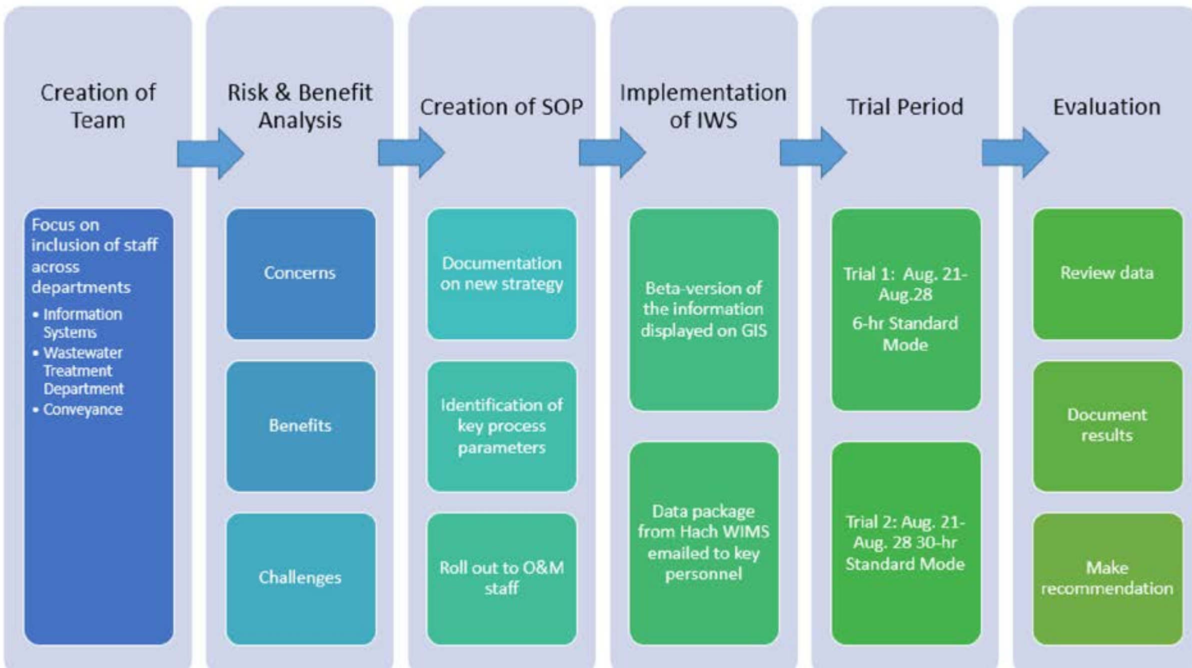
What is the metric of success in this situation? Although we can easily enough set a desired technical outcome; creation of a common platform for all departments to access meaningful data on real-time conditions in the conveyance system and the influent pump station. True success comes in the effect of the intelligent water system to facilitate comfort with the uncomfortable and the strengthening of inter-departmental ties, neither of which is easily measured.

The Solution

The Intelligent Water System (IWS) needed to provide a communication medium between the wastewater treatment and field operations departments. This solution would provide visibility into different critical alarm points and provide a common communication tool to allow both departments to understand system impacts.

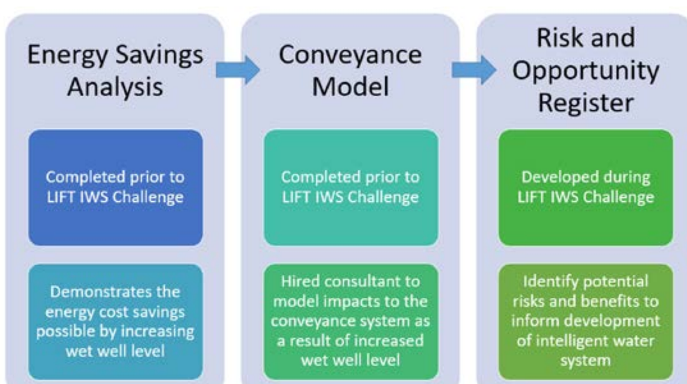
The Plan

To evaluate what characteristics and information would be needed for the IWS, there were a variety of steps that the team needed to follow through prior to implementation.



Pre-Implementation Work

Prior to implementation of the IWS, some evaluation had been completed by the wastewater treatment department to determine the impact of making a change in the Influent Pump Station wet well levels. This work included the following items:



The Intelligent Water System

Definition of our intelligent water system began with an inventory of data streams from multiple departments that held promise to predict influent flows and conveyance conditions. The information systems department is critical in this regard as they typically see data from every department and have no predilection to dismiss any data stream as inapplicable. The widest net cast yielded radar data collected by the watershed department, river flow and reservoir level data collected by regulatory affairs, flow and pump cycle data from the remote pump stations crew, rain gauges and key manhole flows and levels from conveyance, influent flow, pump station level, and pump speed from the production facility, and water quality data from the laboratory.

By evaluating the perceived risks, we were able to narrow the data collected to validate the impact resulting from adjustment to the wet well operating level. Data collection was narrowed to include the following existing devices:

- One Flo-Dar® level, velocity, flow meter. Installed close to IPS, where the water surface elevation was expected to be measurable and changing.
- IPS pressure transmitting level indicators (2)
- IPS flow magmeters (2)
- IPS pump speed feed back
- Grit storage hopper load cells (2)
- Influent screen run status (2)
- H_2S OdaLog (2, non-transmitting)

Data generated by the IWS devices is managed with multiple software platforms. Influent pump station and headworks data is collected through the plant SCADA system and stored with the associated historian server. Hach WIMS is used to manage summary statistics from SCADA and laboratory data. Flo-Dar®information is managed on the Microsoft Power BI platform.

Data Streams

The data streams generated by the IWS had to be used to provide information regarding conditions in the conveyance system and the efficiency gained in the IPS.

- Conveyance System
  - Flow and Level, to inform the potential for SSO
  - Grit weight, to inform the amount of settled inorganic material retained in conveyance
  - Influent screen run status, to inform the amount of floatable material retained in conveyance
  - Influent TSS and primary sludge TS, to inform the amount of settled organic material retained in conveyance
- Influent Pump Station
  - Flow and level, to inform the current status
  - Number of pumps online, to inform efficiency
  - Percent speed, to inform efficiency

Since the data streams are not yet used in a control loop, only a cursory QA/QC analysis was done for this pilot project. Field Flo-Dar® flow data and IPS flow data were plotted in time-series for visualization of correlation. Grit production values based on daily average hourly weight were compared against historical values based on daily min and max hopper weight. QA/QC analysis to identify and quantify outliers was not performed.

Leverage, Analysis, Interpretation

We realized that this data could be leveraged in two ways, through analysis and manipulation into more meaningful statistics, and through human intelligence by communication to a larger group of staff.

By calculating the influent screen run cycles per hour we were able to generate a SCADA trend that would indicate if floatable material is being retained in conveyance.

The grit hoppers load cells were used to calculate the grit hopper hourly weight to indicate the potential for grit settling in the conveyance system. We realized that while the relative mass of grit in the conveyance system was useful, what would cause problems is the volume. Making assumptions for specific gravity and porosity (2.65 and 0.2) we calculated the volume of grit produced daily. The daily grit volume was then compared against the 3 year average for the same day to give an estimated grit deficit/surplus volume.

To indicate and communicate the effect on efficiency at the IPS, the daily average pump speed of each pump and the daily average wet well level were plotted in time series. This produced a good visualization indicating the reduced energy demand. The statistics developed in WIMS were summarized in a graph package and automatically emailed to key personnel on a daily basis

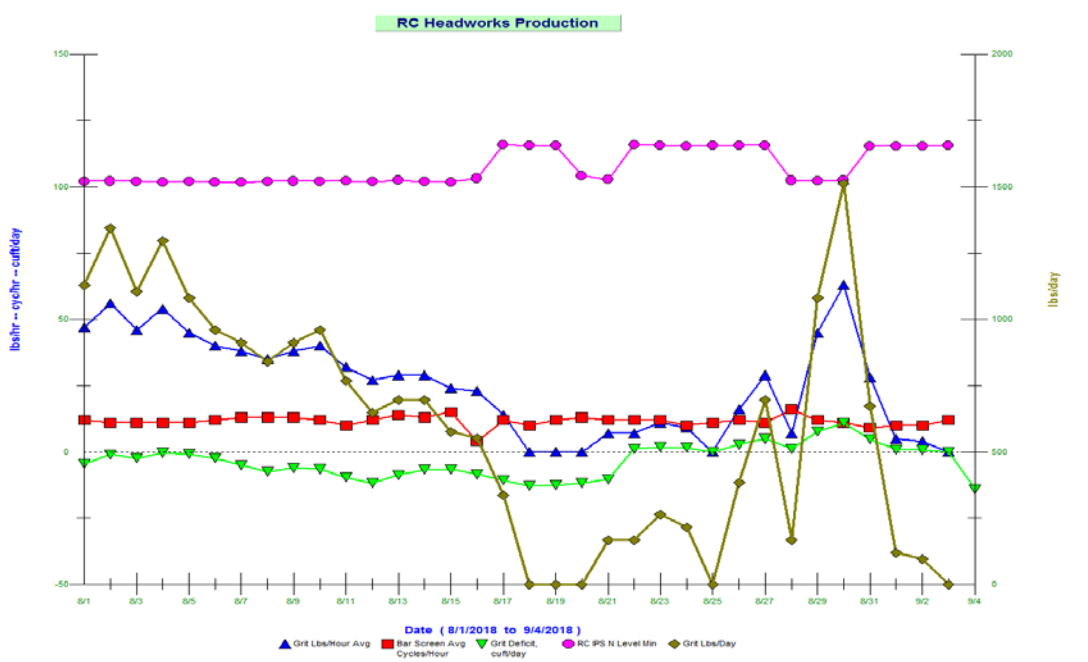
Field operators work in GIS, plant operators work in SCADA, but they all operate in real time. A common interface was needed to allow each group to monitor current conditions in the field and the IPS. Leveraging existing assets, a web map and graph package was developed to integrate and display the information generated from the IWS. The process, written in Python:

- Queries the plant process Historian for recent values for selected tags.
- Updates an ArcGIS Server feature service with current conditions for the selected tags.
- Updates a SQL Server database with information for the selected tags at 15 minute intervals.

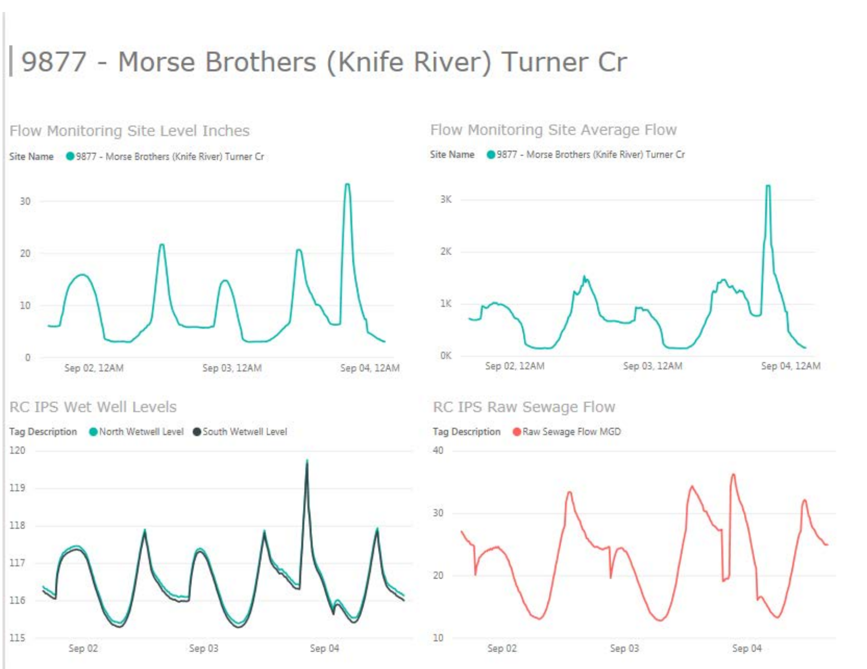
The map consumes ArcGIS Server map services, one of which is a newly created service to contain current plant IPS conditions. The map also consumes pre-existing flow monitoring and background layer services. Each flow monitoring location contains a link to graphs. The graphs were developed with Microsoft Power BI. They contain 72 hour history of level and flow for the site selected by the user, as well as a 72 hour history of information from Historian (IPS conditions) at 15 minute increments, which was stored in the integration process. The map is accessible from the CWS Sharepoint site.

Results

Two weeks of pilot testing have been completed, during which the wet well level setpoint was increased by 14 feet, and a weekly drawdown was performed to refresh the IPS and the conveyance system. The information provided by the IWS was effectively communicated and used to inform operations during and between drawdowns. The data showed that there was likely a significant amount of grit settling in the line, to the point that there was no production at the plant. The first drawdown (8/21) lasted only 4 hours and failed to make up any of the grit deficit. The second drawdown (8/29) was then extended to 36 hours and was better able to make up some of the deficit.



The graph pack developed from the ArcGIS map provided valuable real time data that was accessed by both field and plant operations staff and enabled the beginning of co-ownership of the systems.



Value of the IWS

If the project can continue into permanent implementation, the financial value the IWS has enabled is best summarized by a life cycle cost analysis that considers not only the reduced energy demand on the pumps, but the total O&M savings realized specific to the pump station. CWS could save $700,000 on the 20 year cost of operating and maintaining the IPS by increasing the wet well level.

At this time the organizational culture value can only be documented anecdotally. This is the first instance at CWS of the integration of real time plant SCADA data with field ArcGIS data. While some staff remain uncomfortable with the process change, the process of sharing data between field and plant operations staff has been enthusiastically received.

Future of the IWS

Additional intelligence may be required to make this a long term solution. For example, transmitting odor monitors or level sensors may be required at key locations. Each of these will be evaluated based upon cost and benefit provided. When possible, the information will be gathered using tools and resources available to determine if useful information is collected prior to purchase of additional equipment. Creative leverage of current data streams is also likely to continue. In the long term the IWS would include more data sources and machine learning that could predict influent flows to the plant and adjust the wet well level to manage the risk of SSO in a wet weather event.

Scalability and Repeatability

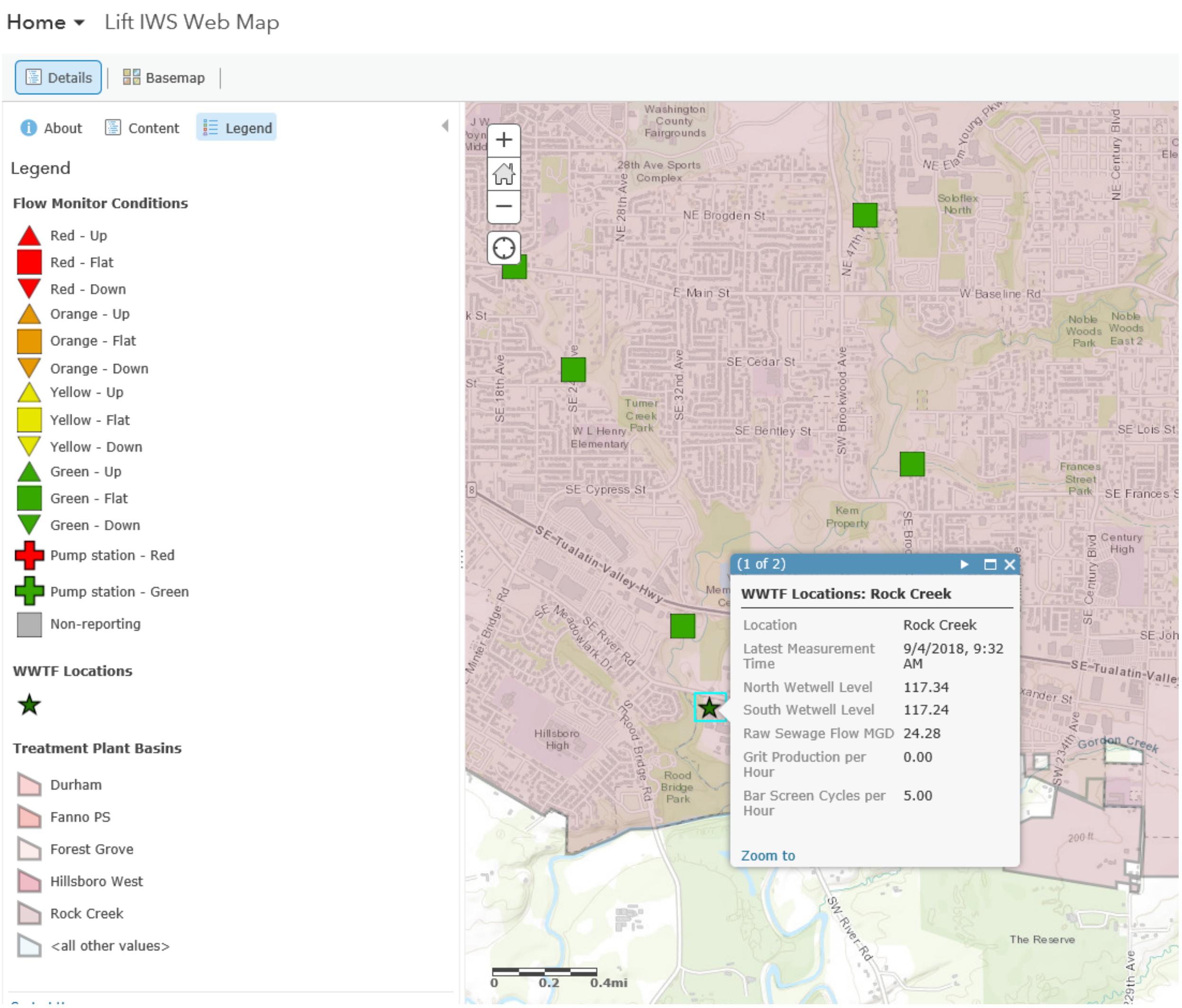
The concept presented here could be applied to any pump station, in the field or in the plant, with available suction head. These pump stations are generally designed for a peak flow condition that happens infrequently. The risks depend on the specific situation, but if the risk can be informed and mitigated by intelligent devices, the potential exists for more efficient operation. These intelligent devices can be as simple as load cells and run status. Many utilities likely monitor grit and screenings production, but may be able to leverage and communicate that data to conveyance system staff to their benefit.

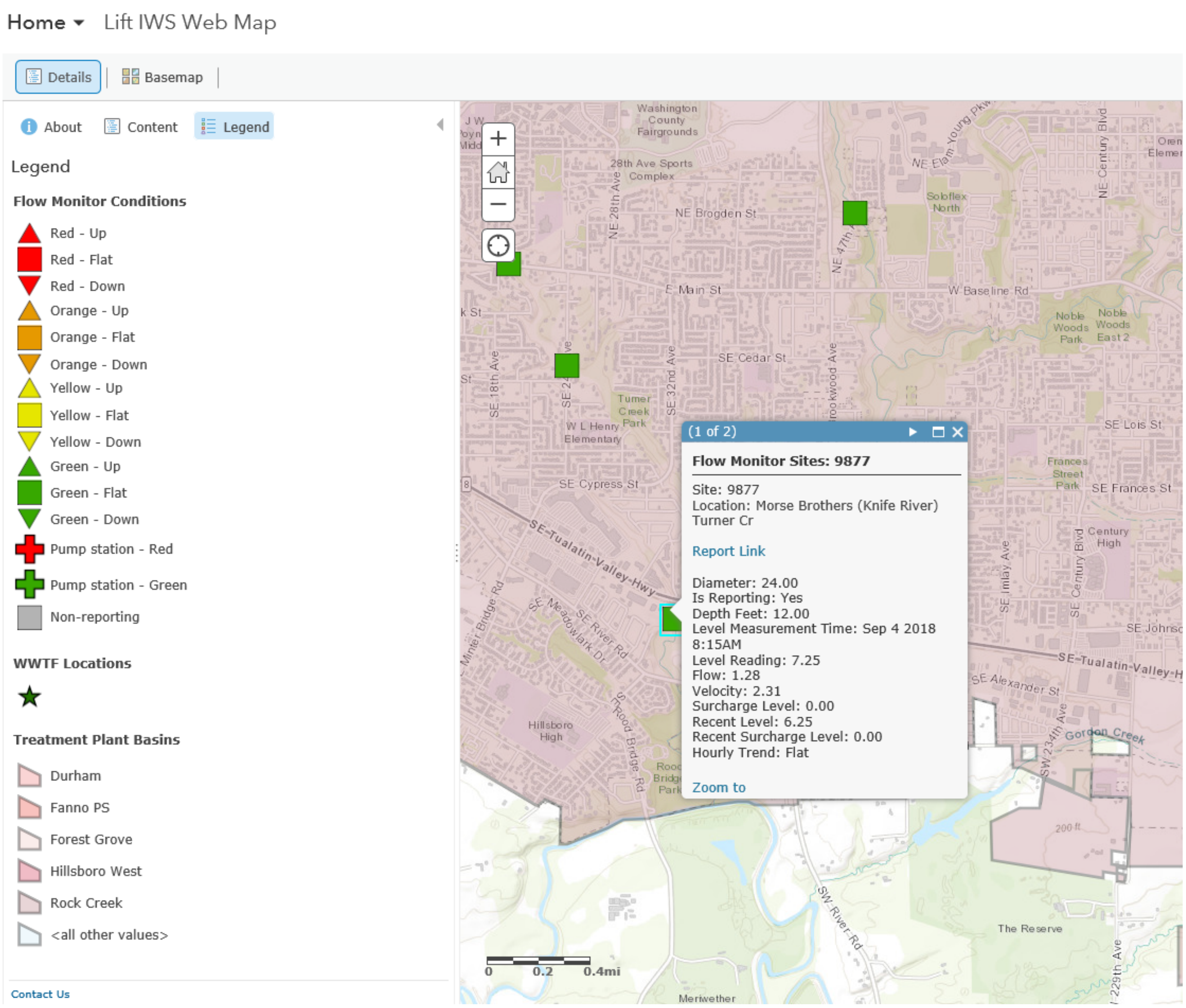
The pay off on the investment made in the networking of data and devices across platforms and between departments is hard to quantify. Once the structure exists, however, the addition of devices and data leveraging should be limited only by the creativity of the organization.

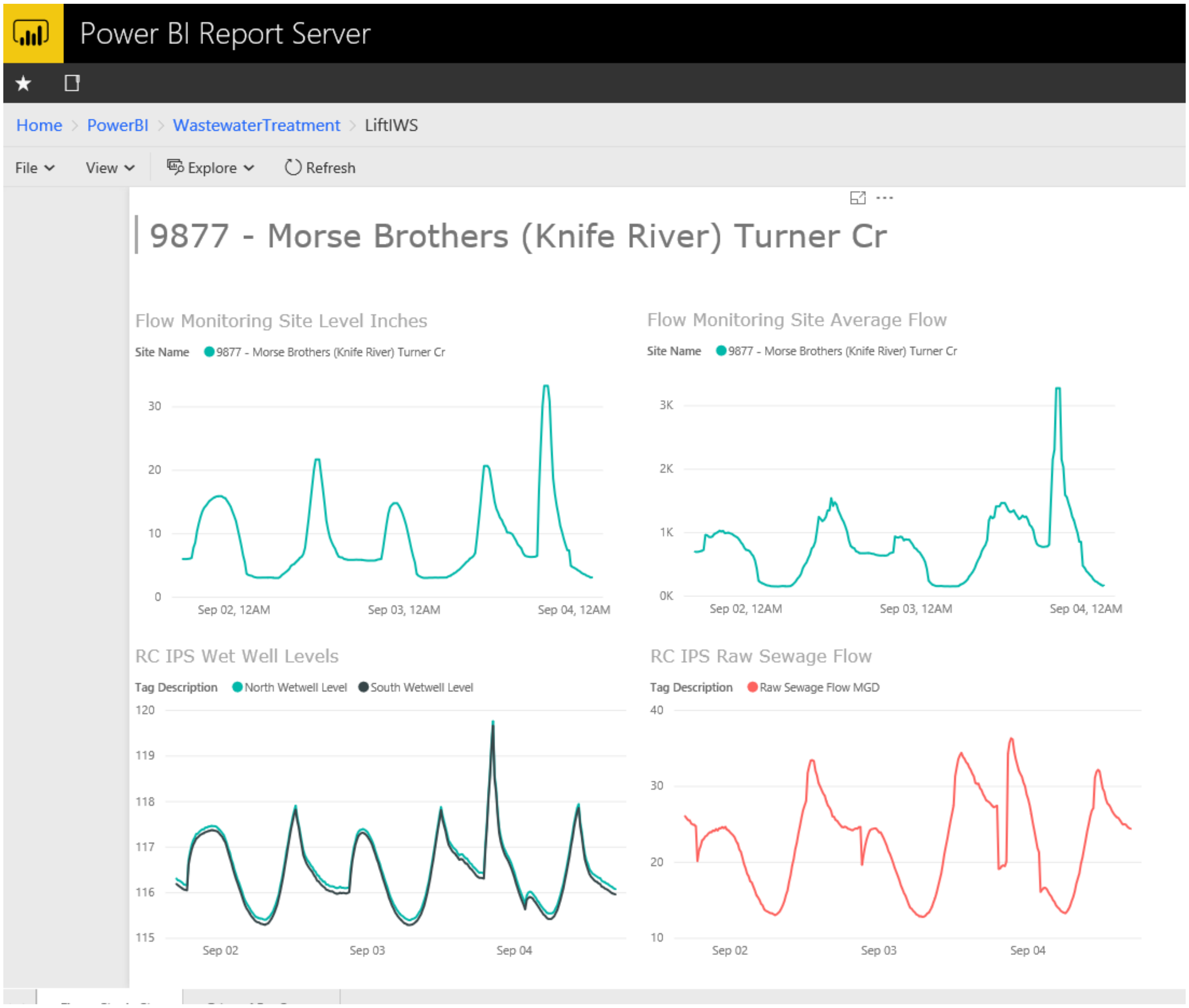
Appendicies

1. WebMap and Graph Package
2. Hach WIMS Data Package
3. Energy Analysis and Net Present Worth
4. Risk and Opportunity Register
5. Conveyance Modeling
6. IPS Operation and Drawdown Standard Operating Procedure

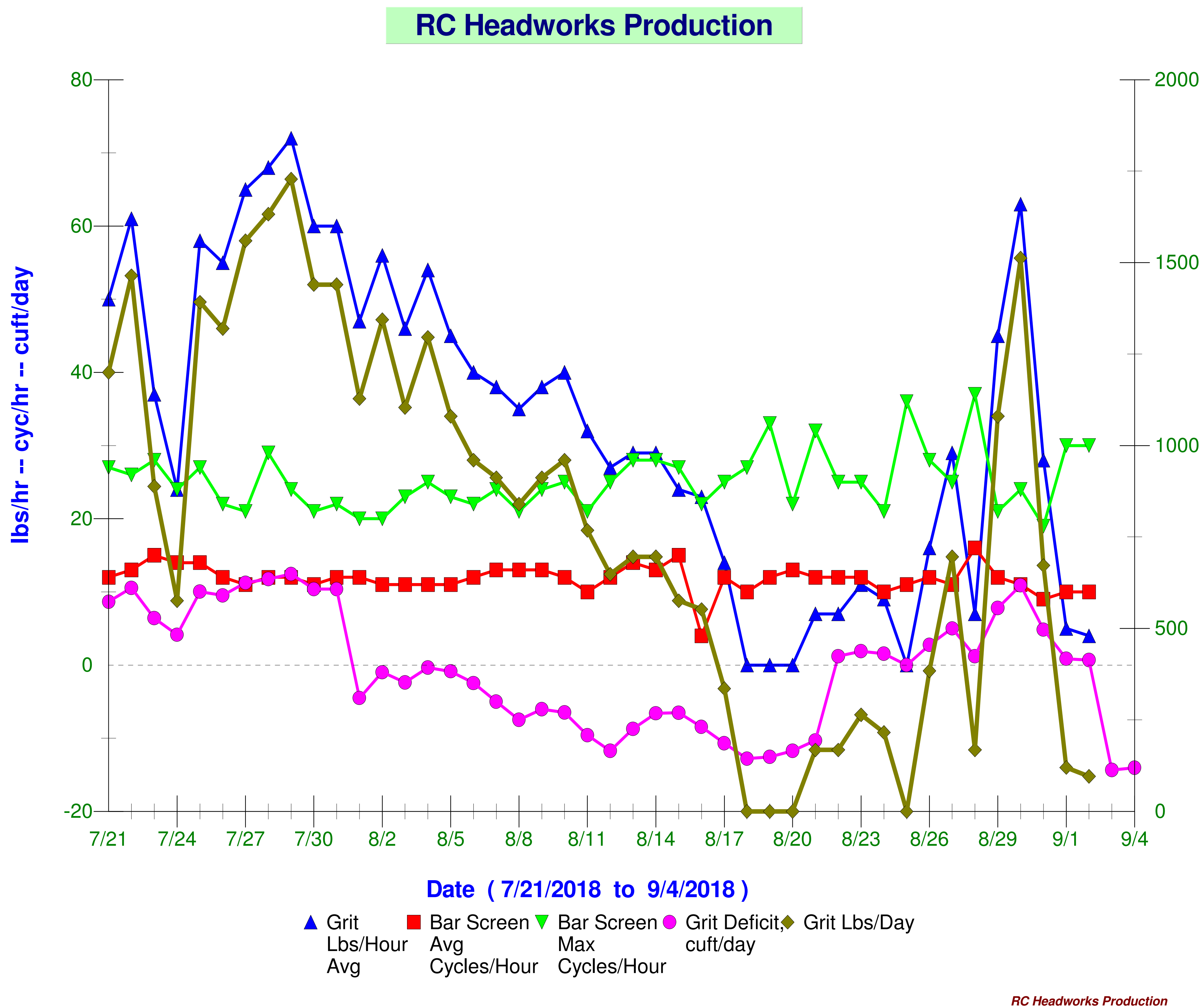
Appendix 1: Intelligent Water System Solution – Arc GIS Map



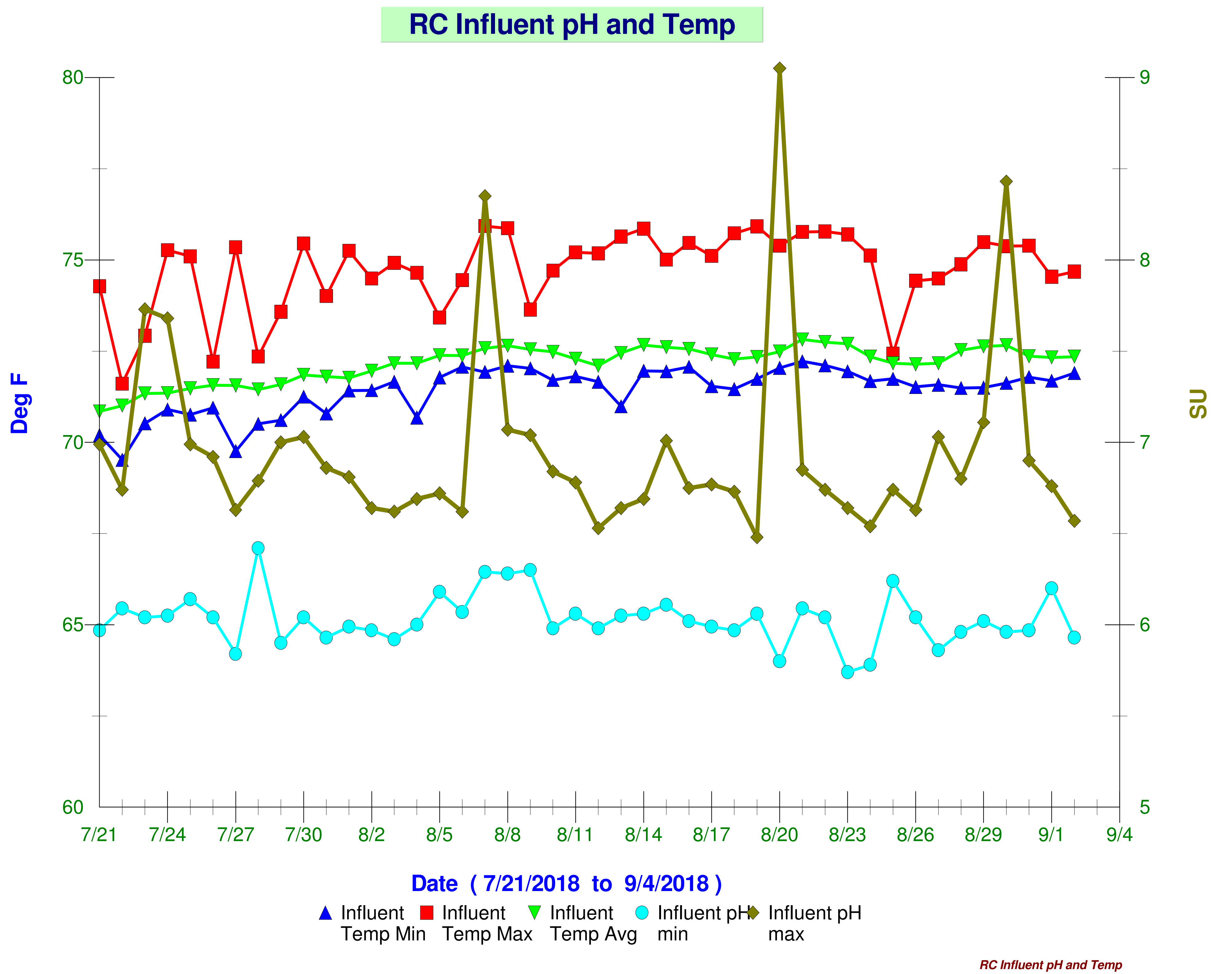

Home
Lift IWS Web Map
Details
Basemap
About
Content
Legend
Legend
Flow Monitor Conditions
Red - Up
Red - Flat
Red - Down
Orange - Up
Orange - Flat
Orange - Down
Yellow - Up
Yellow - Flat
Yellow - Down
Green - Up
Green - Flat
Green - Down
Pump station - Red
Pump station - Green
Non-reporting
WWTF Locations
Treatment Plant Basins
Durham
Fanno PS
Forest Grove
Hillsboro West
Rock Creek
<all other values>
Contact Us
(1 of 2)
Flow Monitor Sites: 9877
Site: 9877
Location: Morse Brothers (Knife River) Turner Cr
Report Link
Diameter: 24.00
Is Reporting: Yes
Depth Feet: 12.00
Level Measurement Time: Sep 4 2018 8:15AM
Level Reading: 7.25
Flow: 1.28
Velocity: 2.31
Surcharge Level: 0.00
Recent Level: 6.25
Recent Surcharge Level: 0.00
Hourly Trend: Flat
Zoom to
0
0.2
0.4mi


Power BI Report Server
Home
PowerBI
WastewaterTreatment
LiftIWS
File
View
Explore
Refresh
9877 - Morse Brothers (Knife River) Turner Cr
Flow Monitoring Site Level Inches
Site Name
9877 - Morse Brothers (Knife River) Turner Cr
30
20
10
0
Sep 02, 12AM
Sep 03, 12AM
Sep 04, 12AM
Flow Monitoring Site Average Flow
Site Name
9877 - Morse Brothers (Knife River) Turner Cr
3K
2K
1K
0K
Sep 02, 12AM
Sep 03, 12AM
Sep 04, 12AM
RC IPS Wet Well Levels
Tag Description
North Wetwell Level
South Wetwell Level
120
119
118
117
116
115
Sep 02
Sep 03
Sep 04
RC IPS Raw Sewage Flow
Tag Description
Raw Sewage Flow MGD
40
30
20
10
Sep 02
Sep 03
Sep 04

Appendix 2: Hach WIMS Data Package

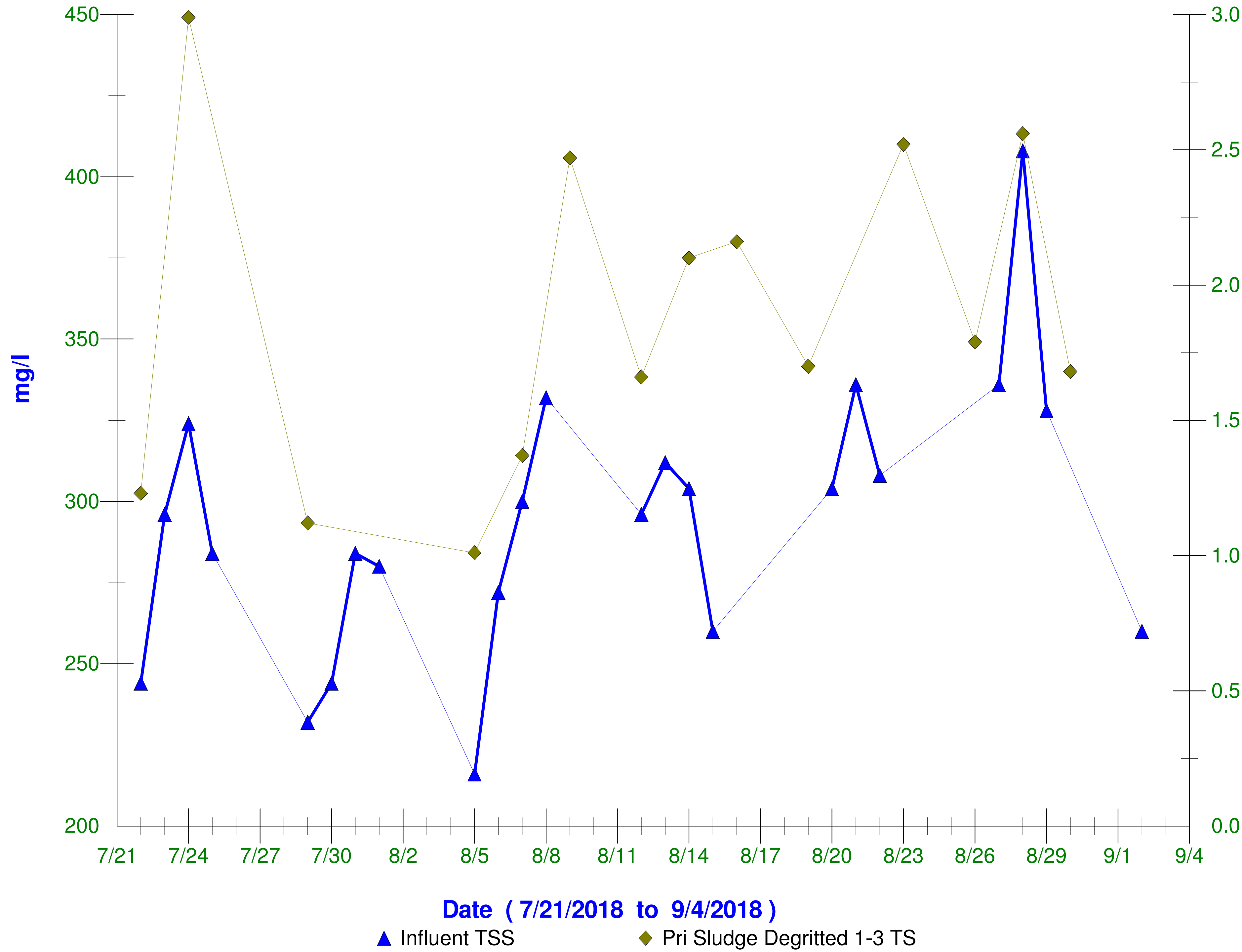


RC Headworks Production
lbs/hr -- cyc/hr -- cuft/day
lbs/day
80
60
40
20
0
-20
2000
1500
1000
500
0
7/21
7/24
7/27
7/30
8/2
8/5
8/8
8/11
8/14
8/17
8/20
8/23
8/26
8/29
9/1
9/4
Date (7/21/2018 to 9/4/2018)
Grit Lbs/Hour Avg
Bar Screen Avg Cycles/Hour
Bar Screen Max Cycles/Hour
Grit Deficit, cuft/day
Grit Lbs/Day
RC Headworks Production

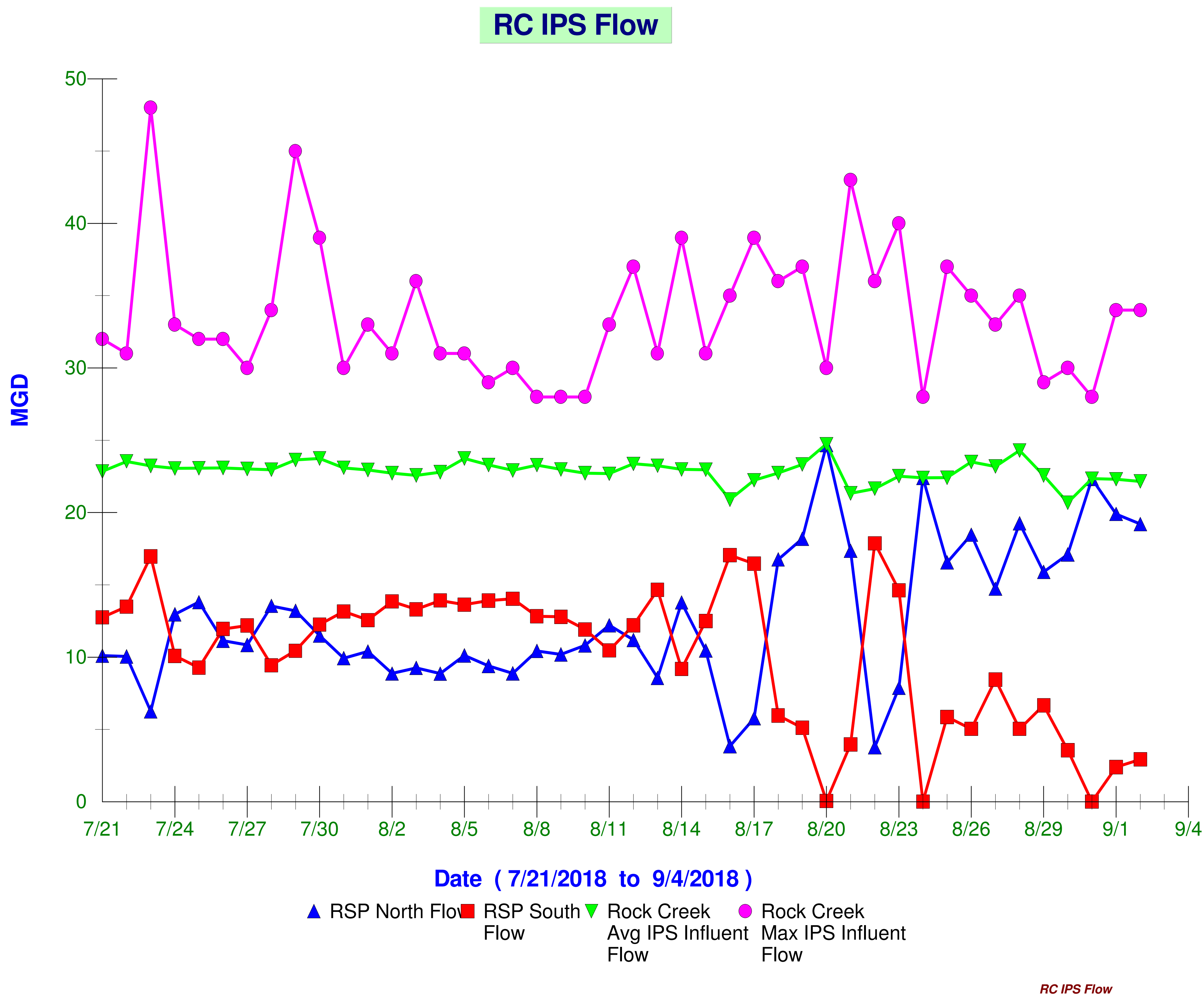


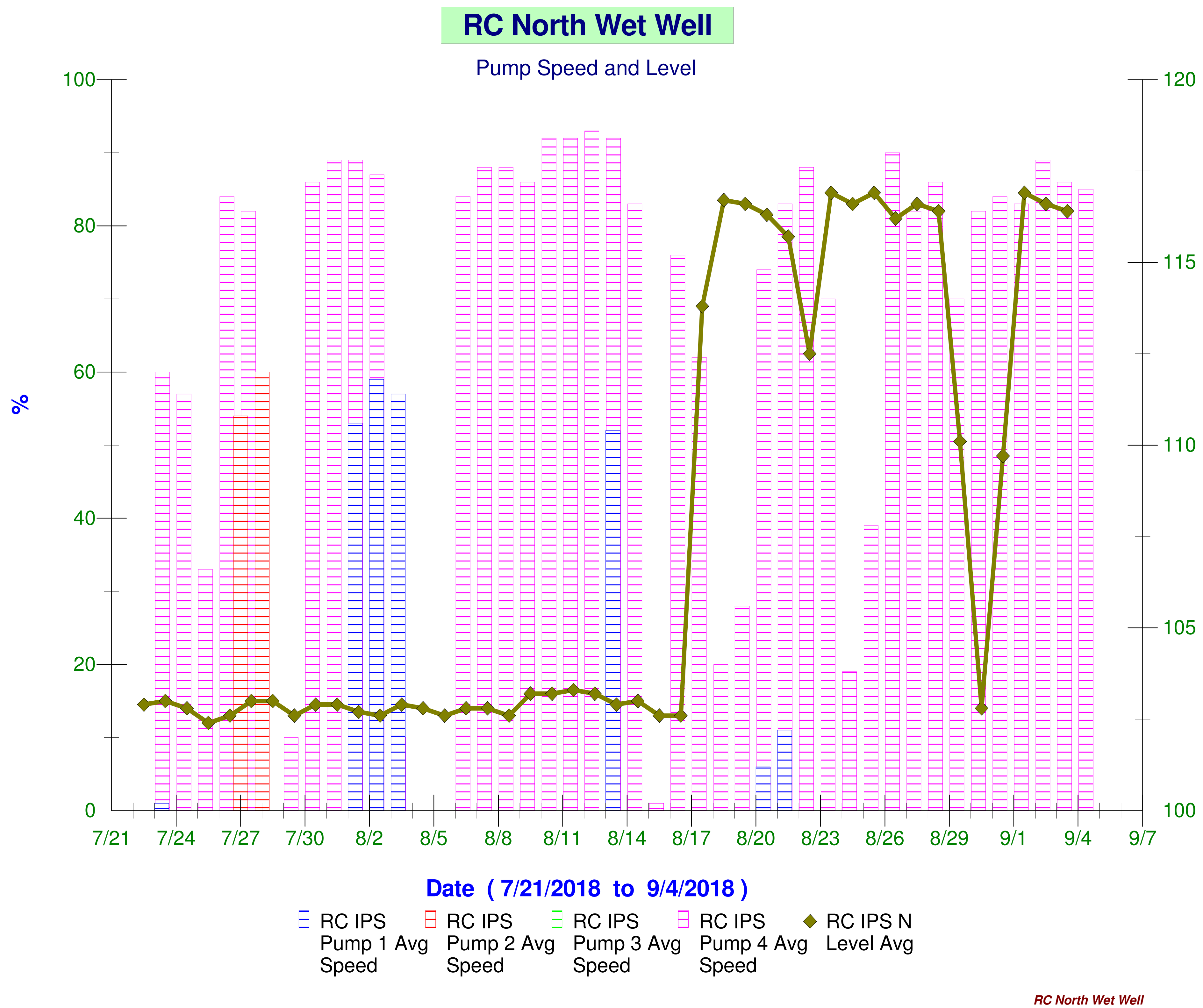
RC Influent pH and Temp
Deg F
SU
80
75
70
65
60
9
8
7
6
5
7/21
7/24
7/27
7/30
8/2
8/5
8/8
8/11
8/14
8/17
8/20
8/23
8/26
8/29
9/1
9/4
Date (7/21/2018 to 9/4/2018)
Influent Temp Min
Influent Temp Max
Influent Temp Avg
Influent pH min
Influent pH max
RC Influent pH and Temp

RC Influent Solids

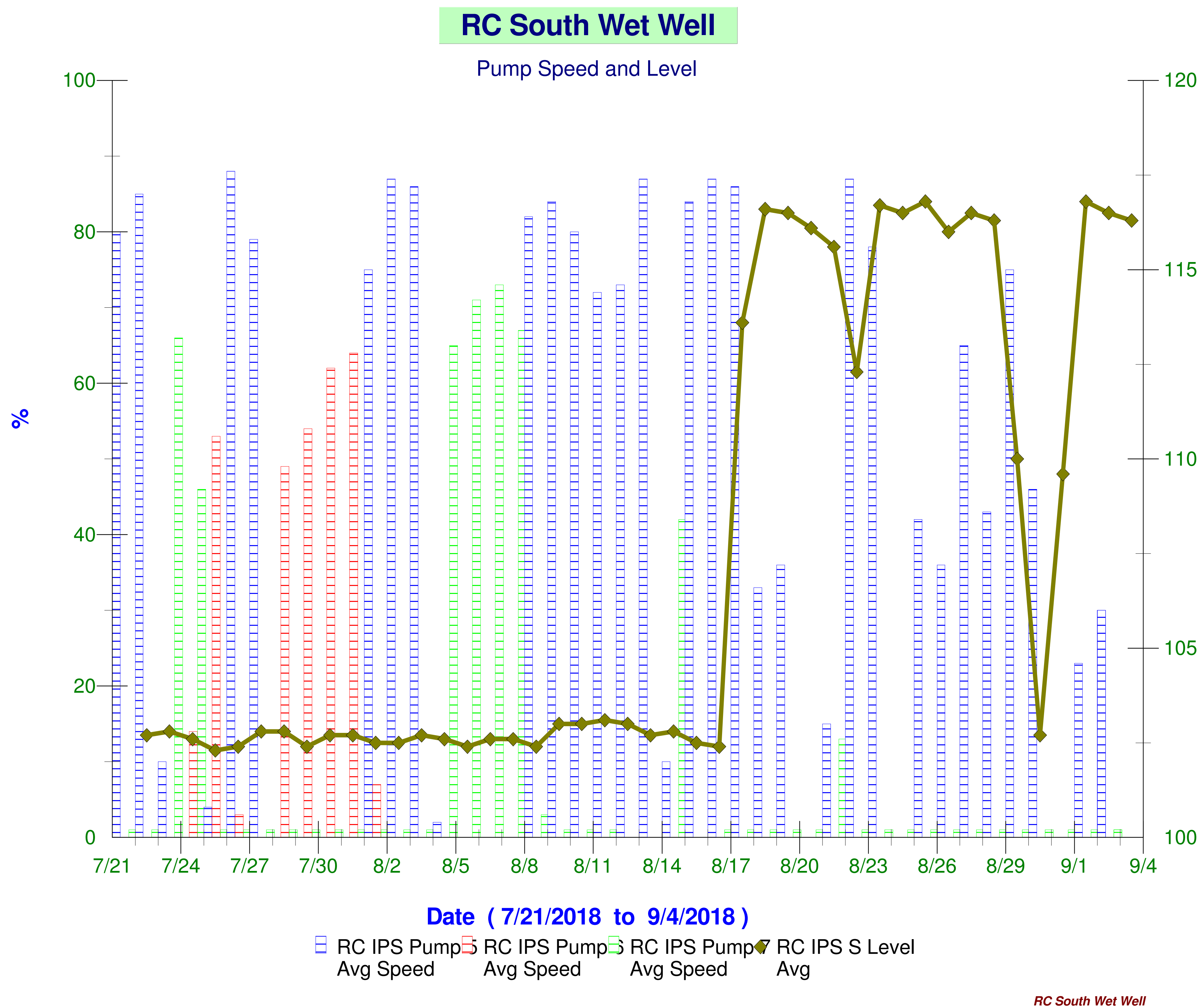


RC Influent Solids


RC IPS Flow
MGD
50
40
30
20
10
0
7/21
7/24
7/27
7/30
8/2
8/5
8/8
8/11
8/14
8/17
8/20
8/23
8/26
8/29
9/1
9/4
Date (7/21/2018 to 9/4/2018)
RSP North Flow
RSP South Flow
Rock Creek Avg IPS Influent Flow
Rock Creek Max IPS Influent Flow
RC IPS Flow



RC North Wet Well
Pump Speed and Level
%
ft
100
80
60
40
20
0
120
115
110
105
100
7/21
7/24
7/27
7/30
8/2
8/5
8/8
8/11
8/14
8/17
8/20
8/23
8/26
8/29
9/1
9/4
9/7
Date (7/21/2018 to 9/4/2018)
RC IPS Pump 1 Avg Speed
RC IPS Pump 2 Avg Speed
RC IPS Pump 3 Avg Speed
RC IPS Pump 4 Avg Speed
RC IPS N Level Avg
RC North Wet Well


RC South Wet Well
Pump Speed and Level
100
80
60
40
20
0
%
120
115
110
105
100
ft
7/21
7/24
7/27
7/30
8/2
8/5
8/8
8/11
8/14
8/17
8/20
8/23
8/26
8/29
9/1
9/4
Date (7/21/2018 to 9/4/2018)
RC IPS Pump 5 Avg Speed
RC IPS Pump 6 Avg Speed
RC IPS Pump 7 Avg Speed
RC IPS S Level Avg
RC South Wet Well

Appendix 3: Energy Savings & Net Present Worth Analysis Summary

Energy Savings Summary

Typical Flows	Typical Flows	# Operating Hours	Wet Well Levels (ft) & Estimated Power (kW)											
			103 ft. WW			105 ft. WW			110 ft. WW			115 ft. WW		
MGD	gpm	Hrs/Yr	Power (kW)	% Spd	dP	Power (kW)	% Spd	dP	Power (kW)	% Spd	dP	Power (kW)	% Spd	dP
17.5	12152	1974	277.94	80.20%	93.40	271.05	79.45%	91.4	254.26	77.50%	86.4	237.76	75.67%	81.4
31.2	21665.28	4294	515.604	79.00%	93.50	502.536	78.25%	91.508	470.36	76.30%	86.5	438.6	74.40%	81.5
48.4	33608.96	874	781.14	79%	92.60	761.37	78.25%	90.608	712.518	76.35%	85.6	664.65	74.41%	80.6
Totals		**8130**	**3,445,373**			**3,358,380**			**3,144,376**			**2,933,591**		
		Base Cost / Year	**$ 206,722**			**$ 201,503**			**$ 188,663**			**$ 176,015**		
Savings (kWh/yr)						**86,994**			**300,998**			**511,783**		
Cost Savings ($)						**$ 5,220**			**$ 18,060**			**$ 30,707**		

Net Present Worth Summary

Financial Criteria						
Present Worth	($3,237,515)	**3**	($3,162,510)	**2**	($2,531,153)	**1**
Annual Cost	$238,222	**3**	$232,703	**2**	$185,515	**1**

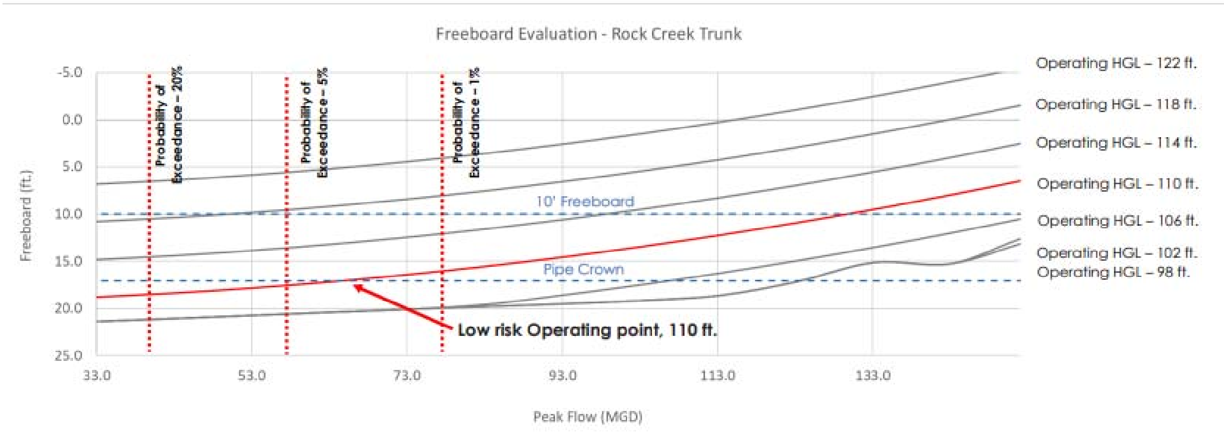
Appendix 4: Risk/Benefit Analysis

Risk and Opportunity Register

Category	Weight	Probability of Realization	Consequence/Benefit	Expense/Savings	Data Availability and Reliability	Score	Existing Intelligence	Data Leverage	Potential Intelligence
		2	3	3	1				
Surcharged Collection System	**Risk**								
	SSO- lower safety factor in flow rate and flow rate delta	5	5	3	4	9.5	Flow and level metering, model; rain gauges; radar/storm data	Distribute alarms to RC Ops; display trends	AI for flow prediction
	SSO- shorter contingency time for equipment failure at IPS	5	5	3	3	9.25	Flow and level	Calculate volume from collection system flows and IPS flows to calc contingency time	Influent flow prediction based on Flodar flows
	Trunk line other damage	2	5	5	1	8.75			Gas Monitor, Smart Linings, pressure transmitter
	Opportunity								
	Thermal sink - underground water storage may provide cooling	2	4	2	1	5.75	RC Inf Temp On-line		Upstream Temps
	Flow Equalization	3	3	3	2	6.5	Flow and Level		
Floating Solids Accumulation	**Risk**								
	Clogging in lines	1	5	2	2	6.25	Bar Screen Run Status	Est. volume of screening	Load cell
	Clogging in influent pumps	4	2	2	4	6	Pump Speed and Flow	Dual condition Alarm, speed and flow setpoints	Power Monitor, Efficiency Calc, Auto Reverse
	Odors in collection system	2	5	2	1	6.5	GIS based odor complaint system		Field H2S monitor
	Opportunity								
Settleable Solids Accumulation	**Risk**								
	Clogging in lines	1	5	2	1	6	Grit Hopper Load Cell	Grit Deficit	
	Gas generation	1	5	1	1	5.25	Influent TSS, TS		
	Odors in collection system	2	5	2	1	6.5	Influent TSS, TS		
	Trunk line corrosion	2	4	5	2	8.25	Inspections		Gas Monitor, Smart Linings
	Opportunity								
	VFA generation in collection system	3	5	2	3	7.5	Lab data		On-line COD
Air flow elimination	**Risk**								
	Trunk line corrosion	2	4	5	2	8.25	Inspections		Gas Monitor, Smart Linings
	Opportunity								
	Reduce odor control fan speed	5	3	3	5	8.25	Fan Speed, Air Flow		Power Monitor
	Prolong life of OC activated carbon	4	3	5	3	8.75			
Organizational Challenges	**Risk**								
	Damage to Conveyance	1	5	5	1	8.25			
	Damage to Treatment Plant	1	3	3	1	5.25			
	Opportunity								
	Staff awareness of additonal data streams	4	5	3	0	8			
	Staff leverages data	3	5	3	0	7.5			
	Staff finds opportunity for new intelligent devices	4	5	3	0	8			

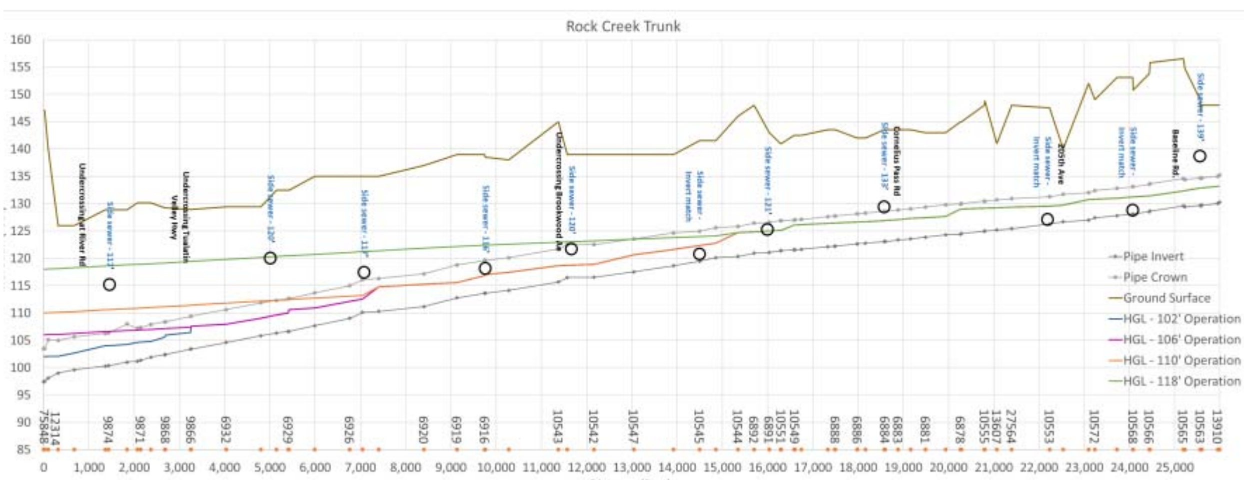
Appendix 5: Conveyance Modelling

Rock Creek Trunk - Freeboard Evaluation



- Rock Creek Trunk Freeboard Evaluation, Exceedance Based on Existing Flow
  - Near manhole 6929

Rock Creek Trunk Profile



Appendix 6: Standard Operating Procedures

Standard Operating Procedures

Title:	Influent Pump Station High Efficiency Operation
Last Update:	7/24/2018
Approved By:	Chris Maher
Purpose:	To begin and end high efficiency mode operation of the RC influent pump station. High efficiency mode increases the wet well level setpoint by 14 ft to decrease the total dynamic head on the system and the power needed to lift the influent to headworks.

Operational Precautions: The major risks to operations are:

1. Shorter contingency time for IPS failures
2. Ending high efficiency operation in advance of a wet weather event
3. Preliminary treatment operation as the wet well is lowered to standard mode
4. Influent flow management to prevent very high or low flows

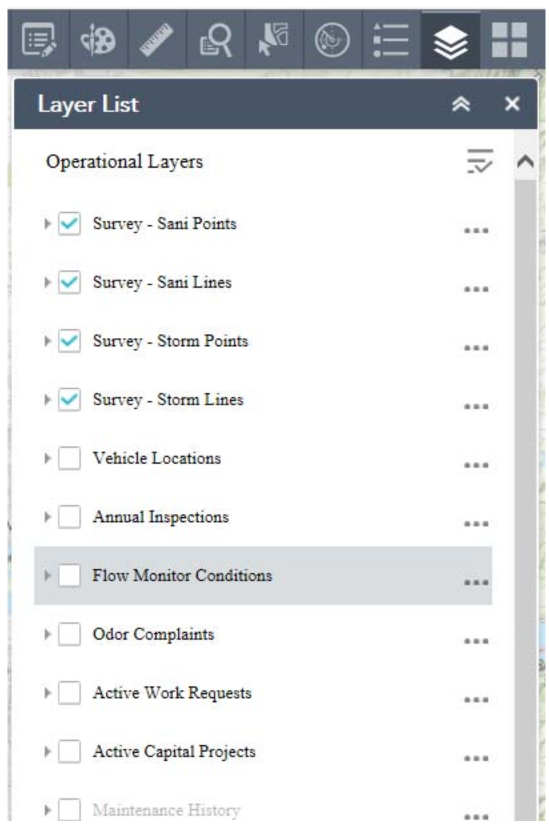
High efficiency mode has an effect on multiple workgroups. Notification of status change should be given to Field Operations, Pumps Stations, Laboratory, Source Control, and WWTD.

If you have a question about starting or ending high efficiency mode consult the Plant Manager, Operations Analyst, or Senior Operator

SOP: The PLC program increases the wet well level setpoint slowly over time (approx. 12 hours). This should be done over the peak flow diurnal, approx. 1000 hours to 2200 hours so that the overnight baseline low flow is not further reduced. Returning to standard mode should be done from 2200 to 1000 hours, so that the collection system is free flowing during the peak daily flow. This will facilitate moving any accumulated material out of the collection system.

1. NOTIFICATION – The business day prior to initiating a mode change notify the managers of FO, PS, WQL, SC, and WWTD (develop email notification group)
2. Look at the RSPS Total Flow trend and find the approx. time the flow begins to increase for the morning peak. Make the mode change around this time.

3. On SCADA, open the Influent Pump Station Control popup and change the mode to High Efficiency.
4. MONITOR – During both the startup AND operation of high efficiency mode the RC Area 1 operator should pay particular attention to the:
    a. Wet well level, pump speed, and flow
    b. Collection System Indicators
        i. Headworks bar screen hourly cycle count – this will indicate the relative amount of screenings being retained in the collection system
        ii. Headworks grit hopper hourly weight – lbs/hour grit production will indicate the amount of settling occurring in the collection system. It is important to remember that the same velocity exists in the pipe, but it is full pipe velocity with different conditions.
        iii. Primary sludge TS% - thinning sludge is a secondary indicator of organics settling in the pipe
    c. Collection System Flow Meters – The operator should consider the ARCGIS Field Operations View an extension of SCADA when in high efficiency mode and make it part of daily electronic rounds. This map can display the flow and level of FO's Flodar remote manhole monitors. Easily navigate from Sharepoint Home or go to https://arcgisprod2.usa.org/FieldOperationsMapViewer/ .
        i. In the upper right corner, open the Layer List.
        ii. Check the box for Flow Monitor conditions
        iii. It is also useful to go under the Sanitary layer (click the word not the box) and turn on treatment plant basins.
        iv. Level/Flow meters should show as colored boxes:
            1. Green – Normal, less than 90% of full pipe
            2. Yellow – Submerged Pipe
            3. Red – 6 inches from Rim
        v. Zoom in and double click on a site then scroll through information screens to see levels, flow and elevations



5. During high efficiency operation RSP #’s 4 and 5 should be the Lead and Lag 1. The wet well level should allow them to operate with less exposure to ragball formation. Monitor the flow and pump speed as always.

RETURN TO STANDARD MODE

1. NOTIFICATION – The business day prior to initiating a mode change notify the managers of FO, PS, WQL, SC, and WWTD (develop email notification group)
2. The return to standard mode should be initiated around 2000 to 2200 hours. To return to Standard mode, on SCADA, open the Influent Pump Station Control popup and change the mode to Standard.
3. The new operating level should be reached by peak morning flow the next day.
4. MONITOR – During both the startup AND operation of standard mode the RC Area 1 operator should pay particular attention to the:
    a. Wet well level, pump speed, and flow
    b. Collection System Indicators
        i. Headworks bar screen hourly cycle count – this trend will indicate when production has re-stabilized
        ii. Headworks grit hopper hourly weight this trend will indicate when production has re-stabilized
    c. Physical monitoring of bar screens and WAPs
5. Operator should put on a second barscreen at their discretion.

END OF DOCUMENT